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.

2 Pediatric Infection Prevention and Control

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During the past decade, there has been a surge in interest to reduce healthcare-associated infection (HAI) as an integral part of patient safety. Involvement of new stakeholders for improving patient safety and outcomes related to HAI (e.g., Child Health Corporation of America (CHCA), National Association of Children's Hospitals and Related Institutions (NACHRI), individual states' mandatory HAI public reporting programs, the Centers for Medicare and Medicaid Services (CMS), the Joint Commission) has broadened the arena for HAI prevention efforts. Of note, 5 of the 15 Joint Commission National Patient Safety Goals for 2011 target prevention of HAIs (www.jointcommission.org/hap_2011_npsgs/). Additionally, the National Healthcare Safety Network (NHSN) (previously National Nosocomial Infection Surveillance (NNIS) System) now is reporting more pediatric-specific rates of device-associated infections.[1] An understanding of the complexities of prevention and control of HAIs in children is critical to many different leaders of healthcare facilities caring for children.

Infection Prevention and Control (IPC) for the pediatric population is a unique science that requires understanding 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), now is used since much care of high-risk patients, including those with medical devices (e.g., central venous catheters (CVCs), ventilators, ventricular shunts, peritoneal dialysis catheters), has shifted to ambulatory settings, rehabilitation or chronic care facilities, and to the home; thus, the geographic location of acquisition of the infection often 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 after hospital admission or ≤48 hours after hospital discharge. A *surgical site infection* is classified as an HAI (www.cdc.gov/nhsn) if it develops within ≤30 days of the procedure or within one year after a permanently placed nonhuman-derived implant. 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 ≥48 hours after her admission. The principles of transmission of infectious agents in healthcare settings and recommendations for prevention are reviewed in the Guideline for Isolation Precautions: Preventing Transmission of Infectious Agents in Healthcare Settings, 2007.[2]

Historically, HAI rates between 2% and 13% of admissions or discharges from pediatric intensive care units have been reported.[3,4] Rates of all HAIs as high as 7% to 25% are reported in neonatal intensive care units (NICUs) and are inversely proportional to birthweight.[1,5,6] NICU outbreaks are unique and often involve large numbers of patients due to the traditional design of housing large numbers of high-risk infants in close proximity.[7] However, infection rates have decreased substantially in recent years with consistent adherence to bundled practices for insertion and maintenance of CVCs,[8,9] care of patients on ventilators,[10] and high-risk surgical procedures.[11] 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.[4,6,12,13] 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) also are at increased risk for invasive aspergillosis and other environmental fungal infections, especially during periods of facility renovation, construction, and water leaks.[14,15]

RISK FACTORS FOR HAIs IN CHILDREN

Unique aspects of HAIs in children have been reviewed in detail[4,16,17] and are summarized below. Specific risks and pathogens are addressed in multiple other chapters in this textbook.

Host or Intrinsic Factors

Intensive care units, oncology services, and gastroenterology services caring for patients with short gut syndrome who are dependent on total parenteral nutrition (TPN and lipids) have the highest rates of bacterial and fungal infection associated with CVCs. HAIs can result in the serious morbidity and mortality such as occur in adults and in lifetime physical, neurologic, and developmental disabilities. Host, or intrinsic, factors that make children particularly vulnerable to infection are immaturity of the immune system, congenital abnormalities, and congenital or acquired immunodeficiencies. 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 compromised in neonates and the degree of deficiency is proportional inversely to the gestational age (see Chapter 9, Immunologic Development and Susceptibility to Infection). Additionally, the underdeveloped skin of the very-low-birthweight (VLBW, <1000 g) infant provides another mode of entry for pathogens. Populations of immunosuppressed children have expanded with the advent of more intense immunosuppressive therapeutic regimens used for oncologic conditions, HSCTs, solid-organ transplantation, and rheumatologic conditions and inflammatory bowel disease for which immunosuppressive agents and tumor necrosis factor-α inhibitors (infliximab (Remicade)) and other immune modulators are used.

Children with congenital anomalies have a high risk of HAI because their unusual anatomy may predispose to contamination of normally sterile sites with body fluids. Also, 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 (personal communication, Leigh Grossman).

