Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

health terms and to compare an intervention with other potential uses of available resources. *Cost-effectiveness* analyses determine the cost per health outcome achieved, such as the cost per death or complication averted. In a cost-effectiveness formula, costs appear in the numerator and health benefits appear in the denominator. The numerator includes expenditures for the prevention program from which cost savings occurring with disease prevention are subtracted. In addition to direct costs averted (e.g., savings from decreased medical care), indirect costs savings occur from increased productivity of people who do not become ill or miss time from work while receiving care or caring for ill family members. *Cost–utility* calculations are similar to cost-effectiveness but assess cost per QALY saved or YPLL averted.

Cost–benefit analyses differ from cost-effectiveness analyses in that the calculation is made entirely in economic terms. Health benefits are assigned an economic value and expenditures are compared with savings. One problem with this approach lies in the difficulty assigning an economic value to a health effect. For example, the value of a life saved may be quantified as the estimated value of a person's earnings over his or her lifetime, foregone earnings due to premature death, or by a standard amount; both economic and ethical issues may be raised by the choice of approach. Because the parameters used in economic analyses are often uncertain or based on limited data, and because choices made by the investigator (e.g., regarding the value of life) may be influential to the analysis, *sensitivity analyses* are often performed where parameters are varied across a range of potential values. In addition to defining a range of possible economic outcomes, sensitivity analyses can identify the factors that most influence the results, elucidating where further studies may be important.

EVALUATING THE MEDICAL LITERATURE

Basic epidemiologic knowledge is important not only in performing research but also in evaluating studies reported in the medical literature. Steps in reviewing published medical research are shown in Box 1-2. The ability to assess published studies carefully is often limited by the information presented in the report. To improve reporting of randomized controlled trials, a group of investigators and editors developed a Consolidated Standards of Reporting Trials (CONSORT)[23] and later extended these recommendations to reporting of noninferiority and equivalence randomized trials.[24] Although these standards have been adopted by many journals and editorial groups, reporting often does not adhere to the quality standards proposed.[25, 26] Although the guidelines refer to experimental rather than observational studies, most criteria still apply.

Assessing the research hypothesis allows readers to determine the relevance of the study to their practice and to judge whether the analyses were done to test the hypothesis or to identify other interesting associations. The ability to make causal inferences from a confirmatory study that tests a single hypothesis is greater than from an exploratory study in which multiple exposures are considered as potential explanations for an outcome.

Several components of study design are important to consider. Details should be presented regarding the criteria for selecting a cohort or cases and controls. Exposure and outcome variables should be clearly defined, and the potential for misclassification and its impact should be considered. Quantifying exposure may be important to establish a dose–response relationship. Finally, sample size estimates should be presented, making clear the magnitude of difference between study groups considered clinically meaningful and the type I and type II error levels.

In the analysis, it is important that outcomes for all study subjects are reported, even if that outcome is "lost to follow-up." *Intent-to-treat* analyses consider outcomes for all enrolled subjects, whether or not they completed the therapy (e.g., those who were nonadherent with therapy or who received only part of a vaccination series). The appropriateness of the statistical tests should be assessed; for example, if data are not normally distributed, they can be transformed to a scale that is more normally distributed (e.g., geometric mean titers) or nonparametric statistical tests should be used. In assessing a multivariable model, the reader should critically evaluate the type of model chosen, the variables included, and whether interaction terms were considered. Missing data pose a particular problem in modeling, in that study subjects can only be included if data are available for each variable in the model; thus, the power of a multivariate model may be much less than that predicted in a sample size calculation.

Bias can have an important impact on study results and must be carefully considered. Approaches to minimize bias should be clearly described. The direction and potential magnitude of remaining bias should be estimated and its impact on results considered. Potential confounding, the presence of important unmeasured variables, and possible effect modification can have a major impact on the results. Investigators should openly discuss the potential limitations of the investigation and describe the strategies they applied to overcome those limitations.

Finally, interpretation of study results includes assessing the magnitude of the associations, their relevance to practice, and the likelihood that the relationships observed are causal. The importance of an exposure in explaining an outcome can be expressed by the attributable proportion. The external validity of the results, however, and the potential impact on one's own patient population must still be assessed.

ACKNOWLEDGMENT

Thanks to Paul M. Gargiullo, PhD, for assistance.

BOX 1-2. Steps in the Critical Evaluation of Epidemiologic Literature[24]

1. Consider the research hypothesis
2. Consider the study design
   - Type of study
   - Selection of study participants
   - Selection and definition of outcome variables
   - Selection and definition of exposure (predictor) variables
   - Sample size and power
3. Consider the analysis
   - Complete accounting of study subjects and outcomes
   - Appropriateness of statistical tests
   - Potential sources and impact of bias
   - Potential impact of confounding and effect modification
4. Consider the interpretation of results
   - Magnitude and importance of associations
   - Study limitations
   - Ability to make causal inferences

CHAPTER 2

Pediatric Infection Prevention and Control

Jane D. Siegel and Leigh Grossman

Developing effective prevention strategies for healthcare-associated infections (HAIs) in pediatric patients is a unique science that requires consideration of various host factors, sources of infection, routes of transmission, behaviors associated with care of infants and children, pathogens and their virulence factors, treatments, preventive therapies,

and behavioral theory. Although the term *nosocomial* still applies to infections that are acquired in acute care hospitals, a more general term, *healthcare-associated infections* (HAIs), is now used since much care of high-risk patients, including those with medical devices (e.g., central venous catheters, ventilators, peritoneal dialysis catheters), has shifted to ambulatory settings, rehabilitation or chronic care facilities, and to the home; thus, often the geographic location of acquisition of the infection cannot be determined. A true *nosocomial* infection is defined as an infection that was not incubating or present at the time of hospital admission, and that develops 48 hours or more after hospital admission or within 10 days of hospital discharge. In neonates, a transplacental infection is not considered a nosocomial infection. An infection is nosocomial, however, if a mother is not infected at the time of admission but delivers an infected infant more than 48 hours after her admission. The principles of transmission of infectious agents in healthcare settings and prevention are reviewed in the Guideline for Isolation Precautions: Preventing Transmission of Infectious Agents in Healthcare Settings 2007.[1]

The pediatric host is highly susceptible to common respiratory and gastrointestinal tract viruses (e.g., respiratory syncytial virus (RSV), influenza virus, rotavirus) that may be transmitted in healthcare settings in addition to the usual healthcare-associated bacteria and fungi. HAIs can result in the serious morbidity and mortality that occur in adult patients and in lifetime physical, neurologic, and developmental disabilities. Infection rates between 2% and 13% of admissions or discharges from pediatric units are typical.[2–5] Intensive care units, oncology services, and gastroenterology services that care for patients with short gut who are dependent on total parenteral nutrition (TPN) have the highest rates of bacterial and fungal infection associated with central venous catheters. Those children who have complex underlying diseases are at greatest risk for prolonged hospitalization, complications, and mortality associated with acquisition of new infections in the hospital.[3–8] Severely immunosuppressed patients (e.g., allogeneic hematopoietic stem cell transplant (HSCT) recipients, children with leukemia undergoing intensive chemotherapy, solid-organ transplant recipients during the periods of most intense immunosuppression), are at increased risk for invasive aspergillosis and other environmental fungal infections, especially during periods of facility renovation, construction, and water leaks.[9]

UNIQUE ASPECTS OF HEALTHCARE-ASSOCIATED INFECTION IN CHILDREN

Unique aspects of HAIs in children have been reviewed in detail[5] and are summarized below. Specific risks and pathogens are addressed in multiple other chapters in this textbook.

Host or Intrinsic Factors

Rates of all HAIs as high as 7% to 25% are reported in neonatal intensive care units (NICUs) and are inversely proportional to birthweight.[4,7,10] Host, or intrinsic, factors that make children particularly vulnerable to infection are immaturity of the immune system, congenital abnormalities, and congenital or acquired immunodeficiencies. The populations of immunosuppressed children have expanded with the advent of more intense immunosuppressive therapeutic regimens used for oncologic conditions, HSCTs, solid-organ transplants, and rheumatologic conditions and inflammatory bowel disease for which immunosuppressive agents and tumor necrosis factor-α inhibitors (infliximab) and other immune modulators are used. Fortunately, the population of children with perinatally acquired human immunodeficiency virus (HIV) infection and acquired immunodeficiency syndrome (AIDS) has dramatically decreased since 1994, but new cases of sexually transmitted HIV infection are diagnosed increasingly in teens who are cared for in children's hospitals. Innate deficiencies of the immune system in prematurely born infants, who may be hospitalized for prolonged periods of time and exposed to intensive monitoring, supportive therapies and invasive procedures, contribute to the high rates of infection in the NICU. All components of the immune system are deficient in neonates and the degree of deficiency is inversely proportional to the gestational age (see Chapter 10, Immunologic Development and Susceptibility to Infection). Additionally, the underdeveloped skin of the very-low-birthweight infant (< 1000 grams) provides another mode of entry for pathogens.

Children with congenital anomalies have a high risk of HAI because they require prolonged and repeated hospitalizations, undergo many complex surgical procedures, and have extended exposure to invasive supportive and monitoring equipment. For example, at the University of Virginia Medical Center, children with myelomeningocele have had an average of 9 hospitalizations (range, 3 to 50) and 6 surgical procedures (range, 2 to 30) by 15 years of age. The source of many HAIs may be the endogenous flora of the patient.[11,12] An asymptomatic colonizing pathogen can invade an individual patient or be transmitted on the hands of healthcare personnel to other patients. As the rates of colonization with community-associated methicillin-resistant *Staphylococcus aureus* (CA-MRSA) at the time of hospital admission have increased, so has transmission of community strains, most often USA 300, within the hospital,[13] making prevention especially challenging. Finally, young infants who have not yet been immunized, or immunosuppressed children who do not respond to vaccines or lose their antibody during treatment (e.g., patients with nephrotic syndrome), have increased susceptibility to infections that would be prevented by vaccines.

Sources or Extrinsic Factors

Important sources of HAIs in infants and children include the mother, invasive monitoring and supportive equipment, blood products, infant formula and human milk, healthcare personnel, and other contacts, including adult and sibling visitors. Maternal infection with *Neisseria gonorrhoeae, Treponema pallidum*, HIV, hepatitis B virus, parvovirus B19, *Mycobacterium tuberculosis*, herpes simplex virus, group B streptococcus, or the emerging CA-MRSA pose substantial threats to the neonate. During perinatal care, procedures such as fetal monitoring with scalp electrodes, fetal transfusion and surgery, umbilical cannulation, and circumcision are risk factors for infection. Intrinsically contaminated powdered formulas and infant formulas prepared in contaminated blenders or improperly stored or handled, or both, have resulted in sporadic and epidemic infections in the nursery (e.g., *Enterobacter sakazakii*).[14] Human milk that has been contaminated by maternal flora or by organisms transmitted through breast pumps has caused isolated serious infections and epidemics. The risks of neonatal hepatitis, cytomegalovirus infection, and HIV infection from contaminated human milk warrant further caution for handling.

