66 Healthcare-Associated Infections in Pediatrics

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Introduction/Definitions

Formerly, infections associated with hospitalization were termed nosocomial infections but in recent years, the term healthcare-associated infections (HAI) has been considered a better term to indicate that the issues extend to physicians offices, home nursing, and any interactions with healthcare facilities. Thus, HAI are infections that patients acquire during the course of interacting with a healthcare setting. HAI are not infrequent complications of serious illnesses. HAI occurring in hospitals are defined as infections not present or incubating at the time of admission that develop during admission or less than one incubation period after discharge. Illness from HAI may be any degree from minor infections to life-threatening ones. In practice, infections with an onset 48 h or more after admission are assumed to be HAI unless the infection is clearly community-acquired and follow-up surveillance 1 or 2 weeks after discharge should be sufficient to detect infections that were not apparent during admission. Severely ill and immunocompromised patients have a greater risk of acquiring HAI, so this problem is greatest in intensive care units (ICUs), transplant centers, and oncology units. Studies have demonstrated that nosocomial infections are frequently associated with preventable risk factors. Adherence to recommended techniques for patient care will benefit all patients but have the greatest effect in units where the sickest patients are cared for.

Certain patients are at increased risk because of the severity and possible immunosuppressive nature of their illness, and their need for invasive monitoring and life-support equipment. Studies of HAI rates in Pediatrics have therefore been largely limited to neonatal intensive care units and critical care units that care for children beyond the neonatal period. The epidemiologic factors which are associated with high susceptibility to nosocomial infection have been studied in infants, children, and adults.

Epidemiology and Rate of Nosocomial Infections in Pediatrics

Rates of nosocomial infections in pediatrics. Several studies have established the expected rates of HAIs in children hospitalized in general care wards and have defined the most common types of HAIs, the organisms responsible, and the risk factors. Rates of HAIs have generally been defined as the number of HAIs divided by the number of patients at risk times 100. The denominator is usually the number of admissions or discharges in the unit studied. This rate is sometimes expressed as a percentage. Risk may also be calculated according to the rate of infection per day of hospitalization. This is usually expressed as number of HAIs or specific types of HAIs such as bloodstream infections (BSI), or infection associated with the presence of certain devices (e.g., urinary catheters, assisted ventilation) per 100, 1,000, or 10,000 patient-days or device-days.

The method of obtaining data to determine the rate of infection may vary from one institution to another. Research surveillance studies use defined methodology that needs to be uniform if multiple institutions combine their data. As shown in ❯ *Table 66.1* there are many resources that can be used to identify nosocomial infections. Clinical ward rounds by a trained surveyor generally yields the most information but other sources may add information not available at the bedside or the patient's chart. ❯ *Table 66.2* lists the relative sensitivity of various sources of data indicating that active surveillance on a continuous basis is the most accurate method and data obtained from either the microbiology laboratory or the pharmacy is considerably less sensitive. Relying on clinicians to report nosocomial infections to a central collection point (passive surveillance) is notoriously inaccurate and greatly underestimates the rate of infection. Total daily hospital bedside surveillance is usually impractical as there is often neither sufficient time nor personnel to carry it out. Therefore, intensive surveillance is often limited to the highest-risk units such as the intensive care

Abdelaziz Y. Elzouki (ed.), *Textbook of Clinical Pediatrics*, DOI 10.1007/978-3-642-02202-9_66,

Table 66.1
Sources of information for surveillance of nosocomial infections

Clinical ward rounds
Microbiology laboratory reports
Radiology reports
Pharmacy data
Admissions department
Medical records department
Operating room activity reports
Post discharge surveillance
Regional health resources

Table 66.2
Relative "sensitivity" of selected methods of surveillance for nosocomial infections[a]

"Ideal" continuous active surveillance	+++++
Total chart review	++++
Microbiology reports	++ to +++
Fever plus antibiotic use	+++
Fever	++
Antibiotic use	++
Physician self-report forms	+ to ++

[a]+, least sensitive; +++++, most sensitive

units, oncology units, and surveillance of surgical procedure outcomes.

Each hospital must have a source of information for the criteria of diagnosing nosocomial infections. In the United States, most collaborative studies use the definitions recommended by the Centers for Disease Control and used in the National Healthcare Safety Network (NHSN).

In the United States, it has been estimated that one-third of infections in hospitalized patients are nosocomial. Thus, nosocomial infections occur in two million patients per year, result in four million extra days of hospitalization with costs of 4.5 billion dollars.