Fortunately, the population of children with perinatally acquired human immunodeficiency virus (HIV) infection and acquired immunodeficiency syndrome (AIDS) has decreased dramatically since 1994, but new cases of sexually transmitted HIV infection continue to be diagnosed in teens who are cared for in children's hospitals. 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

The source of many HAIs is the endogenous flora of the patient.[2,18,19] An asymptomatic colonizing pathogen can invade a patient's bloodstream or be transmitted on the hands of healthcare personnel (HCP) to other patients. Other important sources of HAIs in infants and children include the mother; invasive monitoring and supportive equipment, blood products, total parenteral nutrition fluids, lipids; infant formula and human milk; HCP, 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 colonization with multidrug-resistant organisms, pose substantial threats to the neonate. During perinatal care, procedures such as fetal monitoring using 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., *Cronobacter* (formerly *Enterobacter*) *sakazakii*).[20] 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 (CMV) infection, and HIV infection from human milk warrant further caution for handling.

Devices. Rates of central line associated bloodstream infections (CLABSIs) in the pediatric intensive care units (PICUs) and high-risk nurseries (HRNs) in the NNIS system, now the NHSN, from January 2002 to June 2004 were among the highest for all reporting ICUs, with a mean of 6.6 CLABSIs per 1000 catheter-days in the PICUs; this rate was surpassed only in trauma and burn units, with a mean of 7.4 and 7.0 CLABSIs per 1000 catheter-days, respectively[21] (Table 2-1). Rates of umbilical catheter- and CVC-associated BSIs varied by birthweight (BW) from 3.5 per 1000 catheter-days in those >2500 g BW, to 9.1 per 1000 catheter-days in those <1000 g BW (Table 2-2). Medical device-related infections (e.g., CLABSIs, 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

TABLE 2-1. Comparison of Laboratory-Confirmed Central Line-Associated Bloodstream Infection (CLABSI) Rates in ICUs from National Nosocomial Infection Surveillance (NNIS) 2002–2004[5] with National Healthcare Safety Network (NHSN) 2009[1]

	No. ICUs Reporting		Rate/1000 Catheter-Days[a]: Pooled Mean (Median, Range 10–90%) Mean Device Utilization Ratio[b]	
ICU Type	**2002–2004**	**2009**	**2002–2004**	**2009**
Trauma	22	74	7.4 (5.2, 1.9–11.9) 0.61	2.6 (2.0, 0–6.7) 0.59
Burn	14	33	7.0 (NA[c]) 0.56	5.3 (3.8, 0.2–12.4) 0.50
Pediatric	54	–	6.6 (5.2, 0.9–11.2) 0.46	–[d] –
Cardiothoracic	–	21	– –	2.5 (2.7, 0.4–4.0) 0.70
Medical	–	13	– –	2.6 (NA) 0.40
Medical/Surgical	–	135	– –	2.2 (1.7, 0–4.5) 0.50
Medical	94	–	5.0 (3.9, 0.5–8.8) 0.52	– –
Major teaching facility	–	134	– –	2.2 (1.7, 0.2–4.7) 0.62
All other facilities	–	183	– –	1.6 (0–4.1) 0.43
Respiratory	6	9	4.8 (NA) 0.47	2.1 (NA) 0.58
Surgical	99	223	4.6 (3.4, 0–8.7) 0.61	1.8 (1.2, 0–4.2) 0.60
Neurosurgical	30	79	4.6 (3.1, 0–10.6) 0.48	1.5 (1.2, 0–3.6) 0.46
Coronary (medical cardiac)	60	252	3.5 (3.2, 1.0–9.0) 0.38	1.7 (1.1, 0–4.2) 0.40
Medical-surgical				
Major teaching facility	100	192	4.0 (3.4, 1.7–7.6) 0.57	1.7 (1.3, 0–3.8) 0.58
All other facilities	109	–	3.2 (3.1, 0.8–6.1) 0.50	– –
≤15 beds	–	771	– –	1.4 (0, 0–3.8) 0.39
>15 beds	–	323	– –	1.3 (0.9, 0–3.0) 0.48
Surgical cardiothoracic	48	219	2.7 (1.8, 0–4.9) 0.79	1.2 (0.8, 0–2.5) 0.71