Rates of central vascular line-associated bloodstream infections (CLA-BSIs) in the pediatric intensive care units (PICUs) and high-risk nurseries (HRN) in the National Nosocomial Infection Surveillance (NNIS) system (now the National Healthcare Safety Network (NHSN)) from 1/2002 to 6/2004 are among the highest for all reporting ICUs, with a mean of 6.6 CLA-BSIs per 1000 catheter-days in the PICUs; this rate is only surpassed in trauma and burn units, with a mean of 7.4 and 7.0 CLA-BSIs per 1000 catheter-days, respectively.[10] Rates of umbilical and CLA infections vary by birthweight category from 3.5 per 1000 catheter-days in the > 2500 gram birthweight group to 9.1 per 1000 catheter-days in the < 1000 gram birthweight group (Tables 2-1 and 2-2). Medical device-related infections (e.g., CLA-BSIs, ventilator-associated pneumonia (VAP), and surgical site infections (SSIs)) can be prevented by implementing 3 to 5 sets or "bundles" of evidence-based practices, as defined in the Institute for Healthcare Improvement (IHI) 100,000 lives campaign (www.ihi.org/IHI/Programs/Campaign).

Although most work has been done in adult populations, there are modifications for pediatrics and the efficacy of CLA-BSI preventive practices was demonstrated in a 1-year collaborative of children's hospitals sponsored by the Child Health Corporation of America (CHCA) in 2005. Thus, it is likely that rates of device-related infections have been reduced even further since the NNIS report

TABLE 2-1. National Nosocomial Infection Surveillance Central Line 'Infection' (CLI)-Associated Bloodstream Infection (CLA-BSI) Rates: Intensive Care Units (ICUs) January, 2002 to June, 2004[a]

ICU Type	No. of ICUs Reporting	Rate/1000 Catheter-Days: Pooled Mean (Median, Range)
Trauma	22	7.4 (5.2, 1.9–11.9)
Burn	14	7.0 (NA)
Pediatric	54	6.6 (5.2, 0.9–11.2)
Medical	94	5.0 (3.9, 0.5–8.8)
Respiratory	6	4.8 (NA)
Surgical	99	4.6 (3.4, 0–8.7)
Neurosurg	30	4.6 (3.1, 0–10.6)
Coronary	60	3.5 (3.2, 1.0–9.0)
Medical-surgical		
Major teaching	100	4.0 (3.4, 1.7–7.6)
All others	109	3.2 (3.1, 0.8–6.1)
Cardiothoracic	48	2.7 (1.8, 0–4.9)

[a] $\frac{\text{No. of central catheter-associated BSIs}}{\text{No. of central catheter-days}} \times 1000$

TABLE 2-2. National Nosocomial Infection Surveillance Central Line (CLA-BSI)-Associated Bloodstream Infection Rates: Umbilical and Central Catheter Bloodstream Infection Rates: High-Risk Nursery, January, 2002 to June, 2004[a]

Birthweight Group	No. of Nurseries Reporting	Rate/1000 Catheter Days: Pooled Mean (Median, Range)
≤ 1000 grams	104	9.1 (8.5, 1.6–16.1)
1001–1500 grams	98	5.4 (4.0, 0–12.2)
1501–2500 grams	97	4.1 (3.2, 0–8.9)
> 2500 grams	94	3.5 (1.9, 0–7.4)

[a] $\frac{\text{No. of central catheter-associated BSIs}}{\text{No. of central catheter-days}} \times 1000$

Adapted from the National Nosocomial Infections Surveillance (NNIS) System Report, data summary from January 1992 through June 2004, issued October 2004. Am J Infect Control 2004;32:470–485.

published in December, 2004. Use of more specialized life-saving technologies, such as extracorporeal membrane oxygenation (ECMO), hemodialysis/hemofiltration, pacemakers, and implantable ventricular assist devices (VADs), further increases the risk of infection in the sickest children who require the most intense, invasive support.

Many standard infection control procedures for prevention of device-related infections in adults cannot be followed routinely for children. In adults, for example, peripheral intravascular catheters are changed routinely every 3 to 4 days to reduce the risk of catheter colonization and subsequent infection of the bloodstream. Infants, however, may have such limited vascular access that catheters remain in place until they become unnecessary, nonfunctional, or contaminated. Additionally, the specific indications for deep-vein thrombosis and peptic ulcer disease prophylaxis have not been defined for children requiring mechanical ventilator support and there is some evidence suggesting that peptic ulcer disease prophylaxis is associated with an increased risk of necrotizing enterocolitis and candidemia in low-birthweight infants.[15]

There are theoretical concerns that infection risk will also increase in association with the innovative practices of co-bedding and kangaroo care in the NICU because of increased opportunity for skin-to-skin exposure of multiple-gestation infants to each other and to their mothers, respectively. However, the infection risk is reduced with kangaroo care.[16] Finally, exposure to vancomycin and to third-generation cephalosporins contributes substantially to the increase in infections caused by vancomycin-resistant enterococcus (VRE) and multidrug-resistant gram-negative bacilli, including extended-spectrum beta-lactamase (ESBL)-producing organisms, respectively. Exposure to third-generation cephalosporins is also a risk factor for the development of invasive candidiasis in low-birthweight infants in the NICU.[17,18]

Transmission

The principal modes of transmission of infectious agents are direct and indirect contact, droplet, and airborne. Most infectious agents are transmitted by the contact route via hands of healthcare personnel, but many pathogens can be transmitted by more than one route. Viruses, bacteria, and *Candida* spp. can be transmitted horizontally. Although the source of most *Candida* HAIs is the patient's endogenous flora, horizontal transmission, most likely via healthcare personnel hands, has been demonstrated in studies using DNA fingerprinting in the NICU and in a pediatric oncology unit. Transmission of infectious agents by the droplet route requires exposure of mucous membranes to large respiratory droplets (> 5 μm) within 1 to 2 meters (3 to 6 feet) of the infected individual, who may be coughing or sneezing. Large respiratory droplets do not remain suspended in the air. Adenovirus, influenza virus, and rhinovirus are primarily transmitted by the droplet route whereas other respiratory viruses (e.g., RSV, parainfluenza) are primarily transmitted by the contact route. Although influenza virus can be transmitted via the airborne route under unusual conditions of reduced air circulation or relative humidity, there is ample evidence that transmission of influenza is prevented by droplet precautions and, in the care of infants, the addition of contact precautions under usual conditions.[19]

Some agents (e.g., severe acute respiratory syndrome–coronavirus (SARS-CoV)) can be transmitted as small-particle aerosols under special circumstances of aerosol-producing procedures (e.g., endotracheal intubation, bronchoscopy); therefore, an N95 or higher respirator is indicated for those in the same airspace when these procedures are performed, but an airborne infection isolation room (AIIR) may not always be required. Roy & Milton proposed a new classification for aerosol transmission when evaluating routes of SARS transmission[20]: (1) *obligate*: under natural conditions, disease occurs following transmission of the agent only through small-particle aerosols (e.g., tuberculosis); (2) *preferential*: natural infection results from transmission through multiple routes, but small-particle aerosols are the predominant route (e.g., measles, varicella); and (3) *opportunistic*: agents naturally cause disease through other routes, but under certain environmental conditions can be transmitted via fine-particle aerosols. This conceptual framework may explain rare occurrences of airborne transmission of agents that are transmitted most frequently by other routes (e.g., smallpox, SARS, influenza, noroviruses). Concerns about unknown or possible routes of transmission of agents that can cause severe disease and have no known treatment often result in more extreme prevention strategies than may be necessary; therefore, recommended precautions could change as the epidemiology of emerging agents is defined and these controversial issues are resolved. Although transmission of *M. tuberculosis* can occur rarely from a child with active tuberculosis, the more frequent source is the adult visitor who has not been diagnosed with active pulmonary tuberculosis; thus screening of visiting family members is an important component of control of tuberculosis in pediatric healthcare facilities.[21]

Transmission of microbes among children and between children and healthcare personnel is a frequent risk due to the very close contact that occurs during care of infants and young children. Traditionally, multi-bed rooms are crowded with children, parents, and

healthcare personnel. However, with the increasing evidence that single-patient rooms provide improved environments for patients that includes reduced risk of transmission of infectious agents and reduced medical errors, the American Institute of Architects' 2006 Guidelines for Design and Construction of Health Care Facilities recommends single-patient rooms for acute medical/surgical and postpartum patients as the standard for all new construction (www.aia.org/aah_gd_hospcons). Although there are insufficient data at this time to support a definitive recommendation for single-patient rooms in NICUs, there is increasing experience that suggests a benefit to reduce the risk of infection and to improve neurosensory development.[22] Toddlers often share waiting rooms, playrooms, toys, books, and other items and therefore have the potential of transmitting pathogens directly and indirectly to one another. Contaminated bath toys were implicated in an outbreak of multidrug-resistant *Pseudomonas aeruginosa* in a pediatric oncology unit.[23]

Before effective preventive measures were established,[24] 17% of preschool children hospitalized for more than 1 week had a nosocomial viral respiratory tract illness.[25] Infection of pediatric healthcare workers was also common. Since routine care of infants and younger children involves holding, cuddling, wiping noses, feeding, and changing diapers, it is easy to see how RSV and other respiratory tract viral agents can be transmitted in secretions that are then inoculated into the eyes and noses of healthcare workers. RSV infections were more likely in healthy volunteers who held or cuddled infants or handled items that the infants had touched and did not occur in those who were in the patients' rooms but had no direct patient contact and did not touch any items or surfaces.[26] A source of further concern involves healthcare workers with mild symptoms of infection who unknowingly become intermediary hosts and who transmit organisms to susceptible children. Several published studies have shown that infected pediatric healthcare personnel, including resident physicians, transmitted *Bordetella pertussis* to other patients.[27] Healthcare personnel have been implicated as the source of outbreaks of rotavirus[28] and influenza.[29]

Transmission of infectious agents is further facilitated by overcrowding and understaffing. Several studies demonstrated the association of understaffing and overcrowding with increased rates of HAIs in NICUs, PICUs, and general pediatrics units[30–33] and contributed substantially to the evidence base that supports recommendations to consider staffing levels and composition as important components of an effective infection control program in the 2007 revision of the Healthcare Infection Control Practices Advisory Committee (HICPAC)/Centers for Disease Control and Prevention (CDC) guideline for isolation precautions in healthcare settings.[1]

Healthcare personnel are rarely the *source* of outbreaks of HAIs caused by bacteria and fungi, but when they are, there are usually factors present that increase the risk transmission of infectious agents to others (e.g., sinusitis, draining otitis externa, respiratory tract infections, dermatitis, onychomycosis, wearing of artificial nails).[34] Those individuals with direct patient contact wearing artificial nails have been implicated in outbreaks of *Pseudomonas aeruginosa* and ESBL-producing *Klebsiella pneumoniae* in NICUs.[35,36] These studies contributed to the recommendation to prohibit use of artificial nails or extenders when having direct contact with high-risk patients.[1,37]

Pathogens

While there is no agreed-upon definition for what constitutes an "epidemiologically important organism," the following characteristics apply and are presented for guidance to infection control staff in the 2007 revision of the HICPAC/CDC Guideline for Isolation Precautions in Healthcare Settings (www.cdc.gov/ncidod/dhqp/pdf/guidelines/isolation2007.pdf):

1. A propensity for transmission within healthcare facilities based on published reports and the occurrence of temporal or geographic clusters of >2 patients (e.g., VRE, MRSA, and methicillin-susceptible *Staphylococcus aureus* (MSSA), *Clostridium difficile*, norovirus, RSV, influenza, rotavirus, *Enterobacter* spp., *Serratia* spp., group A streptococcus). A single case of healthcare-associated invasive disease caused by certain pathogens (e.g., group A streptococcus postoperatively or in burn units; *Legionella* sp.; *Aspergillus* sp.) should trigger an investigation.
2. Antimicrobial resistance (e.g., MRSA, VRE, ESBL-producing gram-negative bacilli, *Burkholderia cepacia, Ralstonia* spp., *Stenotrophomonas maltophilia,* and *Acinetobacter*. Many of the intrinsically resistant gram-negative bacilli also suggest possible water or medication contamination.
3. Association with serious clinical disease, increased morbidity and mortality (e.g., MRSA and MSSA, group A streptococcus).
4. A newly discovered or reemerging pathogen (e.g., vancomycin-insensitive or resistant *Staphylococcus aureus* (VISA, VRSA), *C. difficile*).