One of the earliest reported studies having to do with rates and risk factors for nosocomial infections dealt with children. In the early 1960s, T.E. Roy and associates reported on an extensive survey of hospital infections at the hospital for sick children in Toronto, Ontario, Canada. They found a 6.5% overall rate of hospital-acquired infections. This figure is somewhat higher than the rate of 3.2% reported in a 1970 study from Children's Hospital Medical Center in Boston, in which there were twice as many surgical patients as medical patients. In both studies, the rates were substantially higher on those services that dealt with debilitated patients and certain types of surgical patients. In the Toronto study, the two surgical wards had rates of 10.55% and 24.64%; however, rates were lower than average when surgery was performed on "clean" sites (2.1%).

Clean surgical cases are those in which there is an incision through prepared normal skin and the operative field does not include infected tissue, abscess, or entry into normally unsterile areas such as the bowel, the upper respiratory tract, or the lower female genital tract. *Table 66.3* shows that in surgically related HAI, the type of surgery and the degree to which the surgical field is likely to be contaminated with microorganisms determines the risk of infection.

In the Boston study, higher than average HAI rates were found among debilitated patients (e.g., a rate of 21.4% in patients on the tumor therapy ward,) and surgical patients (neurosurgery patients, 18.5%), but they were lower than average on services whose patients enjoyed good general health and had short hospital stays such as dental, ophthalmology, and otolaryngology patients.

More recent studies by The Pediatric Prevention Network Study in the United States (Stover et al.) looked at HAI rates in 43 Children's hospitals. In 1998, the nosocomial infection rate was 8.9 nosocomial infections per 1,000 patient days in newborn ICUs (NICUs) and 13.9 nosocomial infections per 1,000 patient days in pediatric ICUs (PICUs). In that study in the NICU, the device-associated rates were reported by device-days by birthweight ($>$2,500, 1,501–2,500, 1,001–1,500, and $\leq$1,000 g), bloodstream infections 4.4, 4.7, 8.9 and 12.6 per 1,000 device-days, and ventilator-associated pneumonia 0.9, 1.1, 4.9 and 3.5 per 1,000 device-days, respectively. In the PICU, the median nosocomial infection rates were 6.5 for BSI, 3.7 for ventilator-associated pneumonia, and 5.4 for urinary tract infection all per 1,000 device-days.

In a report from the Centers for Disease Control and Prevention in the United States, the overall rate of nosocomial infections in all services was 3.37% in 1978 and on pediatric services, it was 1.2%. The sites of infection were more commonly the gastrointestinal (GI) tract and the respiratory tract in children than in adults. A study published in 1984 from the Children's Hospital of Buffalo was one of the very few to examine the rate of nosocomial infections in various units within a children's hospital.

Table 66.3
Surgical wound classification

Type of wound	Definition	Estimated rate of infection
Clean	Elective surgery with primary closure and no drains: No breaks in sterile technique nor entry into non-sterile organs	<5%
Clean-contaminated	The alimentary or respiratory tract is entered without significant spillage or mechanical drainage	~10%
Contaminated	Fresh trauma or operations with a major break in sterile technique, gross spillage from the GI, infected biliary, urinary tract, etc.	~20%
Dirty wound	Presence of organisms in ordinarily sterile tissue before the operation – "Clean" incision into a collection of pus – Traumatic wounds with devitalized tissue – Fecal contamination – Delayed surgical treatment of dirty contaminated wounds	~30% or greater

The rate of nosocomial infections was 4.1 nosocomial infections per 100 patients discharged. The rate in the intensive care nursery unit was 22.2 infections per 100 discharges and the rate in the pediatric intensive care unit was 11.0 infections per 100 discharges.

The most common sites of nosocomial infection in pediatric patients are bloodstream infections followed by surgical site infections, lower respiratory tract and urinary tract infections. In adults, the most common sites are urinary tract infections followed by surgical site infections, lower respiratory tract and bloodstream infections. For pediatric patients outside of the neonatal period, the most common organism causing nosocomial infections is *Staphylococcus aureus*, followed by *Escherichia coli*, coagulase negative staphylococci, and *Klebsiella* species. Nosocomial infections in neonates are most commonly caused by coagulase negative *staphylococci*, followed by *Staphylococcus aureus*, *E. coli*, group *B Streptococcus* and *Klebsiella* species.