[a]*Number of CLABSIs/number of central line days × 1000.*

[b]*Number of central line days/number of patient days.*

[c]*Not available.*

[d]*Not reported.*

Campaign (www.ihi.org/IHI/Programs/Campaign), the NACHRI collaboratives (www.childrenshospitals.net),[9] and single center studies. This effect is evident in the NHSN data summary for 2009.[1] Although the highest rates of CLABSI (5.3 per 1000 catheter-days) in ICUs occurred in burn ICUs, and in smallest infants in NICUs (3.4 per 1000 catheter-days at ≤750 g) rates fell in all units/groups measured (Tables 2-1 and 2-2). In the NHSN reports for 2006–2008[22] and for 2009,[1] data are presented for CLABSI in pediatric hematology-oncology units: permanent-line CLABSI rates per 1000 catheter-days were 2.3 and 3.0, respectively, and temporary-line CLABSI rates were 4.6 and 4.8, respectively. 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, prolonged, and invasive support. However, these infections are not included in the NHSN device-associated module and no benchmarking data are available.

Many standard infection prevention and 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 BSI. 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

TABLE 2-2. Comparison of Laboratory-Confirmed Central Line-Associated Bloodstream Infection (CLABSI) Rates in Level III Neonatal Intensive Care Units (NICUs) from the National Nosocomial Infection Surveillance (NNIS) 1992–2004[5] with National Healthcare Safety Network (NHSN) 2009[1,a]

	No. NICUs Reporting		Rate/1000 Catheter-Days[b]: Pooled Mean (Median, Range 10–90%) Mean Device Utilization Ratio[c]	
Birthweight Group Category	**1992–2004**	**2009**	**1992–2004**	**2009**
≤750 grams	–[d]	150	–	3.4 (2.7, 0–8.6) 0.37
751–1000 grams	–	159	–	2.7 (1.4, 0–8.8) 0.31
≤1000 grams	104	–	9.1 (8.5, 1.6–16.1) 0.42	– –
1001–1500 grams	98	156	5.4 (4.0, 0–12.2) 0.30	1.9 (0, 0–5.8) 0.23
1501–2500 grams	97	134	4.1 (3.2, 0–8.9) 0.21	1.5 (0,0–4.7) 0.16
>2500 grams	94	106	3.5 (1.9, 0–7.4) 0.29	1.3 (0,0–3.5) 0.19

[a]*Inborn NICUs with very-low-birthweight infants are combined with outborn NICUs with larger-birthweight infants usually requiring surgical procedures.*

[b]*Number of CLABSIs/number of central line days × 1000.*

[c]*Number of central line/number of patient days.*

[d]*Not reported.*

prophylaxis against deep-vein thrombosis and peptic ulcers have not been defined for children requiring mechanical ventilator support; some evidence suggests that prophylaxis against peptic ulcers is associated with an increased risk of necrotizing enterocolitis and candidemia in LBW (<1500 g) infants.[23]

Practices. Several practices must be evaluated with respect to the associated risk of infection. A significant association between reduced levels of nurse staffing and appropriately trained nurses has been demonstrated to increase risk in many studies in both children and adults.[24] There are theoretical concerns that infection risk also will 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. Overall, the infection risk is reduced with kangaroo care,[25] but transmission of tuberculosis[26] and RSV[27] has occurred in kangaroo mother care units in South Africa. Neither the benefits nor the safety of co-bedding multiple-birth infants in the hospital setting have been demonstrated in studies reviewed by the American Academy of Pediatrics in 2007. With increasing numbers of procedures being performed by pediatric interventional radiologists, an understanding of appropriate aseptic technique and recommended regimens for antimicrobial prophylaxis is important.[28]

Antimicrobial selective pressure. Exposure to vancomycin and to third-generation cephalosporins contributes substantially to the increase in infections caused by vancomycin-resistant enterococcus (VRE)[29] and multidrug-resistant gram-negative bacilli, including extended-spectrum β-lactamase (ESBL)-producing organisms,[30] respectively. Exposure to third-generation cephalosporins also is a risk factor for the development of invasive candidiasis in LBW infants in the NICU.[31] Trends in resistance of certain organisms to certain antibiotics as tracked by NHSN show increasing resistance of *Pseudomonas aeruginosa, Klebsiella pneumoniae,* and *Escherichia coli*.