Pathogens associated with HAIs in hospitalized children differ from those in adults. Viral agents and other respiratory tract pathogens (e.g., *Bordetella pertussis*) have heightened potential for transmission in pediatric facilities. Gram-negative bacilli, including ESBL and other multidrug-resistant isolates, may be more frequent than MRSA and VRE in many PICUs and NICUs. Patients who are transferred from chronic care facilities may be colonized with resistant gram-negative bacilli at the time of admission to the PICU.[11] Trends in targeted multidrug-resistant pathogens that have been tracked in the NNIS (now NHS) ICUs are summarized in Figure 2-1. Continued increases in MRSA, VRE, and certain resistant gram-negative bacilli are a "call to action" for all healthcare facilities. The CDC Campaign to prevent antimicrobial resistance and the Guideline for Management of Multi-Drug Resistant Organisms (MDRO) in Healthcare Settings 2006 can be accessed on the following websites, respectively: www.cdc.gov/drugresistance/healthcare; www.cdc.gov/nciod/dhqp/index.html. Of note, in 2004, rates of healthcare-associated MRSA and VRE appear to have reached a plateau, whereas there are steep increases in the incidence of *Klebsiella pneumoniae* resistant to third-generation cephalosporins in the ICUs reporting to the current CDC surveillance system, NHSN (formerly NNIS) (www.cdc.gov/ncidod/dhqp/ar_mrsa_data.html). HAIs caused by MDROs are associated with increased length of stay, increased morbidity and mortality, and increased cost, in part due to the delay in initiating antimicrobial therapy that will be active against the infecting agent.[38] While there is lower prevalence of specific MDROs in pediatric institutions, the same principles of target MDRO identification and control interventions apply to all settings. The emergence of CA-MRSA isolates characterized by the unique Scc *mec* type IV element was first observed among infants and children and is now being transmitted in hospitals, notably in NICUs,[13] making prevention more complex.

The viruses most frequently associated with transmission in a pediatric healthcare facility are RSV, rotavirus, and influenza. However, other respiratory viruses (e.g., parainfluenza, adenovirus) have been implicated in outbreaks in high-risk units. Outbreaks of varicella and measles in pediatric healthcare facilities are rare events now due to consistent uptake during the past decade of vaccines in children and in healthcare personnel. Clinical manifestations with certain pathogens are more severe in infants and young children. RSV and *Bordetella pertussis* usually cause mild upper respiratory tract infections and cough, respectively, in older children and adults, yet cause severe disease with substantial morbidity and mortality in infants and children, especially those who are immunocompromised or who have underlying cardiac or pulmonary disease. An excessive burden of disease and mortality associated with influenza in infants and young children is also recognized.[39,40]

Candida sp. had been increasing in incidence in most PICUs and NICUs during the 1990s. There is considerable center-to-center variability in both the incidence of invasive candidiasis and the proportion of *Candida* infections caused by *Candida* non-*albicans* sp., most of which are resistant to fluconazole. Risk factors for *Candida* infections include prolonged length of stay in an ICU, use of CVCs, intralipids, H_2-blocking agents, and exposure to third-generation cephalosporins. Gram-negative bacilli and *Candida* sp. are especially

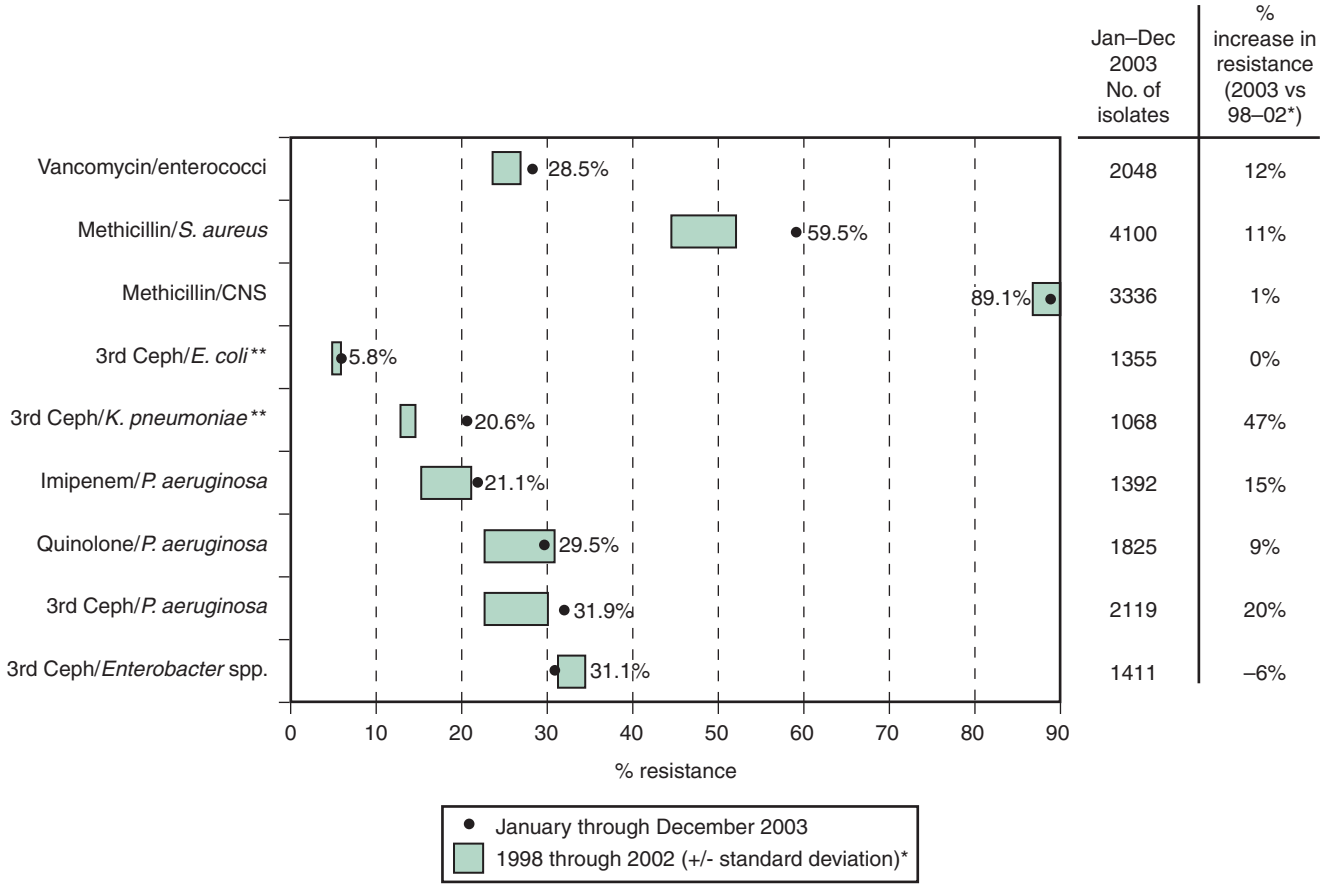

Figure 2-1. Selected antimicrobial-resistant pathogens associated with nosocomial infections in intensive care unit patients; comparison of resistance rates from January through December 2003 with 1998 through 2002, National Nosocomial Infections Surveillance (NNIS) system. CNS, Coagulase-negative staphylococci; 3rd Ceph, resistance to third-generation cephalosporins (ceftriaxone, cefotaxime, or ceftazidime); Quinolone, resistance to either ciprofloxacin or ofloxacin. *Percent (%) increase in resistance rate of current year (January–December 2003) compared with mean rate of resistance over previous 5 years (1998–2003): [(2003 rate—previous 5-year mean rate)/previous 5-year mean rate] × 100. **"Resistance" for *Escherichia coli* or *Klebsiella pneumoniae* is the rate of nonsusceptibility of these organisms to either 3rd Ceph group or aztreonam. Redrawn from the National Nosocomial Infections Surveillance (NNIS) System Report, data summary from January 1992 through June 2004, issued October 2004. Am J Infect Control 2004;32:470–485.

important pathogens for HAIs in patients with short gut who are TPN-dependent and can cause repeated episodes of sepsis.[41,42] Finally, environmental fungi (e.g., *Aspergillus, Fusarium, Scedosporium, Bipolaris*, Zygomycetes), are important sources of infection for severely immunocompromised patients, demanding meticulous attention to the conditions of the internal environment of any facility that provides care for severely immunocompromised patients and prevention of possible exposure to construction dust in and around healthcare facilities.[9,43] With the advent of more effective and less toxic antifungal agents, it is important to identify the infecting agent by obtaining tissue samples and to determine susceptibility to candidate antifungal agents.[43,44]

PREVENTION

Prevention remains the mainstay of infection control and requires special considerations in children. The goals of infection control and prevention are to prevent the transmission of infectious agents among individual patients or groups of patients, visitors, and healthcare personnel who care for them. If prevention cannot always be achieved, the next best strategy is early diagnosis, treatment, and prevention of continued transmission. An effective infection control program should improve patient and healthcare personnel safety and decrease short- and long-term morbidity, mortality, and healthcare costs. This chapter describes the unique principles and practice of infection control for the care of children. Specific pathogens and diseases are discussed in detail in chapters dedicated to those topics. Recommended isolation precautions by infectious agent can be found in the *Red Book Report of the Committee on Infectious Diseases* (COID) of the American Academy of Pediatrics (AAP) and in the Guideline for Isolation Precautions: Preventing Transmission of Infectious Agents in Healthcare Settings 2007.[1] In addition, textbooks on healthcare epidemiology and infection control contain chapters devoted to pediatric-specific programs.