Neonatal intensive care unit rates. The pediatric population in which HAI have been studied most extensively is the patients in the neonatal ICU (NICU). In an early report, Hemming and associates demonstrated a high rate of nosocomial infections (24.6%) at the University of Utah Medical Center, neonatal regional ICU for infants hospitalized for greater than 48 h. By comparison, the nosocomial infection rate for the entire hospital was 7.3%. It was 5.4% for the general pediatric ward and 0.6% for the well-baby nursery. In another study of nosocomial infection in a neonatal ICU from Boston, it was hypothesized that proper staffing, adequate working space around incubators, control of traffic flow, and the presence of convenient scrub areas would decrease the rate of nosocomial infections. This was confirmed in a prospective study when a new nursery was built with improvements in all of these areas. The nosocomial infection rate for serious infections fell from 5.2% to 0.9%. The rates in this study were lower than in others because the unit transferred out newborns who required surgery. In the Pediatric Prevention Network study, the overall nosocomial infection rate was 8.9 per 1,000 patient-days, the bloodstream infection rate in the NICU was a median of 8.6 per 1,000 central venous catheter-days, and the ventilator-associated pneumonia rate was a mean of 2.5 per 1,000 ventilator-days. For all categories, the infection rates were inversely proportional to the birthweight. In a more recent study by the Centers for Disease control, the rate for HAIs for NICUs was 16.2–17.6 per 100 patients or 5.2–5.9 cases per 1,000 patient-days.

Pediatric and adult intensive care units. In an early study of patients in an adult surgical ICU by Northey and associates reported a nosocomial infection rate of 23.4% in 1974. Upper respiratory and urinary tract infections were the most common. If one takes into consideration the published nosocomial infection rates in pediatric patients with the underlying predisposing illnesses, the rate is similar to patients in a pediatric ICU and the data for neonatal and adult ICUs; 15–20% is a good approximation of the expected rate in a pediatric ICU. In the Pediatric Prevention Network study, the overall PICU HAI rate was a median of 13.9 per 1,000 patient-days; the bloodstream infection rate was 8.5 per 1,000 central venous catheter days, and the ventilator-associated pneumonia rate was 3.7 per 1,000 ventilator-days. In the later CDC study, HAI rate was 12.2–14.9 per 100 patients, or 5.8–19.0 per 1,000 patient-days.

Risk of Nosocomial Infections

General Risk Factors

Prior colonization with healthcare-acquired microorganisms. Several classic studies have addressed the question of the risk factors associated with the development of HAI. Most of the earlier studies were in adult populations. Studies from the Denver Veterans Administration Hospital by Selden and associates attempted to quantify the factors associated with risk of infection from a strain of *Klebsiella pneumoniae*, which was the cause of a large cluster of nosocomial infections, primarily in ICU patients, and was resistant to multiple antibiotics. They found that asymptomatic gastrointestinal colonization frequently preceded manifest infection. In a prevalence study, it was shown that 18% of those who were GI carriers of the *Klebsiella* strain had an infection due to the organism during their admission, while only 3% of those who were not colonized were infected. In a separate prospective longitudinal study, those who became carriers of *Klebsiella* during hospitalization, but were culture-negative on admission, had a 48% incidence of nosocomial *Klebsiella* infection. Length of hospitalization was another major factor. The rate of colonization rose steeply after 3 days of hospitalization to a maximum prevalence of 66% for those who were hospitalized for longer than 30 days. The therapeutic interventions associated with acquisition of *Klebsiella* in the gastrointestinal tract were inhalation therapy, nasogastric suction, and antibiotic therapy. These factors probably account for the high rates of HAI in patients who have been in an ICU. These findings were validated in subsequent studies.

Colonization of the upper respiratory tract with hospital-acquired flora is also associated with the development of nosocomial infections. The prevalence of pharyngeal colonization with gram-negative bacilli was studied in Texas by Johanson and associates. Colonization rate was proportional to the estimated degree of illness: it was low (2%) in physiologically normal inpatients and nonhospitalized normal subjects; moderately ill patients had a 16% rate of colonization, and moribund patients had a rate of 57%. It was assumed that the sicker patients had defective clearance mechanisms and that they also had more contact with contaminated materials. Patients receiving antibiotics also had a higher prevalence of gram-negative bacilli in the pharynx. This is attributed to the suppression of normal flora by antibiotics, allowing new organisms to colonize mucosal surfaces. Although pharyngeal colonization does not mean that there is active infection, it frequently precedes invasion, especially in patients who aspirate or already have other respiratory infections.

Catheters. The use of intravascular catheters and intravenous (IV) infusions are frequently implicated in the development of HAI. Septicemia rates associated with IV cannulae have varied in studies from 0% to 8%. The care of the infusion set and the cannulation site are important variables. The degree of risk is related to the method of insertion, type of catheter, type of infusion, and, to a very large extent, duration of catheter placement. There have been extensive studies of colonization of the catheter insertion site in the skin but it is related only indirectly to the development of sepsis. Bloodstream invasion, local skin infection, thrombophlebitis, and a particularly virulent form of septic thrombophlebitis are associated with IV catheters in the critically ill. Numerous studies of risk factors for nosocomial infections in sick neonates have shown that catheters are a major risk factor for nosocomial bloodstream infections, possibly the most important single factor.