Transmission

Modes

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 HCP, 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 HCP's hands, has been demonstrated in studies using DNA fingerprinting in the NICU and in a pediatric oncology unit.[32] 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 transmitted primarily by the droplet route whereas other respiratory viruses (e.g., RSV, parainfluenza) are transmitted primarily 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.[33]

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 and Milton proposed a new classification for aerosol transmission when evaluating routes of SARS transmission:[34] (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). Concern about airborne transmission of influenza arose again during the 2009 influenza A (H1N1) pandemic. However, the conclusion from all published experiences during the 2009

pandemic is that droplet transmission is the usual route of transmission and that surgical masks were non-inferior to N95 respirators in preventing laboratory-confirmed influenza, including 2009 H1N1, among HCP.[35,36] 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 an infant or young 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 for control of tuberculosis in pediatric healthcare facilities.[37]

Transmission of microbes among children and between children and HCP 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 HCP. However, with the increasing evidence that single-patient rooms provide improved environments for patients, which include 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.[38] 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 *P. aeruginosa* in a pediatric oncology unit.[39]

Before effective preventive measures[40] were established, 17% of preschool children hospitalized for >1 week had a nosocomial viral respiratory tract illness.[41] Infection of pediatric HCP also was 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 onto mucous membranes of HCP. RSV infections were more likely to develop in healthy volunteers who held or cuddled infants with RSV infection (cuddlers, 70%) or in those who handled items that the infants had touched, but did not touch the infant (touchers, 41%); infection did not develop in those who sat in the patients' rooms (sitters) but had no direct contact with the patient, items, or surfaces.[42] HCP with mild symptoms of infection also can unknowingly become intermediary hosts and transmit organisms to susceptible children.

Healthcare Personnel

Transmission of infectious agents is facilitated by overcrowding, understaffing, and too few appropriately trained nurses. Several studies have established the association of understaffing and overcrowding with increased rates of HAIs in NICUs, PICUs, and general pediatrics units.[24,43] The 2007 Guideline for Isolation Precautions recommends that healthcare facilities consider staffing levels and composition as important components of an effective infection control program.[2] HCP rarely are the *source* of outbreaks of HAIs caused by bacteria and fungi, but when they are, there usually are factors present that increase their risk of transmission (e.g., sinusitis, draining otitis externa, respiratory tract infections, dermatitis, onychomycosis, wearing of artificial nails).[44] Individuals with direct patient contact who were wearing artificial nails have been implicated in outbreaks of *P. aeruginosa* and ESBL-producing *K. pneumoniae* in NICUs;[45,46] therefore, the use of artificial nails or extenders is prohibited in individuals who have direct contact with high-risk patients.[2,47] Several published studies have shown that infected pediatric HCP, including resident physicians, transmitted *Bordetella pertussis* to other patients.[48] HCP also have been implicated as the source of outbreaks of rotavirus[49] and influenza.[50]

Environment

The role of environmental surfaces in transmission of a variety of pathogens during outbreaks (e.g., *Clostridium difficile,* norovirus, methicillin-resistant *Staphylococcus aureus* (MRSA), VRE, MDR/gram-negative bacilli (GNB)) has been defined in recent years.[51] Therefore, heightened attention is directed appropriately toward cleaning and monitoring the effectiveness of cleaning by training, observation, and feedback[52] and by using various markers (e.g., an invisible fluorescein powder[53] and adenosine triphosphate (ATP) bioluminescence[54]).