A series of infection control prevention and control guidelines have been developed and updated by HICPAC/CDC and others to provide evidence-based, rated recommendations for practices that are associated with reduced rates of HAIs, especially those associated with the use of medical devices and surgical procedures (Box 2-1). Bundled practices are groups of three to five evidence-based "best practices" with respect to a disease process that individually improve care, but when applied together result in substantially greater reduction in infection rates. Adherence to the individual measures within a bundle is readily measured. Bundles for the reduction of CLA-BSIs, surgical site infections (SSIs), and ventilator assocated pneumonia (VAP) established for adults have been adapted to pediatrics (www.ihi.org/IHI/Programs/Campaign).

BOX 2-1. Resources for Infection Control Recommendations

CENTERS FOR DISEASE CONTROL AND PREVENTION/ HEALTHCARE INFECTION CONTROL PRACTICES COMMITTEE (www.cdc.gov/ncidod/dhqp/index.html)

Influenza vaccination of health-care personnel: recommendations of the Healthcare Infection Control Practices Committee (HICPAC) and the Advisory Committee on Immunization Practices (ACIP). MMWR 2006;55:RR-2

Guideline for disinfection and sterilization in health-care facilities (in revision)

Guideline for prevention of healthcare-associated pneumonia, 2003. MMWR 2004;53(RR-3)

Guideline for environmental infection control in health-care facilities, 2003. MMWR 2003;52(RR-10)

Guideline for hand hygiene in health-care settings, 2002. MMWR 2002;51(RR-16)

Guideline for prevention of intravascular catheter-related infections, 2002. MMWR 2002;51(RR-10)

Recommendations for preventing transmission of infections among chronic hemodialysis patients, 2001. MMWR 2001;50(RR-5)

Guidelines for preventing opportunistic infections among hematopoietic stem cell transplant recipients, 1999. MMWR 2000;49(RR-10)

Guideline for the prevention of surgical site infection, 1999. Infect Control Hosp Epidemiol 1999;20:247–278

Infection control in health care personnel, 1998. Infect Control Hosp Epidemiol 1998;19:407–463

Guideline for isolation precautions in hospitals in healthcare settings, 2007. www.cdc.gov/neidod/dhqp/pdf/guidelines/isolation2007.pdf

Management of multi-drug resistant organisms (MDROs) in healthcare settings, 2006. www.cdc.gov/nciod/dhqp/index.html: posted 10/19/06

Guidelines for preventing the transmission of Mycobacterium tuberculosis in health-care facilities, 2005. MMWR 2005;54(RR-17)

Guideline for prevention of catheter-associated urinary tract infections. Am J Infect Control 1983;11:28–33

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Committee on Infectious Diseases. 2006 Report of the Committee on Infectious Diseases. In: Pickering LK, Baker CJ, Long SS (eds). Red Book, 27th ed. Illinois, American Academy of Pediatries, 2006

OTHER

Society for Healthcare Epidemiology of America (SHEA) Position Papers (www.shea-online.org/PositionPapers.html)

Infectious Diseases Society of America (IDSA) Clinical Practice Guidelines (www.journals.uchicago.edu/IDSA/guidelines)

Association for Professionals in Infection Control and Epidemiology (APIC) Practice. Guidelines and State of the Art Reports (www.apic.org)

Carrico R (ed.) APIC Text of Infection Control and Epidemiology, 2nd ed. Washington, DC, Association for Professionals in Infection, Control and Epidermiology 2005

Saiman L, Siegel JD, and the Cystic Fibrosis Foundation Consensus. Infection control recommendations for patients with cystic fibrosis: microbiology, important pathogens, and infection control practices to prevent patient-to-patient transmission. Infect Control Hosp Epidermial 2003;24(Suppl. 1–62).

Administrative Factors

The importance of certain administrative measures for a successful infection control program has been demonstrated. There is now an adequate evidence base to designate infection control as one component of the institutional culture of safety and to obtain support from the senior leadership of the healthcare organization in order to provide necessary fiscal and human resources for a proactive, successful infection control program. Critical elements requiring administrative support include access to appropriately trained healthcare epidemiology and infection control personnel; access to clinical microbiology laboratory services needed to support infection control outbreak investigations and multidisciplinary programs to assure judicious use of antimicrobial agents and control of antimicrobial resistance; delivery of effective educational information to healthcare personnel, patients, families, and visitors; and provision of adequate numbers of well-trained infection control, and bedside nursing staff.[1,30–33]

The Infection Control and Prevention Team

The goals of infection control and prevention are to prevent the transmission of infectious agents among individual patients or groups of patients, visitors, and healthcare personnel who care for them. If prevention cannot always be achieved, the next best strategy is early diagnosis, treatment, and prevention of continued transmission. An effective infection control program should improve patient and healthcare personnel safety and decrease short- and long-term morbidity, mortality, and healthcare costs.[45] This chapter describes the unique principles and practice of infection control for the care of children. Recommended isolation precautions by infectious agent may be found in the *Red Book Report of the COID* (AAP) and in the Guideline for Isolation Precautions: Preventing Transmission of Infectious Agents in Healthcare Settings 2006.[1]

The infection control committee establishes policies and procedures to prevent or reduce the incidence and costs associated with HAIs. The infection control committee should be one of the strongest and most accessible committees in the hospital; committee composition should be carefully considered and limited to active, authoritative participants who have well-defined responsibilities on the committee and who represent major groups within the hospital. The chairperson should be a good communicator with expertise in infection control issues, healthcare epidemiology, and clinical pediatric infectious diseases. An important function of the infection control committee is the regular review of infection control policy and the development of new infection control policies as needed. Annual review is required by the Joint Commission on Accreditation of Healthcare Organizations and can be optimally accomplished by careful review of a few policies each month. With the advent of unannounced inspections, a constant state of readiness is required. If a facility chooses not to have an infection control committee, an alternative strategy is needed to accomplish the above tasks.

The infection control and prevention division or team is the working group (including physicians, nurses, microbiologists, and administrators) that performs and coordinates all infection control activities. The hospital epidemiologist or medical director of the infection control division is usually a physician with training in pediatric infectious diseases and a dedicated expertise and interest in healthcare epidemiology. In multidisciplinary medical centers, pediatric infectious disease experts should be consulted for management of pediatric infection control and report to the broader infection control leadership. Infection control and prevention professionals (ICPs) are specialized professionals with advanced training and preferably certification in infection control. Although the majority of ICPs are registered nurses, others, including microbiologists, medical technologists, pharmacists, and epidemiologists, are successful in this position. Pediatric patients should have ICP services provided by someone with expertise and training in the care of children. In a large, general hospital, at least one ICP should be dedicated to infection control services for children. The responsibilities of ICPs have expanded greatly in the last decade and include the following: (1) surveillance and infection prevention in facilities affiliated with the primary acute care hospitals (e.g., ambulatory clinics, day-surgery centers, long-term care facilities, rehabilitation centers, home care) in addition to the primary hospital; (2) oversight of employee health services related to infection prevention, (e.g., assessment of risk and administration of recommended treatment following exposure to infectious agents, tuberculosis screening, influenza and pertussis vaccination, respiratory protection fit testing, administration of other vaccines as indicated during infectious disease crises such as pre-exposure smallpox vaccine in 2003); (3) preparedness planning for annual influenza outbreaks, pandemic influenza, SARS, bioweapons attacks; (4) adherence monitoring for selected infection control practices; (5) oversight of risk assessment and

implementation of prevention measures associated with construction, renovation, and other environmental conditions associated with increased infection risk; (6) prevention of transmission of MDROs; (7) evaluation of new products that could be associated with increased infection risk (e.g., intravenous infusion materials), for introduction and assessment of performance after implementation; (8) mandatory public reporting of HAI rates in states as legislation is enacted; (9) increased communication with the public and with local public health departments concerning infection control-related issues; and (10) participation in local and multicenter research projects. Infection control programs must be adequately staffed to perform all of these activities. Thus, the ratio of 1 ICP per 250 beds that was associated with a 30% reduction in the rates of nosocomial infection in the Study on Efficacy of Nosocomial Infection Control (SENIC) study performed in the 1970s[46] is no longer sufficient, as the complexity of patient populations and the responsibilities of infection control professionals have increased. Many experts recommend that a ratio of 1 ICP per 100 beds is more appropriate for the current workload, but no study has been performed to confirm the effectiveness of that ratio. There is no information on the number of individuals required outside acute care, but it is clear that individuals well trained in infection control must be available for all sites where healthcare is delivered.[1]

Surveillance

Surveillance for HAIs consists of a systematic method of determining the incidence and distribution of infections acquired by hospitalized patients. The CDC recommends the following: (1) prospective surveillance on a regular basis by trained infection control professionals, using standardized definitions; (2) analysis of infection rates using established epidemiologic and statistical methods (e.g., calculation of rates using appropriate denominators that reflect duration of exposure; use of statistical process control charts for trending rates); (3) regular use of data in decision-making; and (4) employment of an effective and trained healthcare epidemiologist who develops infection control strategies and policies and serves as a liaison with the medical community and administration.[47–50] The CDC has established a set of standard definitions of HAIs that have been validated and accepted widely[51] with updates posted on the CDC website or published in HICPAC/CDC guidelines. Standardization of surveillance methodology has become especially important with the advent of state legislation for mandatory reporting to the public of HAI infection rates.[52]

Although various surveillance methods are used, the basic goals and elements are similar and include using standardized definitions of infection, finding and collecting cases of HAIs, tabulating data, using appropriate denominators that reflect duration of risk, analyzing and interpreting the data, reporting important deviations from endemic rates (epidemic, outbreaks) to the bedside care providers and to the facility administrators, implementing appropriate control measures, auditing adherence rates for recommended measures, and assessing efficacy of the control measures. Medical centers can utilize different methods of surveillance, as outlined in Box 2-2. Most experts agree that a combination of methods enhances surveillance and data reliability and that some combination of clinical chart review and database retrieval is important.[47–50] Administrative databases created for the purposes of billing should not be used as the sole source to identify HAIs because of both the overestimates and underestimates that result from inaccurate coding of HAIs.[52] Use of software designed specifically for infection control data entry and analysis facilitates real-time tracking of trends and timely intervention when clusters are identified.