The factors predisposing to nosocomial urinary tract infection are related to instrumentation (including surgery) and indwelling urethral catheters. Rates are higher among females, the elderly, and the critically ill. Breaks in the closed system or improper care of the drainage bag predispose to bacteruria. To reduce the rate of nosocomial urinary tract infections, it is important to preserve a closed system, and to reduce the length of catheterization or the number of catheterizations as much as possible.

Exposure to antibiotics. Prior use of broad spectrum antibiotics appears to be an important risk factor for the development of nosocomial infections. Some recent studies have focused on the particular importance of the expanded-spectrum cephalosporins and have shown that prior exposure to these antibiotics is a risk for colonization with antibiotic-resistant nosocomial bacterial flora. Susceptibility to colonization with nosocomial flora increases the risk of HAI and is the main reason of controlling the rate of HAI by reducing unnecessary use of antibiotics.

The indigenous microbial flora present on the skin and mucus membranes play an important function in protecting from invasion by pathogens and may therefore be considered part of host defenses. Established colonization with numerous organisms of low virulence limits dominance of any one species, and minimizes acquisition of exogenous pathogenic organisms. The mechanisms by which indigenous flora afford protection include competition for the host nutrient sources (bacterial interference), and blocking of cell-surface receptors or mucus blanket adhesions by other bacteria (colonization resistance). Both normal flora as well as pathogens appear to attach

to human tissue by very specific binding between specialized surface elements of the microorganisms (pili, and other specific proteins and carbohydrates) and molecules on the skin and mucosal surfaces. There is some evidence that if normal flora microorganisms, principally nonpathogenic bacteria and fungi, are abundant, there are very few molecules on host surfaces for pathogens to attach to. However, the more numerous and well-established normal flora can be partially or totally eradicated by the use of antibiotics. Should normal flora be lacking, new flora will more easily attach to the exposed receptor molecules on these surfaces. If these new flora have pathogenic potential, such as the ability to invade, generate toxins, or resist antibiotics they may proliferate more quickly than the normal flora can regenerate. This is felt to be the major mechanism for the spread of antibiotic-resistant flora in the hospital because so many patients have a disturbance of their usual normal flora.

Specific Environmental Risk Factors

A number of general principles of risk for nosocomial infections have been discussed above. In addition, there have been large numbers of reports of increased risk of nosocomial infections associated with environmental contamination and the use of devices discussed below. In many cases, problems with these devices have been reduced through recognition of their potential to cause HAI.

Inhalation equipment. While it has been recognized for a long time that the use of inhalation equipment was associated with risk of nosocomial respiratory infection, the mechanism was unknown until the equipment itself was studied. Pierce and Associates reported on the relationship between contamination of reservoir nebulizers and the occurrence of nosocomial necrotizing pneumonia. Aerosols from this type of equipment may contain large numbers of gram-negative bacilli, which are blown from the contaminated reservoir fluid into the patient's respiratory tract. Decontamination of this equipment virtually eliminated nosocomial gram-negative necrotizing pneumonias. Outbreaks of gram-negative pneumonia have been reported to be due to contaminated nebulized medication. The use of room humidifiers in the hospital has also been linked to the aerosolization of bacteria and colonization of exposed patients.

Intravenous solutions and catheters. Infections associated with infected intravenous infusion sites and contaminated IV solutions have become a major source of concern for infection control physicians. All patients who require intravascular fluid therapy are at risk for infection from contaminated IV solutions, medication, and tubing. A tragic example of this risk was a large multistate outbreak of infection due to *Erwinia* and *Enterobacter* in the 1970s from a defect in the manufacturing of the infusion bottles, which was subsequently corrected. Many hospitals reported unexpected episodes of sepsis due to these species with rates of infection and death that were related to the seriousness of the underlying diseases of these patients, although occasionally otherwise healthy patients were infected. Held and Associates recently reported two cases of life-threatening sepsis due to *Burkholderia cepacia* in children with hemophilia. Both had indwelling central venous catheters that were flushed with a heparin-vancomycin solution. This solution was prepared by an out-of-state pharmacy and investigation traced the source of the bacteria to the flush solution. In the past decade, there have been numerous reports of solutions contaminated with this particular species.

Viral Infections

In pediatric practice, there is a great risk of nosocomial infection from viruses. Spread of viruses does not appear to be as clearly related to contaminated equipment, antibiotic use, or inanimate reservoirs as is found in bacterial infection. Viral infections are introduced by infected patients, healthcare workers, or parents, and then spread to patients via infected secretions or direct person-to-person spread. Almost any virus that is spread by respiratory or gastrointestinal tract secretions or excreta can cause HAI if routine care techniques are not enforced or if a particularly infectious virus disease goes undetected. Strict observance of special transmission-based precautions (Droplet, contact or both, see *Table 66.4*) plus respiratory etiquette (*Table 66.5*) are important in limiting spread in healthcare setting. Surveillance studies have indicated certain viruses discussed below to be of special concern for nosocomial infections in pediatrics.