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 Healthcare Infection Control Practice Advisory Committee of the Centers for Disease Control and Prevention (HICPAC/CDC) Guideline for Isolation Precautions in Healthcare Settings:[2]

1. A propensity for transmission within healthcare facilities based on published reports and the occurrence of temporal or geographic clusters of infection in >2 patients (e.g., VRE, MRSA, and methicillin-susceptible *S. aureus* (MSSA), *C. difficile,* norovirus, RSV, influenza, rotavirus, *Enterobacter* spp., *Serratia* spp., group A streptococcus). A single case of HA 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 GNB, *Burkholderia cepacia, Ralstonia* spp., *Stenotrophomonas maltophilia,* and *Acinetobacter* species. Many of the intrinsically resistant GNB also suggest possible contamination of water or medication.
3. Association with serious clinical disease, increased morbidity and mortality (e.g., MRSA and MSSA, group A streptococcus).
4. A newly discovered or re-emerging pathogen (e.g., vancomycin-insensitive or -resistant *S. aureus* (VISA, VRSA), *C. difficile*).

Pathogens associated with HAIs in children differ from those in adults. The importance of HA respiratory viral infections in pediatrics was first recognized in 1984.[3] The viruses most frequently associated with transmission in a pediatric healthcare facility are RSV, rotavirus, and influenza. With the dramatic reduction in rotavirus infections following introduction of the vaccine, rotavirus now is a rare cause of HAI. However, other respiratory viruses (e.g., parainfluenza, adenovirus, human metapnuemovirus) have been implicated in outbreaks in high-risk units. As more respiratory viruses are identified by using highly sensitive molecular methods, epidemiologic studies will be required to define further the risk of transmission in healthcare facilities.[55] HA outbreaks of varicella and measles now are rare events due to consistent uptake during the past decade of vaccines in children and HCP. Clinical manifestations of certain pathogens (e.g., RSV and *Bordetella pertussis*) can be life-threatening in infants and young children, especially those with underlying conditions. Excessive burden of disease and mortality also is associated with influenza in infants and young children.[56,57] Children <18 years of age accounted for approximately 35% (20 million) of cases, 32% (87,000) of hospitalizations, and 10% (1,280) of deaths during the 2009 influenza A(H1N1) pandemic.[58]

The emergence of community-associated (CA)-MRSA isolates characterized by the unique Scc *mec* type IV element was first observed among infants and children. As rates of colonization with CA-MRSA at the time of hospital admission increased, so did transmission of community strains, most often USA 300, within

TABLE 2-3. Trends in Resistance of Selected Pathogens and Drugs in the National Nosocomial Infection Surveillance System (NNIS) 1998–2003 and the National Healthcare Safety Network (NHSN) 2006–2007

Pathogen Antimicrobial Agent	1998–2002[5] All ICU Isolates	2003[5] All Isolates	2006–2007[a] All CLABSI Isolates
Staphylococcus aureus			
Oxacillin R	51.3%	59.5%	56.8%
Enterococcus spp.			
Vancomycin R	12.8%	28.5%	36.4% 78.9% for *E. faecium*
Klebsiella pneumoniae			
3rd-geneneration cephalosporin R	6.1%	20.6%	27.1%
Carbapenem R	–[b]	–	10.8%
E. coli			
3rd-geneneration cephalosporin R	1.2%	5.8%	8.1%
Fluoroquinolone R	5.8%	–	30.8%
Enterobacter spp.			
3rd-geneneration cephalosporin R	26.3%	31.1%	–
Pseudomonas aeruginosa			
Cefipime R	–	–	12.6%
Carbapenem R	19.6%	21.1%	23.0%
Fluoroquinolone R	36.3%	29.5%	30.5%
Acinetobacter baumannii			
Carbapenem R	–	–	29.2%

R, resistant.

[a]*Hidron AI, Edwards JR, Patel J, et al. Infect Control Hosp Epidemiol 2008;29:996–1011.*

