Infection Prevention in the Intensive Care Unit

Mary C. Barsanti, MD, Keith F. Woeltje, MD, PhD *

Managing infections in the intensive care unit (ICU) can be a daunting challenge to any practitioner. In the United States, more than 5 million patients are admitted to an ICU every year.1,2 ICU-related infections increase the cost of hospitalization, morbidity, mortality, and hospital length of stay.3–6 Infection prevention measures can help improve these outcomes by limiting the incidence and spread of hospital-acquired infections.

The past several decades have seen an increased effort in characterizing the epidemiology of health care–associated infections and in advancing the knowledge of infection-prevention practices. The goal of this article is to discuss risk factors and specific nosocomial infections, particularly ventilator-associated pneumonia (VAP), central line–associated bloodstream infections (CLABSIs), catheter-associated urinary tract infections (CAUTIs), and *Clostridium difficile* infections (CDIs). Antimicrobial stewardship will also be discussed briefly.

**RISK FACTORS FOR NOSOCOMIAL INTENSIVE CARE UNIT INFECTIONS**

Estimates from the National Nosocomial Infections Surveillance (NNIS, now the National Healthcare Safety Network [NHSN]) system found approximately 1.7 million nosocomial infections occurred in United States hospitals in 2002 with 24% of these infections in the ICU, a rate of 13 per 1000 patient days.7 ICU patients have numerous insults to normal host mechanisms. Skin integrity is compromised by peripheral and central venous access devices or postoperative wounds. Immunosuppressive medications decrease the ability of humoral and cell-mediated immunity defenses to function properly. Underlying medical conditions, such as diabetes, may predispose

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patients to infectious complications. Potentially modifiable risk factors are related to nutrition, health care personnel, and the hospital environment.

**Malnutrition**

Numerous studies have delineated the connection between poor nutrition and deficiencies in immune function. Hospitalized patients with hypoalbuminemia are noted to have impaired cellular immunity. Immune system function is reduced because of a decrease in lymphocyte, cytokine, and complement production, and an attenuated response to antigenic stimuli. This reduced immune system function impedes normal host responses to infection. A low albumin level in cardiac surgery patients correlates with increased risk of postoperative infections, while malnutrition is a risk factor for surgical site infections. Medical ICU patients who receive less than 25% of the daily recommended calories have a significantly increased risk of nosocomial bloodstream infections. These studies all indicate the importance of appropriate nutrition in critically ill patients.

**Supplemental Nutrition**

To counteract the effects of malnutrition on the immune system, nutritional support in ICU patients is vital. Although necessary, the mode of nutritional support may also have an impact on nosocomial infections. Parenteral feeding requires long-term central venous access catheters, which are a potential source for bacterial colonization and CLABSI. This method of feeding also increases gut mucosal permeability compared with enteral nutrition, increasing the risk of bacterial translocation. However, enteral feeding has also been shown to increase the risk of VAP. This is especially seen in patients who remain in the supine position. In a recent meta-analysis of enteral versus parenteral feeding in critically ill adult patients, enteral feeding significantly decreased the risk of overall infections, but had no impact on mortality. This increased risk of infections in parenteral feeding was also seen in a second meta-analysis, although there was a mortality benefit to this feeding method. The mortality benefit may be explained in this series by its comparison of delayed enteral nutrition to parenteral nutrition. When comparing early parenteral versus early enteral nutrition, the incidence of sepsis or septic shock was significantly lower in the early enteral feeding group. Similarly, when comparing early versus late enteral feeding alone, early feeding results in improved ICU mortality.

**Hyperglycemia**

There has been significant recent interest in the role of glucose control in ICU patients and its relation to the immune system. Hyperglycemia has been found to affect neutrophil function, phagocytosis, and cytokine activity. This may lead to an increased risk of infectious complications, especially in critically ill patients. Diabetics undergoing cardiovascular surgery have more postoperative wound infections than nondiabetics. Trauma patients admitted to the ICU with hyperglycemia have increased risk of infections, particularly respiratory and bloodstream. In a study of 61 surgical ICU patients randomly assigned to tight or standard glycemic control, 34 patients in the strict glucose control group experienced significantly fewer nosocomial infections. Initiation of a continuous insulin drip protocol significantly decreases the incidence of postoperative wound infections in diabetic patients undergoing cardiovascular surgery. However, recent studies revealed intensive glycemic control (between 80 and 110 mg/dL) did not show a mortality benefit and only a nonsignificant reduction in bacteremia. A subgroup analysis of patients staying less than 3 days...
in the ICU even indicated increased mortality with intensive glycemic control.\textsuperscript{33,34} More studies are needed to determine the optimal method of controlling hyperglycemia in ICU patients.

