Prevention of catheter-related urinary tract infections

Catheter-associated urinary tract infection is the most common nosocomial infection, with hospitalized patients having a risk of 5% per day an indwelling catheter is in place. Use of catheters coated with silver alloy-hydrogel significantly reduces the risk of catheter-associated urinary tract infection and the burden on the NHS.

Catheter-associated urinary tract infection is the most prevalent form of nosocomial (hospital-acquired) infection (30% of all) (Stamm, 1991; Panknin and Althaus, 2001). The duration of catheterization is the most important factor in the development of catheter-associated urinary tract infection, but others include age, female sex, diabetes mellitus and raised serum creatinine level (Sedor and Mulholland, 1999). Most patients with catheter-associated urinary tract infection are asymptomatic and treatment is not recommended while the catheter remains in situ (Warren, 1997). The use of systemic antibiotics is complicated by the development of antimicrobial resistance (Mountokalakis et al, 1985). However, there is no generally accepted evidence-based rationale for the use of prophylactic antibiotics to reduce the urinary tract infection rate after catheter removal. A national multidisciplinary survey of healthcare professionals showed a vast diversity in practice (Van der Wall et al, 1992).

Catheterization presents a risk of infection to patients, as it is an invasive procedure. Approximately 25% of hospital patients have indwelling urinary catheters, and it is estimated that one in twenty of these will go on to develop a catheter-associated urinary tract infection. It has also been reported that 80% of all urinary tract infections can be traced to indwelling urinary catheters (Plowman et al, 2001). There is a 5% risk of positive bacteriuria for each day an indwelling catheter is in place, meaning that most patients will experience an infection if their catheter remains in place for more than 30 days (Maki and Tambyah, 2001). In the most extreme cases, catheter-associated urinary tract infections are life-threatening. It is estimated that 1–4% of catheterized patients who develop a urinary tract infection go on to develop bacteraemia. The mortality rate in this group of patients is between 13 and 30%. Catheter-associated urinary tract infections represent a significant burden to the NHS (Bissett, 2005).

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Definition

The definition of catheter-related urinary tract infection varies in published reports and 'bacteriuria' and 'urinary tract infection or UTI' are often used interchangeably. Low-level growth from a catheterized specimen (i.e. 10^2 colony-forming units [CFU]/ml) usually progresses within days to concentrations greater than 10^4 CFU/ml, unless antibiotics are given. Thus, most experts agree that a growth of 10^2 CFU/ml or greater of a predominant pathogen from a catheterized urine specimen, especially when associated with pyuria, represents catheter-related urinary tract infection (Stark and Maki, 1984). Experts in rehabilitation medicine have suggested the following criteria for diagnosing bacteriuria from catheterized patients: 10^2 CFU/ml or greater from patients undergoing intermittent catheterization, any detectable growth from those with an indwelling catheter, and 10^4 CFU/ml or greater from a clean-voided specimen from a man using a condom catheter (Stamm, 1998).

Pathogenesis

Agent–host–environment interaction

Patterns of infectious diseases depend on factors that enhance the probability of contact between an infectious agent and susceptible host. In the urinary tract, such factors include diminished host defences in the urethra, urine and bladder (internal environment), virulence features of infectious bacteria (agent), and the use of instruments such as urinary catheters (external environment). Risk factors for urinary tract infections in women include sexual activity, use of a diaphragm and/or spermicide, cystocoele, anatomical or structural factors such as uterine prolapse or oestrogen deficiency and instrumentation (catheterization), whereas in young men, urinary tract infection is rare unless associated with instrumentation or congenital abnormalities (Benenson, 1990). Antibiotic exposure, functional status, anal intercourse, presence of human immunodeficiency virus infection or genetic factors such as blood group secretor status, may also play a role. In older adults, urinary tract infection rates are similar in both men and women (Raz et al, 2000).

Host defences

The natural host defence mechanisms of the male and female urethra and bladder provide protection against bacterial colonization and urinary tract infection in the healthy person. The healthy bladder empties completely and is a sterile system. Any condition which alters complete emptying or contaminates the system will favour colonization by microorganisms (Goldman, 2001).