Respiratory syncytial virus has been shown in several studies by Hall and colleagues to be a significant nosocomial pathogen in pediatric hospital units. Infection due to respiratory syncytial virus can cause significant disease in any infant and could be responsible for life-threatening decompensation in infants who are already in an unstable state. Infants with congenital cardiac disease and those with pulmonary disease such as bronchopulmonary dysplasia are at especial risk. Studies have shown that transmission by close contact is responsible for dissemination to noninfected individuals; aerosols traveling a

Table 66.4
Transmission-based precautions

Precaution category	Components	Typical organisms
Contact precautions	• Private room • Requires putting on gown and gloves before room entry • Remove gown and gloves before the leaving room • Perform hand hygiene immediately after removal of gown and gloves before touching anything • Dedicated equipment • Essential movement/transport only	• Vancomycin-resistant enterococcus (colonization or infection) • Methicillin-resistant staphylococcus (colonization or infection) • Resistant gram-negative rods • Clostridium difficile colitis • Zoster in a normal host • Respiratory syncytial virus • Parainfluenza virus • Rotavirus
Droplet precautions	• Private room • Masks if within 3 ft of patient • Essential movement/transport only • Mask on patient during transport	• Influenza • Invasive meningococcal disease • Pertussis • Mycoplasma pneumoniae
Airborne precautions	• Private room – door closed • Negative-pressure room • Masks – N95 or HEPA • Essential movement/transport only • N95 mask during transport	• Suspected or confirmed Tuberculosis • Varicella/chickenpox[a] • Disseminated zoster[a] • Zoster in an immunocompromised host[a] • Measles

[a]Requires contact precautions as well

Table 66.5
Components of universal respiratory etiquette (also known as respiratory hygiene/cough etiquette)

• Applies to all patients, persons accompanying patients, visitors

• Source control measures
  • Cover the mouth/nose when coughing
  • Give the patient a surgical mask to wear
  • Use tissues if surgical mask is not available to contain secretions

• Hand hygiene after contact with respiratory secretions
• Spatial separation of person with respiratory infections in common waiting areas

considerable distance are not a major factor. Appropriate handwashing as well as limiting of number of contacts should be emphasized as the major means of infection control. The use of masks and goggles has been shown to further reduce dissemination of respiratory syncytial virus but is not ordinarily employed due to expense, interference with care activities, and marginal effect.

Varicella (chickenpox) is often transmitted in pediatric hospitals via aerosol dissemination. This viral infection is a particular threat to immunocompromised patients who can develop a progressive fulminant form of the disease, which has a high mortality. Immunosuppressed patients who lack antibody to varicella virus must be separated from any patients with chickenpox to prevent exposure to aerosols of their respiratory secretions. Therefore, patients with varicella, those suspected of having varicella or nonimmune patients exposed to varicella 8–21 days after exposure (the shortest and longest possible incubation periods) must be isolated in negative-pressure rooms that do not exhaust back into the hospital. Screening hospital personnel for antibody to varicella virus can pinpoint those individuals who could become infected and, therefore, transmit chickenpox to patients at risk. With varicella vaccine now available, the safest policy for hospital personnel is either to vaccinate all individuals who lack a history of having had chicken pox or who are determined by testing to lack a protective level of antibodies to the virus.

Influenza. Ordinarily, influenza is spread by droplets and the major precaution in addition to standard precautions is wearing a simple surgical-type mask. In recent years, there has occasionally been a requirement for additional precautions including gown, and gloves as well as negative-pressure rooms because of fear of spread of particularly virulent infection. The pandemics of Severe Acute Respiratory Syndrome (SARS caused by coronavirus) and

H1N1 influenza outbreaks demonstrated such a tendency for spread that, in many locales, simple droplet precautions were deemed insufficient.

Diarrheal disease due to viruses has long been noted to cause considerable morbidity in children's hospitals but only in the past few years have these viruses been identifiable. Rotavirus, the most common viral diarrheal agent, has been extensively studied in children and an enzyme-linked immunoassay (ELISA) is available for rapid and specific identification of the agent in stool. In neonates and young infants, this assay is not helpful as it is often positive in asymptomatic patients. In addition, other viruses such as norovirus (formerly Norwalk agent), astrovirus, minirotavirus, and calicivirus have been identified in infantile gastroenteritis. Methods for identification of some of these viruses may not be available except in specialized centers.