**Health Care Personnel**

The complex care of an ICU patient relies upon the interaction of many individuals, including physicians, nurses, and support staff. An appropriate ICU organizational structure is vital to proper and effective patient care. One study of postoperative patients staying in an ICU that did not institute daily rounds by an ICU physician indicated increased rates of mortality and sepsis.\textsuperscript{35} Interventions to improve communication amongst all ICU staff consisting of daily multidisciplinary rounds with discussions on mechanical ventilator, central line, and urinary catheter protocols can significantly decrease the rate of VAP and CLABSI with a downward trend in CAUTI.\textsuperscript{36–38} Periodic educational interventions for ICU staff with reminders of infection-prevention policies can also result in the decline of hospital-acquired infection rates.\textsuperscript{39–43}

In addition, adequate nursing and support staff is necessary. A higher patient-to-nurse ratio increases the risk of nosocomial infection,\textsuperscript{44} including late-onset VAP\textsuperscript{45} and CLABSI.\textsuperscript{46} The difficulties of nurse staffing, including understaffing and the different levels of nurse training, have an impact on risk of infection.\textsuperscript{47–49} Patients cared for by a registered nurse for longer periods of time rather than by a nurse with less education have a decreased risk of developing pneumonia or urinary tract infections while in the hospital.\textsuperscript{50,51} Greater use of float pool nurses may also increase the risk of nosocomial infections.\textsuperscript{52,53} These studies show that improved nurse staffing can have a significant impact in decreasing adverse events in hospitalized patients.

**Hospital Environment**

The hospital environment plays a crucial role in exposing patients to various pathogens, including bacterial, fungal, and viral. These organisms may be found on the hands of caretakers,\textsuperscript{54–56} on the knobs of doors,\textsuperscript{57} on keyboards,\textsuperscript{58,59} or in the structure and environment of the room itself,\textsuperscript{58,60,61} increasing the chances of a nosocomial infection. Measures to decrease the environmental burden of pathogens and subsequently lower the rates of hospital-acquired infections have been studied.

**Hand hygiene**

Appropriate hand hygiene is vital to patient care and is extremely cost-effective. A study evaluating the cost-effectiveness of a hand hygiene educational program found the total cost of providing alcohol-based foam and the campaign itself was less than 1\% of the cost of a nosocomial infection.\textsuperscript{62} Compliance rates of health care workers using proper hand hygiene before and after patient care activities vary, ranging from 24\% to 89\% (an average of 56.6\%) in a recent survey of 40 hospitals.\textsuperscript{63} This survey was conducted after the publication of new guidelines by the Association of Professionals in Infection Control, Healthcare Infection Control Practices Advisory Committee (HICPAC), Society for Healthcare Epidemiology of America (SHEA), and Infectious Diseases Society of America (IDSA) on appropriate hand hygiene practices.\textsuperscript{64} Even with the wide gap in compliance, the overall rates of CLABSI did significantly decline in the 40 hospitals surveyed after the new guidelines were published.\textsuperscript{63} Other studies found similar results when an educational program was instituted resulting in improved hand hygiene compliance and decreased rates of hospital-acquired infections.\textsuperscript{65–67} Continuous encouragement and monitoring with reinforcement of hand hygiene policies are important to maintain improvement in compliance rates.\textsuperscript{68}
In addition, appropriate placement of alcohol-based hand-rubbing solutions or hand-washing sinks is essential to increased compliance rates.64 Alcohol-based foam has been shown to reduce bacterial counts recovered on health care workers’ hands over hand washing.65 In a separate study, no significant difference was found in bacterial colony counts on hands of health care workers who used a chlorhexidine-containing antiseptic wash versus alcohol-based foam.70 Investigators did note, however, that using the alcohol foam significantly decreased workers’ skin damage along with time and cost compared with chlorhexidine wash. Skin damage may itself lead to increased pathogen colonization and decrease the desire for workers to perform hand hygiene. Appropriate emollients or lotions may help.64 In addition, use of alcohol foam for hand hygiene is fast and easily accessible, which therefore can increase compliance with hand hygiene practices.71