The microbiology laboratory can provide online culture information about individual patients, outbreaks of infection, antibiotic susceptibility patterns of pathogens in periodic antibiotic susceptibility summary reports, and employee infection data. This laboratory can also assist with surveillance cultures and facilitation of molecular typing of isolates during outbreak investigations. Rapid diagnostic testing of clinical specimens for identification of viruses and *Bordetella pertussis* is especially important for pediatric facilities. The infection control division and the microbiology laboratory must communicate daily, because even requests for cultures from physicians (e.g., *Mycobacterium tuberculosis, Neisseria meningitidis, Clostridium difficile*) can be an early marker for identifying patients who are infected, are at high risk of infection, or require isolation. If microbiology laboratory work is outsourced, it is important to assure that the services needed to support an effective infection control program will be available, as described in a policy statement of the Infectious Diseases Society of America on this matter.[53]

The pharmacy is an important collaborative member of any multidisciplinary team working on strategies to prevent antimicrobial resistance. Antimicrobial utilization in the hospital should be assessed for appropriateness, efficacy, cost, and association with emergence of resistant organisms. For surveillance purposes, use of specific antimicrobial agents can alert the ICP to potentially infected patients (e.g., tuberculosis). The need to restrict use of antimicrobial agents is a collaborative decision based on review of all of these data. Restriction of new, potent antimicrobial agents is advised to prevent emergence of resistance that occurs with increased exposure to most antimicrobial agents (e.g., extended-spectrum cephalosporins, quinolones, linezolid, daptomycin).[54–56]

Control of unusual infections or outbreaks in the community is generally the responsibility of the local or state public health department; however, the individual facility must be responsible for preventing transmission within that facility. Public health agencies can be particularly helpful in alerting hospitals of community outbreaks so that outpatient and inpatient diagnosis, treatment, necessary isolation, and other preventive measures begin promptly to avoid further spread. Conversely, the responsibility of designated individuals in the hospital is to notify public health department personnel of reportable infections so as to facilitate early diagnosis, treatment, and infection control in the community. Benefits of community or regional collaboratives of individual healthcare facilities and local public health departments for prevention of HAIs, especially those caused by MDROs, have been demonstrated and should be encouraged.[1]

BOX 2-2. Sources of Data for Surveillance

- Clinical rounds with physicians and/or nurses
- Review of:
  - Patient orders
  - Radiology reports/databases
  - Pharmacy reports/databases
  - Operating room diagnoses and procedures
  - Microbiology:
    - bacteriology, virology, mycology, acid-fast bacilli, serology reports
    - autopsy reports
    - data-mining reports
- Postdischarge surveillance, especially for surgical site infections
- Public health surveillance
- Review of:
  - Employee health reports
  - Admission diagnoses
  - Outpatient diagnoses
  - Administrative databases, but should not be used as sole source due to inaccurate coding of healthcare-associated infections

ISOLATION PRECAUTIONS

Isolation of patients with potentially transmissible infectious diseases is a proven strategy for reducing transmission of infectious agents in healthcare settings. During the past decade, many published studies, including those performed in pediatric settings, have provided a strong evidence base for most recommendations for isolation precautions. However, many controversies still exist concerning the most clinically

and cost-effective measures for preventing certain HAIs, especially those associated with MDROs. Since 1970, the guidelines for isolation developed by CDC have responded to the needs of the evolving healthcare systems in the United States. For example, universal precautions became a required standard in response to the HIV epidemic and the need to prevent transmission of bloodborne pathogens (e.g., HIV, hepatitis B and C viruses, rapidly fatal infections such as the viral hemorrhagic fevers). The Occupational Safety and Health Administration (OSHA) published specific requirements[57] in 1991 for universal precautions (now called Standard Precautions) for healthcare personnel who, as a result of their required duties, are at increased risk for skin, eye, mucous membrane, or parenteral contact with blood or other potentially infectious materials. Although all requirements may not have been proven to be clinically or cost-effective, healthcare facilities must enforce these measures. The federal Needlestick Safety and Prevention Act, signed into law in November, 2000, authorized OSHA's revision of its Bloodborne Pathogens Standard more explicitly to require the use of safety-engineered sharp devices (www.osha.gov/SLTC/bloodbornepathogens/index.html).

The 1996 CDC/Hospital Infection Control Advisory Committee Guideline for Isolation Precautions in Hospitals[58] has been updated and published in 2007 as the Guideline for Isolation Precautions: Preventing Transmission of Infectious Agents in Healthcare Settings.[1] This guideline affirms standard precautions, a combination of universal precautions and body substance isolation as the foundation of transmission prevention measures. Healthcare personnel are provided with guidance to recognize the importance of body fluids, excretions, and secretions in the transmission of infectious pathogens and to take appropriate protective precautions by using personal protective equipment (e.g., masks, gowns, gloves, face shields, or goggles) and safety devices even if an infection is not suspected or known. In addition, this updated guideline provides recommendations for all settings where healthcare is delivered (acute care hospitals, ambulatory surgical and medical centers, long-term care facilities, and home health agencies). Extensive background discussion and recommendations for the prevention of transmission of multidrug-resistant organisms (e.g., MRSA, VRE, VISA, VRSA, and gram-negative bacilli) in various settings are also included and were pre-released on the CDC website in October, 2006 (www.cdc.gov/ncidod/dhqp/pdf/ar/mdroGuidelines2006.pdf. The categories of Transmission-based Precautions described previously have been retained: Contact, Droplet, and Airborne Precautions. The characteristics of a protective environment for prevention of environmental fungal infections in HSCT recipients that were introduced in previously published guidelines are summarized. Finally, discussion and recommendations with evidence-based ratings for administrative measures that are necessary for effective prevention of infection in healthcare settings are provided. The isolation information presented in this chapter is based on these 2006 to 2007 isolation recommendations.

Standard Precautions

The term *Standard Precautions* replaced Universal Precautions and Body Substance Isolation in 1996. Standard Precautions should be used when there is likely to be exposure to: (1) blood; (2) all other body fluids, secretions, and excretions, whether or not they contain visible blood, except sweat; (3) nonintact skin; and (4) mucous membranes. Standard Precautions strategy is designed to reduce the risk of transmission of microorganisms from both identified and unidentified sources of infection. The components of Standard

TABLE 2-3. Recommendations for Application of Standard Precautions for the Care of all Patients in all Healthcare Settings

Component	Recommendations for Performance
Hand hygiene	After touching blood, body fluids, secretions, excretions, contaminated items; immediately after removing gloves; between patient contacts. Alcohol-containing antiseptic handrubs preferred except when hands are visibly soiled with blood or other proteinaceous materials or if exposure to spores (e.g., *Clostridium difficile, Bacillus anthracis*) is likely to have occurred
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,[a] 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 to protect healthcare personnel. For patient protection, use of a mask by the individual inserting an epidural anesthesia needle or performing myelograms when prolonged exposure of the puncture site is likely to occur
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
Injection practices (use of 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 needle-free safety devices when available; place used sharps in a puncture-resistant container. Use a sterile, single-use, disposable needle and syringe for each injection given. Single-dose medication vials are preferred when medications are administered to > 1 patient
Patient resuscitation	Use mouthpiece, resuscitation bag, or other ventilation devices to prevent contact with mouth and oral secretions
Patient placement	Prioritize for single-patient room if the patient is at increased risk of transmission, is likely to contaminate the environment, does not maintain appropriate hygiene, or is at increased risk of acquiring infection or developing adverse outcome following infection
Respiratory hygiene/cough etiquette[b]	Instruct symptomatic persons to cover mouth/nose when sneezing/coughing; use tissues and dispose in no-touch receptacle; observe hand hygiene after soiling of hands with respiratory secretions; wear surgical mask if tolerated or maintain spatial separation, > 1 meter (3 feet) if possible

[a]During aerosol-generating procedures on patients with suspected or proven infections transmitted by aerosols (e.g., severe acute respiratory syndrome), wear a fit-tested N95 or higher respirator in addition to gloves, gown, and face/eye protection.
[b]Source containment of infectious respiratory secretions in symptomatic patients, beginning at initial point of encounter (e.g., triage and reception areas in emergency departments and physician offices).

Precautions are summarized in Table 2-3. In the updated isolation guideline, safe injection practices are included as a component of standard precautions, not because new practices are recommended but because recent outbreaks of hepatitis B and C virus infection in ambulatory care settings as a result of failure to follow recommended practices indicate a need to reiterate the established effective practices.[59] There are two new additions to Standard Precautions: (1) *respiratory hygiene/cough etiquette* for source containment by patients with signs and symptoms of respiratory tract infection; and (2) *use of a mask* by the individual inserting an epidural anesthesia needle or performing myelograms when prolonged exposure of the puncture site is likely to occur to prevent introduction of respiratory tract microorganisms from the person performing the procedure into the cerebrospinal fluid of the patient and therefore prevent meninigitis. Both new components have a strong evidence base.

Implementation of Standard Precautions requires critical thinking from all healthcare personnel providing direct patient care and the availability of personal protective equipment in proximity to all patient beds. Healthcare personnel with exudative lesions or weeping dermatitis must avoid direct patient care and handling of patient care equipment. Individuals having direct patient contact should be able to anticipate an exposure to blood or other potentially infectious material and to take proper protective precautions. Individuals should also know what to do if a high-risk exposure does occur. Exposures of concern are exposures to blood or other potentially infectious material defined as an injury with a contaminated sharp object (e.g., needlestick, scalpel cut); a spill or splash of blood or other potentially infectious material on to nonintact skin (e.g., cuts, hangnails, dermatitis, abrasions, chapped skin) or on to a mucous membrane (e.g., mouth, nose, eye); or a blood exposure covering a large area of normal skin. Handling food trays or furniture, pushing wheelchairs or stretchers, using restrooms or phones, having personal contact with patients (e.g., giving information, touching intact skin, bathing, giving a back rub, shaking hands), or doing clerical or administrative duties for a patient do not constitute high-risk exposures. If hands or other skin surfaces are exposed to blood or other potentially infectious material, the healthcare worker should immediately wash the area with soap and water for at least 10 seconds and rinse with running water for at least 10 seconds. If an eye, the nose, or mouth is splashed with blood or body fluids, the area should be immediately irrigated with a large volume of water. If a skin cut, puncture, or lesion is exposed to blood or other potentially infectious material, the area should be immediately washed with soap and water for at least 10 seconds and rinsed with 70% isopropyl alcohol. Any exposure incident should be immediately reported to the occupational health department and a determination must be made if blood samples are required from the source patient and the exposed individual and if immediate prophylaxis is indicated.

All healthcare personnel should know where to find the exposure control plan that is specific for their place of employment, whom to contact, where to go, and what to do if inadvertently exposed to blood or body fluids. Important resources include the occupational health department, the emergency department, and the infection control/hospital epidemiology division. The most important recommendation in any accidental exposure is to seek advice and intervention immediately, because the efficacy of recommended prophylaxis regimens is improved with shorter intervals after exposure, such as for hepatitis B immune globulin administration after exposure to the hepatitis B virus or for antiretroviral therapy after percutaneous exposure to HIV. Chemoprophylaxis following exposure to HIV-infected material is most effective if initiated within 4 hours of exposure.[60] Additionally, reporting a work-related exposure is required for subsequent medical care and workers' compensation.