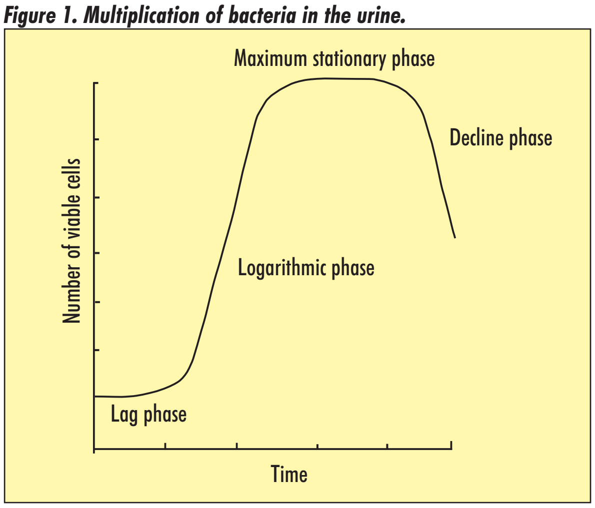
Urine

Multiplication of bacteria in the urine occurs in four phases: lag phase, logarithmic phase, maximum stationary phase and phase of decline (*Figure 1*). The lag phase is a high-energy phase in which the bacteria are adapting to the new environment rather than increasing in cell mass or number. The logarithmic phase begins once bacteria have adapted and accounts for growth at a constant energetic rate until the condition of the urine changes enough to inhibit growth (e.g. reduced nutrients, increased toxic waste). Bacteria vary in growth rates and in the size of cell mass required before the parent cell can split to create two identical daughter cells (Harrington and Hooton, 2000). Viable *Escherichia coli*, for example, can double in number (generation time) in as little as 12.5 minutes while for other organisms the generation time may be hours (e.g. *Mycobacterium tuberculosis*). Eventually, the maximum stationary phase may be reached, while at the same time resources in the urine decline. As a result of lack of nutrients and build up of toxic waste, the phase of decline sets in and bacteria begin to die (Kunin, 1997).

Risk of bacteriuria

The most important risk factor for bacteriuria is the duration of catheterization, bacteriuria defined as a growth of 10^3 CFU/ml or more of a predominant bacterial species. Other risk factors are female sex, rapidly fatal underlying illness, diabetes mellitus, serum creatinine level 177 μmol/litre, age older than 50 years, lack of systemic antibiotics and non-surgical disease. Hospitalization on the orthopaedic or urological service, catheter insertion after the sixth day of hospitalization and catheter insertion outside the operating room also have a sizeable risk (Morris, 1990).

Figure 1. Multiplication of bacteria in the urine.



Risk of bacteraemia

Catheter-associated bacteriuria is usually asymptomatic, uncomplicated, and resolves after the catheter is removed, but up to 30% of patients have genitourinary or systemic symptoms. The outcome of most clinical importance is probably urinary tract-related bacteraemia or urosepsis. Risk factors for urinary tract infection-related bacteraemia are less clearly defined than for catheter-related bacteriuria, in part because it occurs less often. Because 4% or less of patients with catheter-related bacteriuria develop catheter-related bacteraemia, most prospective studies have insufficient statistical power to detect associations with bacteraemia (Garibaldi et al, 1974).

Attempts have been made to assess risk factors for bacteraemia. In patients with nosocomial urinary tract infection (defined as $>10^5$ CFU/ml), nosocomial bloodstream infections occurred in 5.7% of whom had a urinary tract origin. Among patients with a nosocomial urinary tract infection, 86% had an indwelling urinary catheter. Significant risk factors for secondary nosocomial bloodstream infections were urinary tract infection caused by *Serratia marcescens* compared with other organisms and male sex (Shapiro et al, 1984).

Patients with a community-acquired urinary tract infection associated with fever were significantly older (mean age 75 years), more often had a non-infectious urinary tract disease (e.g. nephrolithiasis or prostatic hypertrophy), and more frequently had an indwelling urinary catheter. Factors not predisposing to bacteraemia included the presence of diabetes mellitus or an immunodeficiency disorder, or a history of previous urinary tract infection (Warren, 1997).