Other factors may contribute to pathogen carriage on health care workers’ hands. Fingernail length over 2 mm past the fingertip is associated with significantly more microorganisms recovered on the hands of workers compared with lengths of 0 to 1 mm.71 Wearing a ring also increases the number of microorganisms recovered.71,72

The Hand Hygiene Task Force compiled the trials comparing soap to alcohol-based foam and determined that alcohol-based foams are more effective in decreasing bacterial colony counts and in decreasing the number of multidrug-resistant pathogens than traditional hand washing.64 Many viruses and fungi are also susceptible to alcohol formulas; however, bacterial spores, protozoa, and some nonenveloped viruses are not affected.64 Overall, the Hand Hygiene Task Force has compiled numerous recommendations on this subject and is a valued reference.

Hand colonization

Once health care workers’ hands are colonized with a pathogen, the organism can be transferred to the environment of a patient’s room or to another patient. In a study of vancomycin-resistant Enterococcus (VRE)–colonized patients, some environmental cultures negative before a health care worker entered the room turned positive after the worker performed patient care activities.73 Another study of ICU patients evaluated bacterial colonization of methicillin-resistant Staphylococcus aureus (MRSA) or ceftazidime-resistant gram-negative bacilli on admission and at discharge. At discharge, 21.6% of patients had acquired colonization of one organism and 2.4% with both organisms, which were not present on admission.74 While evaluating an Acinetobacter baumannii outbreak leading to sepsis and the death of three ICU patients, the study investigators discovered the same isolates by culturing health care workers’ hands and patients’ rooms.55 After 10 days of cleaning, the ICU had 1 month without A baumannii infections.

Patient rooms

Patient rooms may harbor significant pathogens long after the source patient was moved. One study found that, if a previous ICU room occupant or environmental sample within the past 2 weeks was VRE positive, then the next occupant had an increased risk of VRE acquisition after 48 hours of hospitalization.75 MRSA patient colonization may also have similar risks.76

Recent studies looking at terminal room-cleaning methods used a mark visible only by UV light in prespecified areas as a surrogate for transmissible pathogens, such as MRSA or multidrug-resistant gram-negative bacilli. At baseline, two studies found 44% and 49% of marks remained after completion of room cleaning by environmental services staff.77,78 Doorknobs, sinks, toilet handles, and light switches were the most common missed surfaces.77,78 An educational campaign with continued feedback
and cleaning-regimen change resulted in a significant decline in positive surfaces. Another small study used culture methods to detect VRE or *C. difficile* in terminally cleaned rooms whose occupants were colonized or infected with these organisms. After cleaning, 71% to 78% of the rooms remained culture-positive. An educational intervention led to significant reductions in positive cultures. Combining environmental cleaning with a hand hygiene educational campaign can significantly decrease both environmental and hand contamination rates.

**Other environmental factors**

Besides a patient’s room, air and water filtration systems provide other sources for pathogen contamination and increased risk of infection. Aspergillus has been found in hospital and ICU air samples. *Legionella pneumophila* can colonize a hospital water system and cause pneumonia in hospitalized patients. Tap water in a patient room can be contaminated with *Pseudomonas aeruginosa*, but placing water filters can decrease infections with this organism. Caution should be taken in any ICU that plumbing, water, and air-filtration systems are closely monitored.

**Patient screening**

The NNIS System Report in 2004 found the percentage of antimicrobial-resistant pathogens in ICU patients increased. The percentage of *S. aureus* that was MRSA in 2003 was 59.5%, an increase of 11% over the mean resistance rates 5 years previously. VRE percentage increased 12% while some gram-negative bacilli, including *Klebsiella pneumoniae* and *P. aeruginosa*, also noted increased resistance to third-generation cephalosporins and carbapenems. With increasing resistance, it is even more important to find strategies to contain and eradicate these organisms.

Patients newly admitted to an ICU who are colonized with multidrug-resistant pathogens are a constant reservoir for transmission and subsequent infection. Surveillance cultures to detect MRSA and VRE have been implemented at many hospitals with significant success in decreasing the rate of colonization and infection with these organisms. The Centers for Disease Control and Prevention’s statement on isolation precautions state surveillance strategies prefer targeting the patients or locations at highest risk as opposed to hospital-wide surveillance for best use of resources. However, hospital-wide surveillance measures may be needed for certain organisms or situations.