Transmission-Based Precautions

Transmission-based Precautions are designed for patients with documented or suspected infection with pathogens for which additional precautions beyond Standard Precautions are needed to prevent transmission. The three categories of Transmission-based Precautions are *Contact Precautions, Droplet Precautions*, and *Airborne Precautions* and are based on the likely routes of transmission of specific infectious agents. They may be combined for infectious agents that have more than one route of transmission. Whether used singly or in combination, they are always used in addition to Standard Precautions. Since the infectious agent is often not known at the time of admission, Transmission-based Precautions are applied based on the clinical presentation and the most likely pathogens – so-called *Empiric* or *Syndromic precautions*. This approach is especially useful for emerging agents (e.g., SARS-CoV, avian influenza, pandemic influenza), for which information concerning routes of transmission is still evolving. The categories of clinical presentation are as follows: diarrhea, central nervous system, generalized rash/exanthem, respiratory, skin or wound infection. Single-patient rooms are always preferred for children needing Transmission-based Precautions. If unavailable, cohorting of patients, and in some cases of staff, according to clinical diagnosis is recommended.

Table 2-4 lists the three categories of isolation based on routes of transmission and the necessary components. Table 2-5 lists precautions by syndromes, to be used when a patient has an infectious disease and the agent is not yet identified. It should be noted that for infectious agents that are more likely to be transmitted by the droplet route except during an aerosol-producing procedure (e.g., pandemic influenza), N95 or higher respirators are indicated during the procedure, but an AIIR is not necessarily needed (www.pandemicflu.gov/plan/healthcare/maskguidancehc.html).

ENVIRONMENTAL MEASURES

Contaminated environmental surfaces and noncritical medical items have been implicated in transmission of several healthcare-associated pathogens, including VRE, *C. difficile*, *Acinetobacter* sp., MRSA, and RSV.[1,9,61] Pathogens on surfaces are transferred to the hands of healthcare personnel and then transferred to other patients or items. Pathogens with a gastrointestinal tract reservoir, including MRSA, are especially likely to contaminate surfaces when the patient has diarrhea; surfaces surrounding such patients may need to be cleaned and disinfected repeatedly. Frequently touched surfaces and those closest to the patient are most likely to be contaminated (e.g., bedrails, bedside tables, commodes, doorknobs, sinks, surfaces, and equipment in close proximity to the patient). Most often, the failure to follow recommended procedures for cleaning and disinfection contributes more than the specific agent to the environmental reservoir of pathogens during outbreaks. In an educational and observational intervention that targeted a defined group of housekeeping personnel, there was a persistent decrease in the acquisition of VRE in a medical ICU; therefore, monitoring for adherence to recommended environmental cleaning practices is an important determinant of success in controlling transmission of MDROs and other environmental pathogens.[62] Certain infectious agents (e.g., rotavirus, noroviruses, *C. difficile*) may be resistant to some routinely used hospital disinfectants; thus, when there is ongoing transmission and cleaning procedures have been observed to be appropriate, a 1:10 dilution of 5.25% sodium hypochlorite (household bleach) or other special disinfectants may be indicated.[9] Pediatric facilities should use disinfectants active against rotavirus.[63]

VISITATION POLICIES

Since acquisition of a seemingly innocuous viral infection in neonates and in children with underlying diseases can result in unnecessary evaluation and empirical therapy for septicemia as well as serious life-threatening disease, special visitation policies are required in pediatric units, especially the high-risk units. All visitors with signs or symptoms of respiratory or gastrointestinal tract infection should be

TABLE 2-4. Transmission-Based Precautions[a]

Component	Contact	Droplet	Airborne
Hand hygiene	Per Standard Precautions Soap and water preferred over alcohol handrub for *Clostridium difficile, Bacillus anthracis* spores	Per Standard Precautions	Per Standard Precautions
Gown	Yes. Don before room entry	Per Standard Precautions	Per Standard Precautions and, if infectious, draining skin lesions present
Gloves	Yes. Don before room entry	Per Standard Precautions	Per Standard Precautions
Mask	Per Standard Precautions	Yes. Don before room entry	N95 particulate respirator or higher
Goggles/face shield	Per Standard Precautions	Per Standard Precautions. Always for SARS, avian influenza	Per Standard Precautions Always for SARS, avian influenza
N95 or higher respirator	When aerosol-producing procedures performed for influenza, SARS, VHF	When aerosol-producing procedures performed for influenza, SARS, VHF	Yes. Don upon entry
Room placement	Single-patient room preferred. Cohort like-infections if single-patient rooms unavailable	Single-patient room preferred. Cohort like-infections if single-patient rooms unavailable	Single-patient room. Negative air pressure; 12 air changes/hour for new construction, 6 air changes/hour for existing rooms
Environmental measures	Increased frequency, especially in the presence of diarrhea. transmission of *Clostridium difficile*, norovirus	Routine	Routine
Transport	Mask patient if coughing. Cover infectious skin lesions	Mask patient	Mask patient Cover infectious skin lesions

SARS, severe acute respiratory syndrome; VHF, viral hemorrhagic fever.
[a]An addition to Standard precautions, use Transmission-based Precautions, use Transmission-based Precautions for patients with highly transmisible or epidemiologically important pathogens for which additional precautions are needed.

restricted from visiting patients in healthcare facilities. During the influenza season, it is preferred for all visitors to have received influenza vaccine. Increased restrictions may be needed in the midst of a community outbreak (e.g., SARS, influenza). For patients requiring Contact Precautions, the use of personal protective equipment by visitors is determined by the nature of the interaction with the patient and the likelihood that the visitor will frequent common areas on the patient unit or interact with other patients and their family members.

Although most pediatricians encourage visits by siblings in inpatient areas, the medical risk must not outweigh the psychosocial benefit. Studies demonstrate that parents favorably regard sibling visitation[64] and that bacterial colonization[65,66] or subsequent infection[67] does not increase in the neonate or older child who has been visited by siblings, but these studies are limited by small numbers. Strict guidelines for sibling visitation should be established and enforced in an effort to maximize visitation opportunities and minimize risks of transmission of infectious agents. The following recommendations regarding visitation may guide policy development:

1. Sibling visitation is encouraged in the well-child nursery and NICU, as well as in areas for care of older children.
2. Before visitation, parents should be interviewed by a trained staff nurse concerning the current health status of the sibling. Siblings who are visiting should have received all vaccines recommended for age. Children with fever or symptoms of an acute illness such as upper respiratory tract infection, gastroenteritis, or dermatitis should not be allowed to visit. Siblings who have been exposed to a known infectious disease and are still within the incubation period should not be allowed to visit. After the interview, the physician or nurse should place a written consent for sibling visitation in the permanent patient record and a name tag indicating that the sibling has been approved for visitation for that day.
3. Asymptomatic siblings who have been recently exposed to varicella but have been previously immunized can be assumed to be immune.
4. The visiting sibling should visit only his or her sibling and not be allowed in playrooms with groups of patients.
5. Visitation should be limited to periods of time that ensure adequate screening, observation, and monitoring of visitors by medical and nursing staffs.
6. Children should observe hand hygiene before and after contact with the patient.
7. During the entire visit, sibling activity should be supervised by parents or another responsible adult.

PETS

Many zoonoses and infections are attributable to animal exposure. Most of these infections result from inoculation of animal flora through a bite or scratch or self-inoculation after contact with the animal, animal secretions or excretions, or contaminated environment. No universal guidelines for hospital pet visitation have been developed because there are no controlled experiences upon which evidence-based recommendations can be made. This topic is reviewed in the Guidelines for Environmental Infection Control in Health-Care Facilities and recommendations are provided to guide institutional policies.[9] Pets can be of significant clinical benefit to the child hospitalized for prolonged periods, and many centers have created their own pet visitation guidelines.

Prudent visitation policies should include limiting visitation to animals that meet the following requirements: (1) they are domesticated; (2) they do not require a water environment; (3) they do not bite or scratch; (4) they can be brought to the hospital in a carrier or easily walked on a leash; (5) they are trained to defecate and urinate outside or in appropriate litter boxes; (6) they can be bathed before visitation; and (7) they are known to be free of respiratory, dermatologic, and gastrointestinal tract disease. Reptiles should be excluded due to the risk of transmission of *Salmonella* sp. and development of severe invasive disease in young infants[68] and exotic animals that are

TABLE 2-5. Clinical Syndromes or Conditions Warranting Empiric Transmission-Based Precautions in Addition to Standard Precautions Pending Confirmation of Diagnosis[a]

Clinical Syndrome or Condition[b]	Potential Pathogens[c]	Empiric Precautions (Always Includes Standard Precautions)
Diarrhea		
Acute diarrhea with a likely infectious cause in an incontinent or diapered patient	Enteric pathogens[d]	Contact Precautions (pediatrics and adult)
Meningitis	*Neisseria meningitidis* Enteroviruses *Mycobacterium tuberculosis*	Droplet Precautions for first 24 hours of antimicrobial therapy; mask and face protection for intubation Contact Precautions for infants and children Airborne Precautions if pulmonary infiltrate Airborne Precautions plus Contact Precautions if potentially infectious draining body fluid present
Rash or Exanthems, Generalized, Etiology Unknown		
Petechial/ecchymotic with fever (general) If traveled in an area with an ongoing outbreak of VHF in the 10 days before onset of fever	*Neisseria meningitidis* Ebola, Lassa, Marburg viruses	Droplet Precautions for first 24 hours of antimicrobial therapy Droplet Precautions plus Contact Precautions, with face/eye protection, emphasizing safety sharps and barrier precautions when blood exposure likely. Use N95 or higher respiratory protection when aerosol-generating procedure performed
Vesicular	Varicella-zoster, herpes simplex, variola (smallpox), vaccinia viruses	Airborne plus Contact Precautions. Contact Precautions only if herpes simplex, localized zoster in an immunocompetent host, or vaccinia viruses most likely
Maculopapular with cough, coryza, and fever	Rubeola (measles) virus	Airborne Precautions
Respiratory Infections		
Cough/fever/upper-lobe pulmonary infiltrate in an HIV-negative patient or a patient at low risk for HIV infection	*Mycobacterium tuberculosis,* respiratory viruses, *Streptococcus pneumoniae*, *Staphylococcus aureus* (MSSA or MRSA)	Airborne Precautions plus Contact Precautions
Cough/fever/pulmonary infiltrate in any lung location in an HIV-infected patient or a patient at high risk for HIV infection	*Mycobacterium tuberculosis,* respiratory viruses, *Streptococcus pneumoniae, Staphylococcus aureus* (MSSA or MRSA)	Airborne Precautions plus Contact Precautions Use eye/face protection if aerosol-generating procedure performed or contact with respiratory secretions anticipated. If tuberculosis is unlikely and there are no AIIRs and/or respirators available, use Droplet Precautions instead of airborne precautions. Tuberculosis more likely in HIV-infected than in HIV-negative individuals
Cough/fever/pulmonary infiltrate in any lung location in a patient with a history of recent travel (10–21 days) to country with outbreak of SARS, avian influenza	*Mycobacterium tuberculosis*, severe acute respiratory syndrome virus–coronavirus (SARS-CoV), avian influenza	Airborne plus Contact Precautions plus eye protection. If SARS and tuberculosis unlikely, use Droplet Precautions instead of Airborne Precautions
Respiratory infections, particularly bronchiolitis and pneumonia, in infants and young children	Respiratory syncytial virus, parainfluenza virus, adenovirus, influenza virus, human metapneumovirus	Contact Precautions plus Droplet Precautions; Droplet Precautions may be discontinued when adenovirus and influenza have been ruled out.
Skin or Wound Infection		
Abscess or draining wound that cannot be covered	*Staphylococcus aureus* (MSSA or MRSA), group A streptococcus	Contact Precautions Add droplet precautions for the first 24 hours of appropriate antimicrobial therapy if invasive group A streptococcal disease is suspected

AIIR, airborne infection isolation room; HIV, human immunodeficiency virus; MRSA, methicillin-resistant *Staphylococcus aureus;* MSSA, methicillin-susceptible *Staphylococcus aureus*; VHF, viral hemorrhagic fever.