Avoiding indwelling catheterization

Hospitalized patients may need indwelling urinary catheters, but their use is often inappropriate. Because up to 80% of patients with a nosocomial urinary tract infection have an indwelling urinary catheter, the best prevention strategy would be to avoid catheterization. A prospective study by Jerkeman and Braconier (1992) found that patients had an indwelling urinary catheter for unjustified purposes for 41% of patient-days in a medical intensive care unit. The use of indwelling catheters was also found to be unnecessary for 58% of patient-days on the general medical ward. Inserting a catheter for the convenience of the nursing or medical staff is rarely appropriate. Another frequent problem is that, even when a catheter is inserted appropriately, it is left in too long. When no longer required, the catheter should be removed immediately (Stamm, 1998).

If temporary or long-term urinary collection is required, options other than indwelling catheterization should be considered. Intermittent catheterization, i.e. inserting and removing a sterile or clean urinary catheter several times daily, may reduce the risk of bacteriuria compared with an indwelling catheter. The incidence of bacteriuria is about 1–3% per insertion; however, most patients become bacteriuric within a few weeks. Intermittent catheterization may also be associated with a lower risk of local and systemic complications of bacteriuria, but further studies are needed to assess these issues (Bryan and Reynolds, 1984).

Preventing urinary tract infection during indwelling catheterization

Because of the high incidence, substantial morbidity and occasional mortality associated with nosocomial urinary tract infection, preventive measures have been evaluated in those requiring an indwelling catheter. The most important infection control advance was the introduction, approximately 3 decades ago, of the closed catheter drainage system (Jerkeman and Braconier, 1992). Proper aseptic techniques, including aseptic insertion and maintenance of the catheter and drainage bag, remain essential in preventing catheter-related urinary tract infection. It is vital that health-care workers wear gloves when manipulating or emptying the drainage bag and wash their hands well between patient contacts. Efforts to prevent bacteriuria also include irrigating the bladder, instilling antibacterial solutions in the urinary collecting bag, rigorous meatal cleaning, using silver-coated urinary catheters, and prescribing short-term prophylactic antibiotic medications (Jain et al, 1995). Each method will be briefly discussed below.

Bladder irrigation

A potential method of preventing catheter-associated urinary tract infection is to irrigate the bladder with antibacterial agents, either continuously or intermittently. Such agents include antiseptics (povidone-iodine or chlorhexidine digluconate) and antibiotics (neomycin or polymyxin B sulfate). Although this method had some value in preventing urinary tract infection when an open drainage system was used, little overall benefit has been seen in studies with closed systems. Infection control principles dictate that unidirectional flow from the bladder to the drainage bag is best. In view of the potential for local toxic effects and the complexity of this method, antibacterial irrigation cannot currently be recommended (Meares, 1991).

Antimicrobial drugs in the drainage bag

In catheterized patients, urinary tract infections may occur when bacterially colonized urine in a drainage bag refluxes into the patient's bladder. This is often a consequence of the bag being lifted above the level of the bladder, allowing a retrograde flow of urine. Several studies have evaluated the effect of adding various antibacterial agents (e.g. chlorhexidine, hydrogen peroxide and povidone-iodine) to the drainage bag. While reports suggest this intervention may prevent catheter-related urinary tract infection, randomized studies show no benefit to this method. Adding solutions to the drainage bag has the disadvantage of usually requiring the closed drainage system to be broken. The bulk of evidence does not favour this approach (Wolff et al, 1976; al-Juburi and Cicmanec, 1989).

Rigorous meatal cleaning

One route to bladder infection occurs when bacteria colonizing the urinary meatus ascend along the external surface of the urinary catheter into the bladder. As such, reducing bacterial colonization at the urethral meatus might decrease catheter-associated bacteraemia. Despite the sound theoretical benefits of this intervention during indwelling catheter use, randomized trials show no benefit of rigorous meatal cleansing even when combined with topical antibiotics, but rather an increased risk of bacteriuria in patients who were having twice-daily meatal cleaning compared with patients who received routine daily bathing. Thus, rigorous meatal cleaning is not recommended (Platt et al, 1983).