It remains controversial whether admission to the hospital or an ICU constitutes an appropriate indication for a surveillance culture, and how to handle a hospital outbreak of a multidrug-resistant pathogen. A multiyear study evaluated baseline levels of MRSA colonization for 12 months, then 12 months of ICU surveillance, and finally 21 months of hospital-wide MRSA testing. The rate per 10,000 days was 8.9, 7.4, and 3.9 respectively for baseline, ICU, and hospital-wide surveillance. The transition from baseline to hospital-wide surveillance significantly improved infections rates. However, a study of surgical patients found no significant difference in the rate of nosocomial MRSA infection between universal versus no screening on admission.

Consideration of risk factors for MRSA colonization may improve the use of hospital resources and infection-prevention strategies. Known risk factors for MRSA colonization or infection include male sex, age over 75 years, recent receipt of certain antibiotics or intravenous therapy, recent hospitalization, intrahospital transfer, HIV infection, a current skin or soft tissue infection, or presence of a urinary catheter. Cost-benefit analyses of VRE and MRSA surveillance appear to favor surveillance as a cost-saving measure, but it remains questionable whether all patients or a subset of patients, possibly ICU admissions, are the best target for this intervention.
Isolation measures

Use of gowns and gloves is a standard procedure for staff caring for patients with multidrug-resistant infections. Recent studies have evaluated the effectiveness of using isolation measures on patients colonized but not currently infected with these organisms. A study of glove use by 50 health care workers who care for VRE-positive patients found the use of gloves decreased the risk of the health care worker acquiring VRE by 71%. Even with glove use, five subjects with VRE cultured from their gloves also had positive VRE cultures on their hands.112 Another study found the use of gloves upon room entry of VRE-positive patients resulted in only 5% of health care workers becoming colonized compared with 37% who did not wear gloves.113

A study comparing the use of gowns and gloves in eight ICU beds versus gloves only in eight separate ICU beds for all patients irrespective of pathogen colonization found no significant difference in acquiring VRE between the two groups. However, the investigators concluded that gown and glove use may improve overall compliance with isolation precautions.114 Recent studies have found advantages in using both gowns and gloves to decrease the risk of transmitting both MRSA and VRE.89,93,115,116 In addition, both HICPAC and SHEA guidelines encourage both gown and glove use upon entering rooms of patients colonized with antibiotic-resistant pathogens.96,104 Cost-benefit analyses of gown use show a temporary increase in costs, but the long-term decrease in VRE or MRSA colonization and infections overall decreases hospital costs.106,116,117

Patient decolonization or prevention of colonization

Methods to treat or prevent MRSA and VRE colonization are under investigation. Use of 2% chlorhexidine cloths to bathe patients has been shown to decrease VRE colonization and rates of CLABSI.118,119 The results are mixed with MRSA, one study failing to show improved decolonization rates with a 4% chlorhexidine bathing solution,120 while others show chlorhexidine could improve decolonization rates.121,122 The positive studies often combine chlorhexidine with nasal mupirocin and oral antibiotics, including rifampin or doxycycline. One effective program to reduce MRSA colonization included chlorhexidine, oral rinses, oral antibiotics, urinary tract decolonization, gastrointestinal tract decolonization, and vaginal decolonization.123 Unfortunately, health care workers may have difficulty completing this intensive program.124 At this time, the best combination remains speculative and ongoing studies may answer this question.

NOSOCOMIAL INFECTIONS

Ventilator-Associated Pneumonia

VAP occurs in 9% to 27% of all intubated patients or 2.1 to 10.7 episodes of VAP per 1000 ventilator days6,125–128 with a crude mortality rate that may exceed 20% or greater if a high-risk pathogen is involved.125 Patients with VAP are twice as likely to die compared with those without VAP.6 Also, patients with VAP have a significantly longer duration of mechanical ventilation and hospital length of stay3,128 accompanied by costlier medical bills ranging from $10,000 to over $40,000 more than patients who do not acquire VAP3,6,129 Knowing the tremendous personal and economic consequences of VAP necessitates increasing the knowledge of health care workers of this problem and working to improve prevention strategies.