[b]*Not reported.*

the hospital and especially within the NICU,[59] making prevention especially challenging. Other multidrug-resistant organisms, e.g., VRE, ESBLs, and carbapenemase-producing gram-negative bacilli (carbapenem-resistant Enterobacteriaceae, *K. pneumoniae* carbapenemase), have emerged as the most challenging HA pathogens in both pediatric and adult settings, and otherwise healthy children in the community can be asymptomatically colonized with these multidrug-resistant organisms.[60–62] GNB, including ESBL and other multidrug-resistant isolates, are more frequent than MRSA and VRE in many PICUs and NICUs. Patients who are transferred from chronic care facilities can be colonized with MDR-GNB at the time of admission to the PICU.[18] Trends in targeted MDR organisms (MDROs) as tracked in the NNIS/NHSN ICUs are summarized in Table 2-3. Continued increases in MRSA, VRE, and certain resistant GNB are a "call to action" for all healthcare facilities. The CDC campaign to prevent antimicrobial resistance by judicious use of antimicrobial agents (GET SMART, www.cdc.gov/getsmart/) and the Guideline for Management of MDROs in Healthcare Settings, 2006[63] provide more epidemiologic information. Of note, in 2004, rates of HA-MRSA and VRE plateaued, but the incidence of *K. pneumoniae* resistant to third-generation cephalosporins in ICUs reporting to NHSN increased (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 effective antimicrobial therapy.[64] While there is lower prevalence of specific MDROs in pediatric institutions, the same principles of target identification and interventions to control MDROs apply in all settings.

The incidence of *Candida* infections increased in incidence in most PICUs and NICUs during the 1990s, but decreased 2000–2004. 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. GNB and *Candida* sp. are especially important pathogens for HAIs in patients with short gut who are receiving TPN and can cause repeated episodes of sepsis.[23,65] There is now evidence that fluconazole prophylaxis in a subset of very high-risk low-birthweight infants is safe and effective in preventing invasive candidiasis;[65] however, the staff of each NICU first must optimize infection practices and then must assess the remaining local risk of *Candida* infections. 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.[66] 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.[15]

PREVENTION

Prevention remains the mainstay of infection control and requires special considerations in children. The goals of infection prevention and control (IPC) are to prevent the transmission of infectious agents among individual patients or groups of patients, visitors, and HCP who care for them. If prevention cannot always be achieved, the strategy of early diagnosis, treatment, and containment is critical. This chapter focuses on 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* of the American Academy of Pediatrics (AAP) and in the Guideline for Isolation Precautions: Preventing Transmission of Infectious Agents in Healthcare Settings, 2007.[2]

A series of IPC 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

BOX 2-1. Resources for Infection Prevention and Control Recommendations

CENTERS FOR DISEASE CONTROL AND PREVENTION/ HEALTHCARE INFECTION CONTROL PRACTICES COMMITTEE (HICPAC)

www.cdc.gov/hicpac/pubs.html

General

- Guideline for Disinfection and Sterilization in Health-Care Facilities, 2008
- Guideline for Isolation Precautions: Preventing Transmission of Infectious Agents in Healthcare Settings, 2007
- Management of Multi-Drug Resistant Organisms (MDROs) in Healthcare Settings, 2006
- Guidelines for Environmental Infection Control in Health-Care Facilities, 2003
- Guidelines for Hand Hygiene in Healthcare Settings, 2002

Device-/Procedure-Related

- Guidelines for the Prevention of Intravascular Catheter-Related Infections, 2011
- Guideline for Prevention of Catheter-Associated Urinary Tract Infections, 2009
- Guideline for Preventing Healthcare-Associated Pneumonia, 2003
- Guideline for the Prevention of Surgical Site Infection, 1999

Other

- Guideline for the Prevention and Control of Norovirus Gastroenteritis Outbreaks in Healthcare Settings, 2011

AMERICAN ACADEMY OF PEDIATRICS

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HAIs, especially those associated with the use of medical devices and surgical procedures (Box 2-1). Bundled practices are groups of 3 to 5 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 CLABSIs,[9] SSIs,[11] VAP[12] established for adults have been adapted to pediatrics (www.ihi.org/IHI/Programs/Campaign). Detailed information on advances in prevention strategies for pediatrics have been reviewed.[16,17]