Prevention and Control of Nosocomial Infections

Physicians should be familiar with current recommendations concerning the control of the factors most frequently associated with transmission of HAI. Discussion of all of these measures is beyond this chapter and the reader is referred to contemporary texts for a fuller discussion. The Centers for Disease Control and Prevention is actively involved in prevention of HAI and keeps the medical community informed about risk factors and control through the journal *Morbidity and Mortality Weekly Report* and their Web site at www.cdc.gov.

General measures. Routine culturing of the environment, preparation of equipment, isolation techniques, and disinfection should be under the control of the surveillance and control team. The guidelines for these operations will not be dealt with here. Physicians need to be familiar with the appropriate precautions necessary to prevent spread of infection from patients to hospital staff, visitors, and other patients. Recommendations are usually modified for the needs of a specific hospital and incorporated in an infection control manual, which may be in the form of a printed text or available through the institution's computer workstation. The recommendations may allow significant individualization for a particular patient's age, mental status, underlying disease, local epidemiology, and hospital resources.

Standard precautions (Table 66.6). Standard precautions combine the major features of previously recommended Universal Precautions and Body Substance Isolation (Table 66.6). They are based on the principle that all blood, body fluids, secretions, excretions (except sweat), nonintact skin, and mucous membranes may contain transmissible infectious agents. Standard precautions apply to all patients, regardless of suspected or confirmed infection status, in any setting in which healthcare is delivered. The components include hand hygiene (Table 66.7); use of gloves, gown, mask, eye protection, or face shield, depending on the anticipated exposure; and safe injection practices. Equipment or items in the patient environment likely to have been contaminated with infectious body fluids must be handled in a manner to prevent transmission of infectious agents. For some interactions (e.g., performing venipuncture), only gloves may be needed; during other interactions (e.g., intubation), use of gloves, gown, and face shield or mask and goggles is necessary.

Universal Respiratory Etiquette

Universal respiratory hygiene/cough etiquette has been added to the other elements of standard precautions. These elements were initially deemed necessary during the SARS-Coronavirus activity in emergency departments and other outpatient areas during the widespread SARS outbreaks in 2003. The strategy proposed has been termed respiratory hygiene/cough etiquette (Table 66.5). The strategy is targeted at patients and accompanying family members and friends with undiagnosed transmissible respiratory infections, and applies to any person with signs of illness including cough, congestion, rhinorrhea, or increased production of respiratory secretions when entering a healthcare facility such as an emergency department, outpatient clinic, or any waiting area.

The elements of respiratory hygiene/cough etiquette include (1) education of healthcare facility staff, patients, and visitors; (2) posted signs, in language(s) appropriate to the population served, with instructions to patients and accompanying family members or friends; (3) source control measures (e.g., covering the mouth/nose with a tissue when coughing and prompt disposal of used tissues, using surgical masks on the coughing person when tolerated and appropriate); (4) hand hygiene after contact with respiratory secretions; (5) spatial separation, ideally >3 ft, of persons with respiratory infections in common waiting areas when possible; and (6) covering sneezes and coughs and placing masks on coughing patients.

Special Precautions

Special precautions are care elements required to prevent transmission of infections and are employed in addition to standard precautions. Decisions about which precautions are

Table 66.6

Recommendations for application of standard precautions for the care of all patients in all healthcare settings applies to all body fluids except sweat[a]

Component	Recommendations[b]
Hand hygiene	After touching blood, body fluids, secretions, excretions, contaminated items; immediately after removing gloves; between patient contacts
Personal protective equipment (PPE)	
Gloves	For touching blood, body fluids, secretions, excretions, contaminated items; for touching mucous membranes and nonintact skin
Gown	During procedures and patient-care activities when contact of clothing/exposed skin with blood/body fluids, secretions, and excretions is anticipated
Mask, eye protection (goggles), face shield	During procedures and patient-care activities likely to generate splashes or sprays of blood, body fluids, secretions, especially suctioning, endotracheal intubation
Soiled patient-care equipment	Handle in a manner that prevents transfer of microorganisms to others and to the environment; wear gloves if visibly contaminated; perform hand hygiene
Environmental control	Develop procedures for routine care, cleaning, and disinfection of environmental surfaces, especially frequently touched surfaces in patient-care areas
Textiles and laundry	Handle in a manner that prevents transfer of microorganisms to others and to the environment
Needles and other sharps	Do not recap, bend, break, or hand-manipulate used needles; if recapping is required, use a one-handed scoop technique only; use safety features when available; place used sharps in puncture-resistant container
Patient resuscitation	Use mouthpiece, resuscitation bag, other ventilation devices to prevent contact with mouth and oral secretions

[a]Table adapted from http://www.cdc.gov/hicpac/pdf/isolation/Isolation2007.pdf (Accessed July 28, 2010)
[b]Subsequent updates include wearing surgical masks for performing lumbar punctures for diagnosis or for injections and for application of universal respiratory etuquette

to be employed in specific situation require categorization of diseases by how they are transmitted. The term *transmission-based precautions* is used to indicate that infectious diseases are categorized by whether they are spread by droplets, aerosols, or direct contact. The appropriate special precautions for hospitalized patients are determined by the mode of transmission of each suspected or proven infection.