Risk factors

A review of risk factors found postsurgical patients, presence of multiple organ failure, age greater than 60 years, supine patient positioning, decrease of gastric pH,
cardiopulmonary resuscitation, continuous sedation, reintubation, presence of nasogastric tube, enteral feeding, sinusitis, and patients transported out of the ICU had increased risk of developing VAP. In a separate review, other nonmodifiable risk factors include the presence of acute respiratory distress syndrome, chronic obstructive pulmonary disease, coma, head trauma, and male patients. Some studies looking at the ventilator circuit found that a lower cuff pressure, less frequent subglottic aspiration, and fewer circuit changes may also contribute to higher rates of VAP.

Use of systemic antibiotics remains controversial with mixed results.

Methods of prevention

Many strategies have been studied to prevent VAP and SHEA/IDSA recently published a concise set of recommendations regarding this topic. Most of the modifiable risk factors involve basic infection-prevention principles, medications, and the ventilator equipment. As previously discussed, hospital staff education of the problem, proper surveillance for multidrug-resistant pathogens, appropriate isolation of patients, hand hygiene, and environmental and equipment cleaning can decrease the risk of VAP.

In addition, a high nurse-to-patient ratio was found in one study to decrease the rates of VAP. These daily strategies can have a significant impact.

Mechanical ventilation is an inherent component to the development of VAP. This basic fact leads to the conclusion that fewer intubated patients will decrease the numbers of VAP. Use of noninvasive ventilation and fewer reintubations is preferred when possible. Semirecumbent positioning appears to give some protection from pulmonary aspiration and is the recommended position for intubated patients when possible; however, one study found 45° to be difficult to achieve. The many components of the ventilator circuit can harbor bacterial pathogens if not frequently and properly cleaned. Continuous aspiration of subglottic secretions appears to significantly decrease the risk of VAP along with maintaining the endotracheal intracuff pressure over 20 cm H2O. In addition, a review of 10 studies found no difference in the risk for VAP in open versus closed endotracheal suction systems. Lastly, a recently published study found the use of silver-coated endotracheal tubes decreased the incidence of VAP among patients who used these experimental tubes.

Other modifications besides respiratory care can improve VAP rates. A summary of eight trials for stress ulcer prophylaxis compared sucralfate to ranitidine with results showing a slightly decreased risk of VAP when using sucralfate, although use of this medication may increase the risk of gastrointestinal bleeding. Daily interruption of sedation medication in ventilated patients can decrease the time of ventilation and in a small study decrease the incidence of VAP. A nurse-implemented sedation protocol with around-the-clock adjustments can significantly decrease days of ventilation and decrease risk of VAP. Use of oral chlorhexidine decreases bacterial colonization of oropharyngeal secretions; however, a recent meta-analysis found oral chlorhexidine use only decreases the incidence of VAP when intubated for less than 48 hours. More studies are needed to gather information for long-term ventilated patients.

Antibiotic use remains a controversial subject. The standard use of antibiotics for all intubated patients may select for multidrug-resistant pathogens. As a result, the American Thoracic Society (ATS)/IDSA guidelines to date do not routinely recommend antibiotic use without signs of infection. Selective decontamination of the digestive system with oral or intravenous antibiotics (which are not actually selective for the digestive system) has been found in some studies to lessen the risk of VAP, however, the same concern remains that the use of antibiotics will select for
multidrug-resistant pathogens. At this time, selective decontamination of the digestive system is not routinely recommended.129

**Bloodstream Infection**

Use of central venous catheters is essential to the care of many ICU patients. Every catheter, though, increases the risk of a CLABSI with an estimated number of 87,500 to 350,000 in the United States per year or 1.0 to 5.6 CLABSIs per 1000 catheter days.126,146 CLABSIs increase the length of stay and incur excess costs of hospitalization ranging from $3,400 to $56,000; however, the evidence is mixed on whether mortality rates are increased.4,5,147–151 Because of the clinical and economic impact of CLABSI, there is an urgent need to study and reorganize infection-prevention practices.

**Risk factors**

The most important element in a CLABSI is the presence of a catheter. The longer a catheter remains in place, the greater is the risk of infection.152 The presence of more than one catheter, use of a catheter with more than one lumen, use of total parenteral nutrition or chemotherapy, or the presence of a surgical wound except a noted clean wound are all noted risk factors for bloodstream infection.152 Patients in the ICU cared by “float pool” nurses for over 60% of the time the CVC was in place, unarousable over 70% of the time, and those who had no antibiotics given within 48 hours of CVC placement had a higher risk of CLABSI.53 Other studies have found evidence that age younger than 65 years, a low hematocrit and low white blood cell count on admission increases the risk of bloodstream infection.153 A case-control study found the number of previous infections, older age, duration of immunosuppressive medications, number of comorbidities, and presence of neutropenia are additional risk factors.154 One study found a majority of the pathogens causing CLABSI correlated to a culture of the patient’s skin.155 This places extra emphasis on skin colonization and need for proper antisepsis.