Silver-coated catheters

The growth of bacteria within a biofilm on both the extra- and intra-luminal surfaces of conventional Foley catheters is one of the most significant catheter-associated urinary tract infection threats. Within days, if not hours, the biofilm process is well and truly established, attracting increasing numbers of potentially infectious organisms (e.g. resistant enterococci, staphylococci, Enterobacteria, *Pseudomonas aeruginosa*, yeasts). By combining a hydrophilic hydrogel coating with silver alloy (to reduce urethral trauma and discomfort), it is possible to provide non-toxic, extra- and intra-luminal catheter surfaces that are highly biocompatible when in contact with healthy cells. The hydrogel–silver alloy combination mediates the slow, sustained release of anti-infective silver ions, minimizing microbial adherence to both the external and internal surfaces of the catheter. There is now convincing clinical evidence that catheters with a hydrogel–silver alloy-coating inhibit biofilm formation, thereby delaying the onset of bacteriuria and reducing catheter-associated urinary tract infection rates (Liedberg, 1989).

Systemic antibiotic drug therapy

As early as 1955, Kass demonstrated the value of prophylactic antibiotic drug therapy in catheterized patients. Because receiving systemic antibiotic drug therapy has been shown repeatedly to lower the risk of developing a urinary tract infection in catheterized patients several investigators have studied this intervention. Most studies of the past 15 years have used fluoroquinolones.

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Comparing results of studies is hampered by differences in definitions of urinary tract infection, timing and duration of antibiotic agents used, and outcomes measured. Studies with short-term catheterization were mainly in postoperative patients, whereas those with long-term catheters were largely in nursing home residents. Low doses of antibiotics were as effective as higher doses (Stickler, 2002).

In general, systemic antibiotic therapy tends to be most useful in patients requiring urinary catheterization for 3–14 days. Those catheterized for shorter durations are not at high enough risk for urinary tract infection, and those with longer durations develop bacteriuria whether treated or not. Most experts do not recommend routinely using prophylactic antibiotic medications for catheterized patients because of their cost, potential adverse effects and role in encouraging antibiotic drug resistance. Prophylactic antibiotic drug therapy may, however, be appropriate in those who require relatively short-term catheterization and are at high risk of complications from a urinary tract infection (Burke et al, 1983).

Cost effectiveness of preventive methods

A hospital-acquired catheter-associated urinary tract infection costs the NHS approximately £1563. Such infections also present challenges to hospital managers as they can result in 'bed-blocking' with evidence that catheter-associated urinary tract infections can extend hospital stays by up to 6 days (Plowman et al, 1999).

Catheter-associated urinary tract infections represent a significant cost to the NHS. However, many of these infections are avoidable with improved infection control and increased use of new catheters and other devices designed to minimize catheter-associated urinary tract infection rates. Furthermore, even a conservative estimate of the risk and costs of managing catheter-associated urinary tract infections in the community suggests that the silver alloy-coated Foley catheter needs to reduce the catheter-associated urinary tract infection rate by less than 9% to be cost-neutral: in clinical trials reductions in catheter-associated urinary tract infections have far exceeded this. The NHS is currently saving a few pence off an individual item's price by using catheters without a silver coating. From a health economic point of view by making steps to reduce infection rates, the potentially huge associated costs can also be reduced (Trueman, 2007).

Discussion

The use of a short course of ciprofloxacin in the absence of catheter-associated urinary tract infection before catheter removal can lead to some patients developing urinary tract infections. The pathogens were resistant to ciprofloxacin in almost all (88%) cases. There was no significant difference in the urinary tract infection rate between the ciprofloxacin and placebo groups in certain studies. The occurrence of urinary tract infection could be related to the efficiency of bladder emptying after catheter removal and urinary retention as a reason for catheterization did not influence the urinary tract infection rate after removal.

The risk of urinary tract infection (both symptomatic and asymptomatic) after removing a urethral catheter is real, even in the absence of a catheter-associated urinary tract infection before, and there was high resistance to ciprofloxacin in those who developed urinary tract infections after catheter removal (Wazait et al, 2004).