Hand hygiene (Table 66.7). The term "hand hygiene" has replaced "handwashing" to emphasize the importance of alcohol gel hand rubs that can be used in place of soap and running water for most situations calling for cleansing of the hands in routine medical practice. Infection control experts consider hand hygiene to be the single most effective and certainly least expensive practice to prevent transmission of pathogens and prevention of HAI. Nevertheless, one recent review documents that even this simple directive has been insufficiently adhered to by medical personnel. In a review of 12 published studies, compliance with recommended hand hygiene was under 50% even in intensive care units. Proper handwashing methodology is summarized in Table 66.7. For handwashing, other than presurgical scrubs, hands should be vigorously lathered and rubbed together for at least 15 s with soap and warm running water. Hands should be rinsed and dried with a paper towel and the towel used to turn off the faucet. Gloves should be worn when touching blood or other body fluids and mucous membranes, to reduce the likelihood of transmitting organisms to patients during invasive procedures, and to prevent transmission of pathogens from an infected patient to another patient. Wearing gloves does not replace the need for handwashing. Adherence to handwashing recommendations is important as contamination of skin due to punctures or defects in a glove is possible. With the widespread use of alcohol-based hand rubs, there is evidence of improvement in hand hygiene compliance among healthcare personnel at many healthcare centers.

Intravenous Therapy

Intravenous devices are associated with a large proportion of HAI. Proper insertion and use of these devices is

Table 66.7
Hand hygiene

When	Before and after every patient contact
	Before and after putting on gloves (sterile or non-sterile)
	Before doing invasive procedures
	After use of bathroom facilities
	Between contaminated body sites
	Before eating or drinking
	After contact with laboratory specimens
	Whenever hands are contaminated
With what	*Soap and water hand hygiene* • Turn on faucet • Apply soap to all surfaces of hands • Rub hands together for 15 s • Make sure to cover thumbs, areas in between fingers, under nails • Rinse thoroughly • Pat dry with clean paper or cloth towel instead of rubbing • Use towel to turn off faucet

	Alcohol-based hand rub hygiene[a]
	• Push dispenser once
	• Coat all surfaces of your hands including
	  • Between fingers
	  • Under fingernails
	  • Back of hands and wrists
	• Rub hands together briskly, until dry
	• No rinsing needed

[a]Soap and water hand hygiene should be employed when hands are grossly contaminated or visibly dirty or when in contact with patients colonized or infected with Clostridium difficile or items contaminated by such patients. Alcohol-based hand rubs are not effective when there is visible dirt on the hands and are not optimally effective in decontamination of spores.

recommended as a method of reducing risk of infection. Because central catheters remain in place for an extended period of time, they have been especially concerning as a source of nosocomial bloodstream infections (central line–associated bloodstream infection – CLABSI). In the United States, it has been estimated that there are 9.7 million central catheter-days in ICUs (54% of ICU days). There have been an estimated 48,600 patients in the ICUs who have a CLABSI (5 BSI/1,000 catheter days) and of major concern, there have been 17,000 deaths attributable to CLABSIs in the ICU. Although the catheter utilization rate is lower outside of the ICU setting, as many or more CLABSIs occur outside the ICU setting.

Certain factors have been shown to increase the risk of catheter-related infections. In adults, the duration of catheterization is >3–4 days adds additional risk of infection but in children duration has not been demonstrated to be associated with extra risk. Other factors increasing risk of infection are increased diameter and number of ports on catheter, location (risk greater for femoral, less for internal jugular, and less for subclavian), and type of catheter (tunneled catheters have a lower risk than non-tunneled catheters). Antimicrobial/Antiseptic coated catheters may have a lower risk than non-coated catheters. Additional risk factors include thrombosis at the site of a central catheter, infusion with TPN or other lipid-rich infusate, and impaired skin integrity such as with burns, and dermatitis.