**Methods of prevention**

Implementation of an intensive infection-prevention program with emphasis on patient safety and communication among health care workers can decrease rates of CLABSI.42,43,156,157 A compendium published by SHEA and IDSA describes in detail current recommendations.158 Additionally, maintaining educated nursing staff with fewer pool nurses46,52 may contribute to decreased infection rates. Some studies have even looked at the establishment of “IV (intravenous) teams,” which standardize care of central venous catheter (CVC) and may lead to decreased rates of infection.159,160

A meta-analysis looking at use of iodine-based versus chlorhexidine skin-prepping solutions before arterial catheter placement shows a trend toward decreased rates of CLABSI.161 Chlorhexidine also decreases catheter colonization rates161 and appears to be the antiseptic solution of choice at this time.162 Specific precautions during catheter insertion are recommended, such as the use of sterile drapes, masks, caps, sterile gowns, and sterile gloves, along with a checklist to ensure proper protocols have been performed.158 A review article of 34 studies evaluated the risk of catheter-related bloodstream infections from heparin-coated, antibiotic- and antiseptic-impregnated catheters. The results showed significant reduction in CLABSI with the use of chlorhexidine/silver sulfadiazine catheters and even further risk reduction with minocycline-rifampicin–coated catheters.163 These catheters, though, are not routinely recommended unless the patient is at higher risk of CLABSI.158 In regards to type of catheter, a peripherally inserted catheter is not preferred over other catheters at this time.
Steps taken after line insertion may also decrease infection rates. Such steps include disinfecting the catheter hub before its access.\textsuperscript{158,164} Thrombus formation in the catheter can become colonized with bacterial pathogens and lead to infection. A meta-analysis found heparin flushes significantly reduced the incidence of thrombus formation with a trend toward reducing the risk of CLABSI.\textsuperscript{165} The use of urokinase locks may also decrease the rate of CLABSI, as noted in a recent study.\textsuperscript{166} These findings need to be further substantiated before advocating the general use of urokinase locks.

Antibiotic lock prophylaxis has been proposed to decrease CLABSI rates. A meta-analysis evaluated infusion of vancomycin with heparin to dwell in the intravascular device lumen and found a significant decrease in the risk of CLABSI among high-risk patients, particularly adults with malignancy or infants in a neonatal ICU.\textsuperscript{167} As of this time, antibiotic lock prophylaxis is not a standard recommendation, but a consideration in particularly high-risk or difficult-access patients.

Catheters should be removed as soon as possible once they are no longer necessary. In addition, they should have the least amount of lumens needed for the patient’s medications. Of course, it is often difficult to predict long term what is needed in a critically ill patient, but, when possible, these guidelines should be followed.\textsuperscript{151,158}

**Urinary Tract Infection**

Approximately 23\% of nosocomial infections in the ICU are urinary tract infections with 97\% of those CAUTIs or 3.1 to 7.7 CAUTIs per 1000 urinary catheter days.\textsuperscript{126,168} A CAUTI costs an additional $589 per incidence.\textsuperscript{169} It is a common infection, but does not appear to be linked with excess patient mortality.\textsuperscript{170} The outcomes are less severe than those for VAP or CLABSI, but the significant number of infections makes it important to find ways to decrease their incidence.

**Risk factors**

The most important risk factor in the development of a CAUTI is the presence of a urinary catheter with other factors being female gender, obesity, immunodeficiency, duration of catheter use, and length of stay in an ICU.\textsuperscript{171–175} Inappropriate placement of urinary catheters when not needed also increases the risk of patients developing a CAUTI.\textsuperscript{175}

**Methods of prevention**

Any patient in the ICU with a urinary catheter should have it removed as quickly as possible. To assist with this, ongoing evaluation for continued need and discussion on rounds are helpful reminders to ICU staff and can decrease the rates of CAUTI.\textsuperscript{176} Even before this point, the need of a urinary catheter should be confirmed before initial placement, which should be done under aseptic conditions. Once placed, it should be maintained in a closed drainage system.\textsuperscript{177}