Administrative Factors

The importance of certain administrative measures for a successful IPC program has been demonstrated. There is evidence to designate IPC as one component of the institutional culture of safety and to obtain support from senior leadership of healthcare organizations to provide necessary fiscal and human resources for a proactive, successful IPC program. Critical elements requiring administrative support include: (1) access to appropriately trained healthcare epidemiology and IPC personnel; (2) access to clinical microbiology laboratory services needed to support infection control outbreak investigations, including ability to perform molecular testing; (3) access to data-mining programs and information technology specialists; (4) multidisciplinary programs to assure judicious use of antimicrobial agents and control of resistance; (5) delivery of effective educational information to HCP, patients, families, and visitors; and (6) provision of adequate numbers of well-trained infection preventionists and bedside nursing staff.[2,24]

The IPC Team

An effective IPC program should improve safety of patients and HCP, and decrease short- and long-term morbidity, mortality, and healthcare costs.[67] The IPC Committee establishes policies and procedures to prevent or reduce the incidence and costs associated with HAIs. This committee should be one of the strongest and most accessible committees in the hospital; committee composition should be considered carefully and limited to active, authoritative participants who have well-defined committee responsibilities and who represent major groups within the hospital. The chairperson should be a good communicator with expertise in IPC issues, healthcare epidemiology, and clinical pediatric infectious diseases. An important function of the IPC committee is the regular review of IPC policies and the development of new policies as needed. Annual review of all policies is required by the Joint Commission and can be accomplished optimally by careful review of a few policies each month. With the advent of unannounced inspections, a constant state of readiness is required.

The hospital epidemiologist or medical director of the IPC division usually is a physician with training in pediatric infectious diseases and dedicated expertise in healthcare epidemiology. In multidisciplinary medical centers, pediatric infectious disease experts should be consulted for management of pediatric IPC

and report to the broader IPC leadership. Infection preventionists (IPs) are specialized professionals with advanced training, and preferably certification, in IPC. Although the majority of IPs are registered nurses, others, including microbiologists, medical technologists, pharmacists, and epidemiologists, are successful in this position. Pediatric patients should have IP services provided by someone with expertise and training in the care of children. In a large, general hospital, at least one IP should be dedicated to IPC services for children. The responsibilities of IPs have expanded greatly in the last decade and include the following: (1) surveillance and IPC in facilities affiliated with 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 occupational health services related to IPC, (e.g., assessment of risk and administration of recommended prophylaxis 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 preexposure smallpox vaccine in 2003 and pandemic influenza A(H1N1) vaccine in 2009); (3) preparedness planning for annual influenza outbreaks, pandemic influenza, SARS, bioweapons attacks; (4) adherence monitoring for selected IPC 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) participation in antimicrobial stewardship programs, focusing on prevention of transmission of MDROs; (7) evaluation of new products that could be associated with increased infection risk (e.g., intravenous infusion materials) and for introduction and assessment of performance after implementation; (8) mandatory public reporting of HAI rates in states according to enacted legislation; (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. IPC programs must be adequately staffed to perform all of these activities. Thus, the ratio of 1 IP 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 is no longer sufficient, as the complexity of patient populations and responsibilities have increased. Many experts recommend that a ratio of 1 IP 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 IPC must be available for all sites where healthcare is delivered.[2]

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 IPs, 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 IPC strategies and policies and serves as a liaison with the medical community and administration.[68–71] The CDC has established a set of standard definitions of HAIs that have been validated and accepted widely with updates posted on the CDC NHSN website or published in HICPAC/CDC guidelines. Standardization of surveillance methodology has become especially important with the advent of state legislation for mandatory reporting of HAI infection rates to the public.[72]

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 reliability of data, and that some combination of clinical chart review and database retrieval is important.[68–71] 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.[72] Use of software designed specifically for IPC data entry and analysis facilitates real-time tracking of trends and timely intervention when clusters are identified. The IPC team should participate in the development and update of electronic medical record systems for a healthcare organization, to be sure that the surveillance needs will be met.