[a]Infection control professionals should modify or adapt this table according to local conditions. To ensure that appropriate empiric precautions are always implemented, hospitals must have systems in place to evaluate patients routinely according to these criteria as part of their preadmission and admission care.

[b]Patients with the syndromes or conditions listed may have atypical signs or symptoms (e.g., neonates and adults with pertussis may not have paroxysmal or severe cough). The clinician's index of suspicion should be guided by the prevalence of specific conditions in the community, as well as clinical judgment.

[c]The organisms listed under the column "Potential Pathogens" are not intended to represent the complete, or even most likely, diagnoses, but rather possible etiologic agents that require additional precautions beyond standard precautions until they can be ruled out.

[d]These pathogens include enterohemorrhagic *Escherichia coli* O157:H7, *Shigella* spp., hepatitis A virus, noroviruses, rotavirus, *Clostridium difficile*.

imported should be excluded because of unpredictable behavior and the potential for transmission of unusual pathogens (e.g., monkeypox).[69] Visitation should be limited to short periods of time and confined to designated areas. Visiting pets should have a certificate of immunization from a licensed veterinarian. Children should observe hand hygiene after contact with pets. Most pediatric facilities restrict pet interaction with severely immunosuppressed patients and those in ICUs.

DISINFECTION, STERILIZATION, AND REMOVAL OF INFECTIOUS WASTE

The topic of disinfection and sterilization as it relates to infection prevention and control has been reviewed.[70,71] *Cleaning* is the removal of all foreign material from surfaces and objects. This process is accomplished using soap and enzymatic products. Failure to remove all organic material from items before disinfection and sterilization

will reduce the effectiveness of those processes. *Disinfection* is a process that eliminates all forms of microbial life except the endospore. Disinfection usually requires liquid chemicals. The ability of an inanimate surface or object to be disinfected can be adversely affected by the presence of organic matter; a high level of microbial contamination; too dilute germicide; inadequate disinfection time; an object that can harbor microbes in protected cracks, crevices, and hinges; and pH and temperature.

Sterilization is the eradication of all forms of microbial life, including fungal and bacterial spores. Sterilization is achieved by physical and chemical processes such as steam under pressure, dry heat, ethylene oxide, and liquid chemicals. Patient care equipment was originally categorized by Spaulding[72] and subsequently by the CDC[71] as critical, semicritical, and noncritical items with regard to sterilization and disinfection. Critical items require sterilization because they enter sterile body tissues and would have a high risk of causing infection if contaminated; semicritical objects require disinfection because they may contact mucous membranes and nonintact skin; and noncritical items require routine cleaning because they only come in contact with intact skin. If noncritical items used on patients requiring Transmission-based Precautions, especially Contact Precautions, must be shared, these items should be disinfected after use on a patient who is under isolation precautions. Guidelines for specific objects and specific disinfectants are published and updated by the CDC. Multiple published reports and manufacturers similarly recommend the use and reuse of objects with appropriate sterilization, disinfection, or cleaning recommendations. Recommendations in guidelines for reprocessing endoscopes focus on training of personnel, meticulous manual cleaning, high-level disinfection followed by rinsing, air-drying, and proper storage to avoid contamination.[73] Medical devices that are designed for single use (e.g., specialized catheters, electrodes, biopsy needles) must be reprocessed by third parties or hospitals according to the guidance issued by the Food and Drug Administration (FDA) in August, 2000 with amendments in September, 2006; such reprocessors will be considered "manufacturers" and will be regulated in the same manner. Available data show that single-use devices reprocessed according to the FDA regulatory requirements are as safe and effective as new devices (www.fda.gov/cdrh/reprocessing).

Healthcare facility waste is all biologic or nonbiologic waste that is discarded and not intended for further use. *Medical waste* is the material generated as a result of use with a patient, such as for diagnosis, immunization, or treatment, and includes soiled dressings and intravenous tubing. *Infectious waste* is that portion of medical waste that could potentially transmit an infectious disease. Microbiologic waste, pathologic waste, contaminated animal carcasses, blood, and sharps are all examples of the estimated infectious waste discarded in the United States each day. Methods of effective disposal of infectious waste include incineration, steam sterilization, drainage to a sanitary sewer, mechanical disinfection, chemical disinfection, and microwave. State regulations guide the treatment and disposal of regulated medical waste. Recommendations for developing and maintaining a program within a facility for safe management of medical waste can be found in the Guidelines for Environmental Infection Control in Health-Care Facilities.[9]

OCCUPATIONAL HEALTH

Occupational health and student health collaboration with the infection control division of a hospital is required by OSHA[57] and is important for a successful infection control program. The occupational health program is of paramount importance in hospitals caring for children because healthcare personnel are at increased risk of infection for various reasons, including the following: (1) children have a high incidence of infectious diseases; (2) personnel may be susceptible to many of the infecting pathogens; (3) pediatric care requires close contact; (4) children lack good personal hygiene; (5) infected children may be asymptomatic; and (6) healthcare personnel are exposed to multiple family members who may also be infected.

The occupational health department should be an educational resource for information on infectious pathogens in the healthcare workplace. Occupational health, in concert with the infection control service, should provide pre-employment education and respirator fit testing; annual retraining for all employees regarding routine health maintenance, available vaccines, standard precautions and isolation categories, and exposure plans; and screening for tuberculosis at regular intervals, as determined by the facility's risk assessment.[74] With new pathogens being isolated, new diseases and their transmission described, and new prophylactic regimens and treatment available, it is mandatory that personnel have an up-to-date working knowledge of infection control and know where and what the available services, equipment, and therapies are for the healthcare worker. Many educational resources are available to assist with employee education.[75]

All healthcare personnel should be screened by history or serologic testing, or both, to document their immune status to specific agents, and immunization should be provided for the following for all employees who are nonimmune and who do not have contraindications to receiving the vaccine: diphtheria, tetanus, hepatitis B virus, influenza (yearly), mumps, poliomyelitis, rubella, rubeola, and varicella. Providing vaccines at no cost to healthcare personnel increases acceptance. Recognition of the importance of raising influenza vaccination rates among healthcare personnel to protect the individuals, their patients, and their family members led to the publication of evidence-based recommendations in 2006.[76] After licensure of the adolescent/adult pertussis (Tdap) vaccine in 2005, the Advisory Committee on Immunization Practices and the AAP recommend administration of a single dose of Tdap to all healthcare personnel in whom > 2 years have elapsed since the most recent Td booster in order to prevent pertussis in the vaccine recipient and to prevent transmission of pertussis to high-risk patients.[77]

Special Concerns of Healthcare Personnel

Healthcare personnel who have underlying medical conditions (e.g., hypertension, diabetes, obesity, tobacco use) should be able to obtain general information on wellness and screening when needed from the occupational health service. Healthcare providers with direct patient contact who have infants younger than 1 year of age at home are concerned about acquiring infectious agents from patients and transmitting them to their susceptible children. An immune healthcare worker who is exposed to varicella does not become a silent "carrier" of this pathogen. However, pathogens to which the healthcare worker is partially immune or nonimmune can cause a severe, mild, or asymptomatic infection in the employee that can be transmitted to family members. Examples include influenza, pertussis, RSV, rotavirus, and tuberculosis.

Important preventive procedures for healthcare workers with infants at home are: (1) consistent observance of Standard Precautions, Transmission-based Precautions, and hand hygiene according to published recommendations[1,37]; (2) annual influenza immunization; (3) routine tuberculosis screening; (4) assurance of immunity or immunization against poliomyelitis, measles, mumps, hepatitis B, rubella, and pertussis (Tdap); (5) early medical evaluation for infectious illnesses; (6) routine, on-time immunization of infants; and (7) prompt initiation of prophylaxis or therapy following exposure or certain infections.

The healthcare worker who is, could be, or anticipates becoming pregnant should feel comfortable working in the healthcare workplace. In fact, with Standard Precautions and appropriate adherence to environmental cleaning and isolation precautions, the vigilant healthcare worker can be at less risk than a preschool teacher, childcare provider, or mother of children with many playmates in the home. Pathogens of potential concern to the pregnant healthcare worker include cytomegalovirus, hepatitis B virus, influenza, measles, mumps, parvovirus B19, rubella, varicella-zoster virus, and *Mycobacterium tuberculosis*. Important preventive procedures include documentation of immunity or immunization before pregnancy for rubella, mumps, measles, poliomyelitis, and hepatitis B virus; annual influenza

vaccine; routine tuberculosis screening; early medical evaluation for infectious illnesses; and prompt prophylaxis or therapy if exposed to or infected with certain pathogens. It is important to note that pregnancy is an *indication* for influenza vaccine to prevent the increased risk of serious disease and hospitalization that occurs in second- and third-trimester women who develop influenza infection. Pregnant workers should assume that all patients are potentially infected with cytomegalovirus and other "silent" pathogens and should use gloves (followed by hand hygiene) when handling body fluids, secretions, and excretions. Table 2-6 summarizes the information about infectious agents that are relevant to the pregnant woman and a comprehensive review has been published.[78]

INFECTION CONTROL IN THE AMBULATORY SETTING

Because most patient visits are in the ambulatory setting and more patients who were formerly admitted to acute care hospitals are being cared for in these settings, it becomes important to establish and maintain rigorous infection control practices in the outpatient environment. The risk of HAIs in ambulatory settings has been reviewed[79,80] and has been associated with lack of adherence to routine infection control practices and procedures, especially recommended safe injection practices.[59] Respiratory viral agents and *M. tuberculosis* are among the infectious agents transmitted in ambulatory settings. Crowded waiting rooms, toys, furniture, lack of isolation of children undiagnosed and waiting to be seen, contaminated hands, contaminated secretions, and susceptible healthcare workers are only some of the factors that result in sporadic and epidemic illness in outpatient settings. Transmission of MRSA and VRE in outpatient settings has not been reported, but the association of CA-MRSA in healthcare personnel working in an outpatient HIV clinic with environmental CA-MRSA contamination of that clinic indicates the potential for transmission in this setting.[81] Patient-to-patient transmission of *Burkholderia* species and *Pseudomonas aeruginosa* in outpatient clinics for adults and children with cystic fibrosis has been confirmed and prevented by implementing recommended infection control practices.[82,83] Outpatient infection control guidelines and policies for