There is no specific material recommended for catheters. Silver alloy catheters may decrease the risk of CAUTI for patients catheterized less than 1 week.\textsuperscript{178} A meta-analysis found a possible decrease in incidence of asymptomatic bacteriuria when using silver alloy or nitrofurazone-coated catheters for the short term.\textsuperscript{179} The evidence is unclear at this time and more studies are necessary. A summary of preventative strategies by the IDSA/SHEA is a good reference for further information.\textsuperscript{177}

**Clostridium Difficile Infection**

CDI is an important source of hospital-acquired infections in the ICU and is associated with increased morbidity, length of hospital stay, cost of hospitalization, a trend toward increased mortality in the ICU, and overall increase in cause of death in the
The emergence of more virulent strains of *C difficile* increases the need to expand research of this pathogen.

**Risk factors**

One of the key risk factors of acquiring CDI is greater colonization pressure. A recent study found only 1 out of 382 patients with CDI had no prior exposure to CDI before developing infection. Other potential risk factors are older age, recent hospitalization, hematologic malignancy, taking medications that decrease gastric acid, and numerous antibiotics, particularly fluoroquinolones and broad-spectrum antibiotics.

**Methods of prevention**

*C difficile* forms spores that can remain in the environment for a prolonged period of time. Appropriate hand hygiene with soap and water and thorough environmental cleaning decreases the spore burden and is essential. One study showed the incidence of CDI decreased from 7.7 cases per 1000 discharges to 1.5 cases per 1000 discharges when hospital staff wore gloves while handling any body substance while also reducing carriage rates. At this time, there is little evidence that using antibiotic prophylaxis to treat colonization decreases the rate of nosocomial CDI.

Proper surveillance for CDI in symptomatic patients is necessary to isolate affected patients. It may be reasonable to instigate general surveillance of patients during a CDI outbreak or endemic setting. General infection-prevention measures with isolation of affected patients help prevent spread of CDI. Besides infection-prevention programs, restricting antibiotic use with antimicrobial stewardship and limiting the number of patients who receive perioperative antibacterial prophylaxis may also help decrease rates of the infection. Strategies to identify and prevent CDI are compiled in the new SHEA/IDSA guidelines.

**ANTIMICROBIAL STEWARDSHIP IN THE ERA OF MULTIDRUG-RESISTANT ORGANISMS**

Given the association between antimicrobial use and the selection of resistant pathogens, the frequency of inappropriate antimicrobial use is often used as a surrogate marker for the avoidable impact on antimicrobial resistance. The combination of effective antimicrobial stewardship with a comprehensive infection control program has been shown to limit the emergence and transmission of antimicrobial-resistant bacteria. A secondary goal of antimicrobial stewardship is to reduce health care costs without adversely impacting quality of care.

Antibiotic resistance in the ICU is more prevalent than in the general hospital ward. Resistance rates to most bacterial pathogens are increasing, as shown in the NNIS System Report from 2004. This increase is therefore especially important in the ICU where critically ill patients have the highest risk of infection. The cause of antibiotic resistance is multifactorial, but one of the most critical and possibly amenable reasons is antibiotic disuse.

Establishing guidelines or interventions for appropriate antibiotic use have been shown to significantly reduce the number of antibiotics used and decrease hospital costs. A Cochrane review of 66 studies found improvement in optimization of antibacterial use and microbiologic outcomes when hospitals put forth interventions to improve antibiotic policies. Many hospitals have added multidisciplinary measures, including antimicrobial stewardship programs, to decrease inappropriate usage of antibiotics with success in decreasing broad-spectrum antibiotic usage, decreasing medication costs, and likely improvement in antimicrobial susceptibility profiles. With increasing antibiotic resistance, risk of CDI from antibiotic use, and constant need to
find new cost-saving health care measures, comprehensive antimicrobial plans are essential to further improve patient care.

SUMMARY

It is vital to recognize and understand the impact of nosocomial infections on ICU patients. The social, economic, and personal costs to patients and hospitals are overwhelming, but researchers have found many interventions to decrease infection rates. A multidirectional approach, including continuing staff education, minimizing risk factors, and implementing guidelines established by national committees, is needed. Infection-prevention committees can assist in implementing policies. This is an active area of research and we anticipate continued advancements to improve patient care.

REFERENCES

11. Scrimshaw NS. Historical concepts of interactions, synergism and antagonism between nutrition and infection. J Nutr 2003;133(1):316S–21S.