There are no significant benefits of using prophylactic ciprofloxacin to reduce the urinary tract infection rate after urethral catheter removal. However, some health-care professionals advocate the use of prophylactic antibiotics after urethral catheter removal, either in all or selected patients, albeit on the basis of little evidence; ciprofloxacin is the choice of one fifth of health-care professionals who advocated the use of antibiotics on urethral catheter removal. Of those who recommended antibiotics, almost half cited the patient developing a urinary tract infection after removal of the catheter as a reason for giving antibiotics. The types of organisms associated with catheter-associated urinary tract infection are always changing, as are patterns of antibiotic resistance. Currently, the most appropriate agents for the empirical management of catheter-associated urinary tract infections seem to be co-amoxiclav, ciprofloxacin and nitrofurantoin (Wazait et al, 2003).

Conclusions

Catheterization presents a risk of infection to patients, as it is an invasive procedure. Approximately 25% of hospital patients have indwelling urinary catheters, and it is estimated that one in twenty of these will go on to develop a catheter-associated urinary tract infection: 80% of all urinary tract infections can be traced to indwelling urinary catheters. There is a 5% risk of positive bacteriuria for each day an indwelling catheter is in place, meaning that the majority of patients will experience an infection if their catheter remains in place for more than 30 days.

There is no strong evidence for using prophylactic antibiotics as this may lead to resistance and colonization with resistance strains. It is accepted in certain cases where risk of developing infections is higher; in these cases local guidelines should be followed with microbiological consent. **BJHM**

Conflict of interest: none.

al-Juburi AZ, Cicmanec J (1989) New apparatus to reduce urinary drainage associated with urinary tract infections. *Urology* **33**(2): 97–101