Recently recommendations for intravenous therapy have been revised and expanded. While it is beyond the scope of this chapter to discuss the use of each type of intravascular device available, among the recommendations for prevention of IV catheter-associated infections are the following general suggestions from the Infectious Diseases Society of America and the Society for Healthcare Epidemiology of America guidelines. Additional recommendations can be found in the referenced articles and detailed information regarding diagnosis and management of intravascular catheter-related infections are contained in a practice guideline of the Infectious Diseases Society of America.

- Intravenous cannulae should be inserted only when clearly indicated. In general, "keep open" intravenous infusion should be discouraged if it is for the convenience of the medical staff. Remove any device as soon as its use is no longer indicated.
- Educate healthcare workers regarding the indications for intravascular catheter use, proper procedures for the insertion and maintenance of intravascular catheters, and appropriate infection control measures to prevent intravascular catheter-related infections.
- Use a catheter checklist to ensure adherence to infection prevention practices at the time of central catheter insertion and for dressing changes.
- Assess knowledge of and adherence to guidelines periodically for all persons who insert and manage intravascular catheters.
- Monitor the catheter sites visually or by palpation through the intact dressing on a regular basis, depending on the clinical situation of individual patients. If patients have tenderness at the insertion site, fever without obvious source, or other manifestations suggesting local or BSI, the dressing should be removed to allow thorough examination of the site.
- Record the operator, date, and time of catheter insertion and removal, and dressing changes on a standardized form.

- Observe proper hand hygiene procedures either by washing hands with conventional antiseptic-containing soap and water or with waterless alcohol-based gels or foams. Observe hand hygiene before and after palpating catheter insertion sites, as well as before and after inserting, replacing, accessing, repairing, or dressing an intravascular catheter. Palpation of the insertion site should not be performed after the application of antiseptic, unless aseptic technique is maintained.
- Maintain aseptic technique for the insertion and care of intravascular catheters.
- Wear clean or sterile gloves when inserting an intravascular catheter as required by the Occupational Safety and Health Administration Bloodborne Pathogens Standard.
- Sterile gloves should be worn for the insertion of arterial and central catheters.
- Wear clean or sterile gloves when changing the dressing on intravascular catheters.

Catheter Site Care

- Disinfect clean skin with an appropriate antiseptic before catheter insertion and during dressing changes. Although a 2% chlorhexidine-based preparation is preferred, tincture of iodine, an iodophor, or 70% alcohol can be used.
- No recommendation can be made for the use of chlorhexidine in infants aged <2 months.
- Do not submerge the catheter under water. Showering should be permitted if precautions can be taken to reduce the likelihood of introducing organisms into the catheter (e.g., if the catheter and connecting device are protected with an impermeable cover during the shower).
- Use aseptic technique including the use of a cap, mask, sterile gown, sterile gloves, and a large sterile sheet for the insertion of central catheters or for guidewire exchange.
- Do not routinely replace CVCs, PICCs, hemodialysis catheters, or pulmonary artery catheters to prevent catheter-related infections.
- Do not use guidewire exchanges routinely for non-tunneled catheters to prevent infection.
- For catheter-site dressing changes, use either sterile gauze or sterile, transparent, semipermeable dressing to cover the catheter site.
- Replace catheter-site dressing if the dressing becomes damp, loosened, or visibly soiled.
- Change dressings at least weekly for adult and adolescent patients depending on the circumstances of the individual patient.
- Do not use topical antibiotic ointment or creams on insertion sites (except when using dialysis catheters) because of their potential to promote fungal infections and antimicrobial resistance.

Recommendations for Umbilical Catheters

1. Remove and do not replace umbilical artery catheters if any signs of CLABSI, vascular insufficiency, or thrombosis are present.
2. Remove and do not replace umbilical venous catheters if any signs of CLABSI or thrombosis are present.
3. Replace umbilical venous catheters only if the catheter malfunctions.
   (a) Cleanse the umbilical insertion site with an antiseptic before catheter insertion. Avoid tincture of iodine because of the potential effect on the neonatal thyroid. Other iodine-containing products (e.g., povidone-iodine) can be used.
   (b) Do not use topical antibiotic ointment or creams on umbilical catheter insertion sites because of the potential to promote fungal infections and antimicrobial resistance.
   (c) Add low doses of heparin (0.25–1.0 U/mL) to the fluid infused through umbilical arterial catheters.
4. Remove umbilical catheters as soon as possible when no longer needed or when any sign of vascular insufficiency to the lower extremities is observed. Optimally, umbilical artery catheters should not be left in place >5 days.
5. Umbilical venous catheters should be removed as soon as possible when no longer needed but can be used up to 14 days if managed aseptically.

A milestone in improving the safety of catheter-related bloodstream infections in the ICU was achieved by Pronovost and associates who virtually eliminated central line–related infections by following the above recommendations as a "bundle" in a study of 103 ICUs.

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