TABLE 2-6. The Pregnant Healthcare Worker: Guide to Management of Occupational Exposure to Selected Infectious Agents[a]

Agent	In-Hospital Source	Potential Effect on the Fetus	Rate of Perinatal Transmission	Maternal Screening	Prevention
Bioweapons Agents, Category A					
Smallpox (vaccinia)	Respiratory secretions, contents of pustulovesicular lesions	Fetal vaccinia, premature delivery, spontaneous abortion, and perinatal death	Limited data	History of successful vaccination with "take" within previous 5 years	Pre-event vaccination contraindicated during pregnancy. Vaccine and vaccinia-immune globulin (VIG) after exposure; pre-exposure vaccine only if smallpox present in the community and exposure to patients with smallpox likely. Airborne plus Contact Precautions
Cytomegalovirus (CMV)	Urine, blood, semen, vaginal secretion, immunosuppressed, transplant, dialysis, day care	Classic disease[b] (5–10%); hearing loss (10–15%)	Primary infection (25–50%); recurrent infection (52%); symptomatic (< 5–15%)	Routine screening not recommended; antibody is incompletely protective	Efficacy of CMV immune globulin not established. No vaccine available. Standard Precautions
Hepatitis A (HAV)	Feces (most common), blood (rare)	No fetal transmission described; transmission can occur at the time of delivery if mother still in the infectious phase and can cause hepatitis in the infant	Unknown	Routine screening not recommended	Vaccine is a killed viral vaccine and can safely be used in pregnancy. Contact Precautions during acute phase
Hepatitis B (HBV)	Blood, bodily fluids, vaginal secretions, semen	Hepatitis, early-onset hepatocellular carcinoma	$HBeAg^-$ and $HBsAg^+$ (10%) $HBeAg^+$ and $HbsAg^+$ (90%)	Routine HBsAg testing advised	HBV vaccine during pregnancy if indications exist. Neonate: HBIG plus vaccine at birth. Standard Precautions
Hepatitis C (HCV)	Blood, vaginal secretions, semen	Hepatitis	5% (0–25%)	Routine screening not recommended	No vaccine or immune globulin available; postexposure treatment with antiviral agents investigational. Standard Precautions
Herpes simplex virus (HSV)	Vesicular fluid, oropharyngeal and vaginal secretions	Sepsis, encephalitis, meningitis, mucocutaneous lesions, congenital malformation (rare)	Primary genital (33–50%) Recurrent genital (1–2%)	Antibody testing minimally useful. Genital inspection for lesions if in labor	Chemoprophylaxis at 36 weeks decreases shedding. Standard precautions. Contact Precautions for patients with mucocutaneous lesions

TABLE 2-6. The Pregnant Healthcare Worker: Guide to Management of Occupational Exposure to Selected Infectious Agents[a]—*Continued*

Agent	In-Hospital Source	Potential Effect on the Fetus	Rate of Perinatal Transmission	Maternal Screening	Prevention
Human immunodeficiency virus (HIV)	Blood, bodily fluids, vaginal secretions, semen	No congenital syndrome. If fetus infected, AIDS in 2–4 years	Depends on HIV viral load and use of antiretroviral agents during pregnancy, labor and postnatally in the infant If viral load < 1000 (rate 2%) If viral load ≥10 000 (rate up to 25%)	Routine maternal screening advised. If exposed, testing every 3 months	Antiretroviral chemoprophylaxis for exposures; intrapartum postnatal chemoprophylaxis for HIV+ mothers and their infants indicated to prevent perienatal transmission. Standard Precautions
Influenza	Sneezing and coughing, respiratory tract secretions	No congenital syndrome (influenza in mother could cause hypoxia in fetus)	Rare	None	Trivalent inactivated vaccine (TIV) for all pregnant women during influenza season to decrease risk of hospitalizations for cardiopulmonary complications in mother. No risk if exposed to individuals who received live attenuated influenza vaccine (LAIV). Droplet Precautions. Add Contact Precautions for young infants
Rubeola (measles)	Respiratory secretions, coughing	Prematurity, spontaneous abortion; no congenital syndrome	Rare	Antibody test, MD-documented disease, or 2 doses of measles - containing vaccine at or > 12 months of age	Vaccine. Airborne Precautions
Parvovirus B19	Respiratory secretion, blood, immunocompromised patients	Fetal hydrops, stillbirth; no congenital syndrome	Approximately 25%; fetal death < 10%	No routine screening. B19 DNA can be detected in serum, leukocytes, respiratory secretions, urine, tissue specimens	No vaccine. Defer care of immunocompromised patients with chronic anemia when possible. Droplet Precautions
Rubella	Respiratory secretions	Congenital syndrome	90% in first trimester; 40–50% overall	Routine rubella IgG testing in pregnancy. Preconceptional screening recommended	Vacccine. No congenital rubella syndrome described for vaccine. Droplet Precautions Contact Precautions for patients with congenital rubella
Treponemia pallidum (syphilis)	Blood, lesion, fluid, amniotic fluid	Congenital syndrome	Variable 10–90%; depends upon stage of maternal disease and trimester of the infection	VDRL, RPR FTA-ABS	Postexposure prophylaxis with penicillin. Standard Precautions; wear gloves when handling infant or caring for patients with primary syphilis with mucocutaneous lesions until completion of 24 hours of treatment.
Mycobacterium tuberculosis	Sputum, skin lesions	Neonatal tuberculosis; liver most frequently infected	Rare	Skin test: PPD Chest radiograph	Varies with PPD reaction size and chest radiograph result; therapy for active disease during pregnancy. Airborne Precautions Contact Precautions if draining skin lesions

TABLE 2-6. The Pregnant Healthcare Worker: Guide to Management of Occupational Exposure to Selected Infectious Agents[a]—*Continued*

Agent	In-Hospital Source	Potential Effect on the Fetus	Rate of Perinatal Transmission	Maternal Screening	Prevention
Varicella-zoster virus	Respiratory secretion, vesicle fluid	Malformations, skin, limb, central nervous system, eye. Disseminated or localized disease	Congenital syndrome (2%)	Varicella IgG serology; history 90% correct	Vaccine[c]; VariZIG within 96 hours of exposure if susceptible. Airborne plus Contact Precautions

AIDS, acquired immunodeficiency syndrome; FTA-ABS, fluorescent treponemal antigen-antibody test; HBeAg, hepatitis B e antigen; HBIG, hepatitis B immune globulin; HBsAg, hepatitis B surface antigen; IgG, immunoglobulin G; PPD, purified protein derivative; RPR, rapid plasma reagin test; VDRL, Venereal Disease Research Laboratory test.
[a]Employment, prepregnancy screening/vaccination is primary prevention for certain agents. Annual immunization for influenza is primary prevention.
[b]Congenital syndrome: varying combinations of jaundice, hepatosplenomegaly, microcephaly, thrombocytopenia, anemia, retinopathy, skin, and bone lesions.
[c]Live virus vaccine given before or after pregnancy.
[d]See Chapter 205, Varicella-zoster Virus.

pediatricians' offices have been published and are being updated.[84] Prevention strategies include definition of policies, education, and strict adherence to guidelines.

CHAPTER 3

Infections Associated with Group Childcare

Andi L. Shane and Larry K. Pickering

On average 11.6 million (63%) children 5 years of age or younger and 53% of children 5 to 14 years of age were in some form of group childcare on a regular basis in the winter of 2002 (National Child Care Information Center Child Care Bureau. http://nccic.org).[1] Aggregation of young children potentiates transmission of organisms that can produce disease in other children, adult care providers, parents, and community contacts. Group childcare settings may potentiate increased frequency of certain diseases, the occurrence of outbreaks of illness (Table 3-1), greater severity of illness, an increase in antibiotic use to permit earlier return to care, which results in the potential for emergence of resistant organisms, and an increased economic burden to individuals and society.[2–4] The extent of illness resulting from interaction of children and adults in group childcare depends on the age and immune status of children and adults involved, season, environmental characteristics of the childcare facility, and inoculum size and virulence potential of microbes. Children newly entered into a childcare program are at especially high risk of enteric and respiratory tract infections,[5–10] but as a consequence of these infections may be protected against respiratory tract viral infections and reactive airway diseases during subsequent years.[11] Children who are exposed to infectious pathogens of siblings and contacts in group care and often manifest clinical symptoms of frequent infections early in life may be protected against developing atopic disease in later childhood.[12]

TYPES OF GROUP CHILDCARE

The United States Census Bureau classifies regular preschool childcare arrangements by provider (relative of a child in care versus nonrelative) and location of care. Of the 63% of preschool children in a regular childcare arrangement in the winter of 2002, 40% regularly received care by a relative, 37% by nonrelatives, and 11% by both relatives and nonrelatives. The remaining 12% were not classified as receiving a form of childcare regularly. Nonrelative care can be further divided into provision of care in an organized care facility or childcare center (23%), by a nonrelative in the child's home (4%) or in the provider's home (10%).[1] Types of facilities can also be classified by size of enrollment, age of enrollees, and environmental characteristics of the facility. Grouping of children by age varies by setting but in organized care facilities usually children are separated as infants (6 weeks to 12 months), toddlers (13 to 35 months), preschool (36 months to 59 months), and school-aged children (5 to 12 years). The classification of group childcare settings has relevance to infectious disease epidemiology with regard to regulation and monitoring. Most nonrelative care provided in an organized care facility is subject to state licensing and regulation, whereas relative care in a child or provider's home may not be subject to state regulations and monitoring.

EPIDEMIOLOGY AND ETIOLOGY OF INFECTIONS

Although almost any infectious disease has the propensity to propagate in the childcare setting, diseases shown in Table 3-1 are commonly associated with outbreaks. Organisms that infect enrollees and providers may do so with a predilection for nonimmune persons of specific ages.

Enteric Infections

Outbreaks of diarrhea occur at a rate of approximately 3 per year per childcare center and are most frequently associated with organisms that result in infection after ingestion of a low inoculum. These organisms generally are transmitted from person to person[13,14] and include rotavirus, sapovirus, norovirus, astrovirus, enteric adenovirus, *Giardia lamblia, Cryptosporidium, Aeromonas, Shigella, Escherichia coli* O157:H7, *E. coli* O114, enteropathogenic *E. coli,* and *Clostridium difficile.*[14–26] These fecal coliforms[27,28] and enteric viruses contaminate the environment;[29] contamination rates are highest during outbreaks of diarrhea. The attack rates and frequency of asymptomatic excretion of these organisms in children in childcare are shown in Table 3-2. Reported attack rates depend on several factors, including methods used for organism detection.[22,23]

Enteric viruses are the predominant etiology of diarrheal syndromes among children in group care, with impact by season. In a prospective study of children enrolled in childcare in Denmark during 6 months of winter, rotavirus was the predominant organism identified in 40% of cases with a confirmed etiology, sapoviruses in 18%, and astroviruses in 7%.[30] Organisms generally associated with foodborne outbreaks, such as *Salmonella* and *Campylobacter jejuni,* are infrequently associated with diarrhea in the childcare setting. How-