Benenson AS (1990) *Control of Communicable Diseases in Man*. 15th

edn. American Public Health Association, Washington DC
Bissett L (2005) Reducing the risk of catheter-related urinary tract infection. *Nurs Times* **101**: 126
Bryan CS, Reynolds KL (1984) Hospital-acquired bacteremic urinary tract infection: epidemiology and outcome. *J Urol* **132**: 494–8
Burke JP, Jacobson JA, Garibaldi RA, Conti MT, Alling DW (1983) Evaluation of daily meatal care with poly-antibiotic ointment in prevention of urinary catheter–associated bacteriuria. *J Urol* **129**: 331–4
Garibaldi RA, Burke JP, Dickman ML, Smith CB (1974) Factors predisposing to bacteriuria during indwelling urethral catheterization. *N Engl J Med* **291**: 215–19
Goldman HB (2001) Evaluation and management of recurrent urinary tract infections. In: Kursh ED, Ulchaker JC, eds. *Office Urology: the Clinicians' Guide.* Humana Press, Totowa, NJ: 105–11
Harrington RD, Hooton TM (2000) Urinary tract infection risk factors and gender. *J Gend Specif Med* **3**(8): 27–34
Jain P, Parada JP, David A, Smith LG (1995) Overuse of the indwelling urinary tract catheter in hospitalized medical patients. *Arch Intern Med* **155**: 1425–9
Jerkeman M, Braconier JH (1992) Bacteremic and non-bacteremic febrile urinary tract infection: a review of 168 hospital-treated patients. *Infection* **20**: 143–5
Kunin CM (1997) *Detection, Prevention and Management of Urinary Tract Infections.* 5th edn. Williams & Wilkins, Philadelphia
Liedberg H (1989) Catheter induced urethral inflammatory reaction and urinary tract infection. An experimental and clinical study. *Scand J Urol Nephrol Suppl* **124**: 1–43
Maki DG, Tambyah P (2001) Engineering out the risk for infection with urinary catheters. *Emerg Infect Dis* **7**(2): 342–7
Meares EM Jr (1991) Current patterns in nosocomial urinary tract infections. *Urology* **37**: 9–12
Morris JG (1990) Metabolism, growth and death of bacteria. In: Parker MT, Collier LH, eds. *Topley and Wilson's Principles of Bacteriology. Virology and Immunity*. 8th edn. B.C. Decker Inc., Philadelphia: 39–70
Mountokalakis T, Skounakis M, Tselentis J (1985) Short-term versus prolonged systemic antibiotic prophylaxis in patients treated with indwelling catheters. *J Urol* **134**: 506–8
Panknin HT, Althaus P (2001) Guidelines for preventing infections associated with the insertion and maintenance of short-term indwelling urethral catheters in acute care. *J Hosp Infect* **47**(Suppl): S39–S46
Platt R, Polk BF, Murdock B, Rosner B (1983) Reduction of mortality associated with nosocomial urinary tract infection. *Lancet* **i**: 893–7
Plowman R, Graves N, Griffin M et al (1999) *The socio-economic burden of hospital-acquired infection.* Public Health Laboratory Service, London (http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/DH_4089724 accessed 8 February 2010)
Plowman R, Graves N, Esquivel J et al (2001) An economic model to assess the cost and benefits of the routine use of silver alloy coated urinary catheters to reduce the risk of UTIs in catheterised patients. *J Hosp Infect* **48**(1): 33–42
Raz R, Gennesin Y, Wasser J, Stoler Z, Rosenfeld S, Rottensterich E, Stamm WE (2000) Recurrent urinary tract infections in post menopausal women. *Clin Infect Dis* **30**: 152–6
Sedor J, Mulholland SG (1999) Hospital acquired urinary tract infections associated with the indwelling catheter. *Urol Clin North Am* **26**: 821–8
Shapiro M, Simchen E, Izraeli S, Sacks TO (1984) A multivariate analysis of risk factors for acquiring bacteriuria in patients with indwelling urinary catheters for longer than 24 hours. *Infect Control* **5**: 525–32
Stamm WE (1991) Catheter-associated urinary tract infections. epidemiology, pathogenesis and prevention. *Am J Med* **91**: 65S–71S
Stamm WE (1998) Urinary tract infections. In: Bennett JV, Brachman PS, eds. *Hospital Infections.* 4th edn. Lippincott-Raven, Philadelphia: 477–85
Stark RP, Maki DO (1984) Bacteriuria in the catheterized patient: what quantitative level of bacteriuria is relevant? *N Engl J Med* **311**: 560–4
Stickler DJ (2002) Susceptibility of antibiotic-resistant Gram-negative bacteria to biocides: a perspective from the study of catheter biofilms. *J Appl Microbiol* (Symposium Suppl) **92**: 163S–170S
Trueman P (2007) An economic analysis of how catheterisation can be made cost-effective. *Urology News* **12**: 21–3
Van der Wall E, Verkooyen RP, Mintjes de Groot J et al (1992) Prophylactic ciprofloxacin for catheter-associated urinary-tract infection. *Lancet* **339**: 946–51
Warren JW (1997) Catheter-associated urinary tract infections. *Infect Dis Clin North Am* **11**: 609–22
Wazait HD, Patel HRH, Veer V et al (2003) Catheter-associated urinary tract infections: prevalence of uropathogens and pattern of antimicrobial resistance in a UK hospital (1996–2001). *BJU Int* **91**: 806–9
Wazait HD, Patel HR, van der Meulen JH et al (2004) A pilot randomized double-blind placebo-controlled trial on the use of antibiotics on urinary catheter removal to reduce the rate of urinary tract infection: the pitfalls of ciprofloxacin. *BJU Int* **94**(7): 1048–50
Wolff G, Gradel E, Buchman B (1976) Indwelling catheter and risk of urinary infection: a clinical investigation with a new closed-drainage system. *Urol Res* **4**: 15–18

KEY POINTS

- Avoid using a urinary catheter whenever possible. When catheterization is necessary, remove the device as soon as possible.
- Always insert a catheter aseptically, use a closed drainage system and properly maintain the catheter during use.
- Consider using systemic antibiotic drug therapy only during short-term (3–14 days) catheterization of patients at high risk of complications of catheter-associated bacteriuria.
- Consider using a silver alloy catheter in patients at high risk of complications of catheter-associated bacteriuria.
- Prophylaxis with antimicrobial agents in accordance to local guidelines should be given to patients undergoing renal transplantation and requiring indwelling catheterization.
- Systemic antibiotic drug prophylaxis should probably be given to men undergoing surgical interventions.
- Bladder irrigation, antibacterial instillation in the drainage bag, rigorous meatal cleaning, and use of meatal lubricants and creams have not been shown to prevent bacteriuria and should not be used.