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

In the past decade, there has been much controversy over the importance of obtaining active surveillance cultures from all patients admitted to an acute care hospital, especially to an ICU, to detect asymptomatic colonization with MRSA. With the implementation of bundled practices to prevent device-related and surgical site infections, emergence of new MDROs, and evidence from well-designed studies, it is clear that active surveillance cultures should be obtained in a targeted fashion in units where there is an indication of ongoing transmission of MRSA or other MDROs, according to 2006 guidelines.[63]

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 also can assist with surveillance cultures and facilitation of molecular typing of isolates during outbreak investigations. Rapid diagnostic testing of clinical specimens for identification of respiratory and gastrointestinal tract viruses and *B. pertussis* is especially important for pediatric facilities. The IPC division and the microbiology laboratory must communicate daily, because even *requests* for cultures from physicians (e.g., *M. tuberculosis, Neisseria meningitidis, C. 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.[73]

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 IP to potentially infected patients (e.g., tuberculosis). The need to restrict use of antimicrobial agents is a collaborative decision based on review of all data. Restriction of new, potent broad-spectrum 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).[30,74–76]

Control of unusual infections or outbreaks in the community generally is 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 helpful particularly in alerting hospitals of community outbreaks so that outpatient and inpatient diagnosis, treatment, necessary isolation, and other preventive measures are implemented promptly to avoid further spread. Conversely, designated individuals in the hospital must 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.[2]

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, 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 (HBV and HCV), rapidly fatal infections such as the viral hemorrhagic fevers). The Occupational Safety and Health Administration (OSHA) published specific requirements[77] in 1991 for universal precautions (now, Standard Precautions) for HCP 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 most recent Guideline for Isolation Precautions published in 2007[2] affirms *Standard Precautions*, a combination of universal precautions and body substance isolation, as the foundation of transmission prevention measures, and *Transmission-based Precautions* for certain suspected pathogens. HCP must recognize the importance of body fluids, excretions, and secretions in the transmission of infectious pathogens and take appropriate protective precautions by using personal protective equipment (PPE) (e.g., masks, gowns, gloves, face shields, or goggles) and safety devices even if an infection is not suspected or known. In addition, these updated guidelines provide recommendations for all settings in which healthcare is delivered (acute care hospitals, ambulatory surgical and medical centers, long-term care facilities, and home health agencies). Evidence and recommendations are provided for the prevention of transmission of MDROs such as MRSA, VRE, VISA, VRSA, and GNB.[63] The components of a protective environment for prevention of environmental fungal infections in HSCT recipients are summarized. Finally, evidence-based, rated recommendations for administrative measures that are necessary for effective prevention of infection in healthcare settings are provided.

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; or (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 Precautions are summarized in Table 2-4. In the updated isolation guideline, safe injection practices are included as a component of Standard Precautions, because recent outbreaks of HBV and HCV in ambulatory care settings as a result of failure to follow recommended practices indicate a need to reiterate the established effective practices.[78] There were two additions to Standard Precautions in 2007: (1) *Respiratory hygiene/cough etiquette* for source containment by people with signs and symptoms of respiratory tract infection; and (2) *Use of a mask* by the individual inserting an epidural anesthesia needle or performing a myelogram when prolonged exposure of the puncture site is likely. Both components have a strong evidence base.

Implementation of Standard Precautions requires critical thinking from all HCP and the availability of PPE in proximity to all patient care areas. HCP 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 also should know what steps to take if high-risk exposure occurs. 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 onto nonintact skin (e.g., cuts, hangnails, dermatitis, abrasions, chapped skin) or onto 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 area should be washed immediately with soap and water for at least 10 seconds and rinsed 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 irrigated immediately 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 washed immediately with soap and water for at least 10 seconds and rinsed with 70% isopropyl alcohol. Any exposure incident should be reported immediately 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 HCP should know where to find the exposure control plan that is specific to each 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 prophylactic regimens is improved with shorter intervals after exposure, such as for hepatitis B immune globulin administration after exposure to HBV or for antiretroviral therapy after percutaneous exposure to HIV. Chemoprophylaxis following exposure to

TABLE 2-4. Recommendations for Application of Standard Precautions for the Care of all Patients in all Healthcare Settings[2]

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, >1–2 meters (3–6 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).*

HIV-infected material is most effective if initiated within 4 hours of exposure.[79] Updates are posted on the CDC website. 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. Transmission-based Precautions are applied at the time of initial contact, based on the clinical presentation and the most likely pathogens – so-called *Empiric* or *Syndromic Precautions.* This approach is useful especially 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 preferably of staff, according to clinical diagnosis is recommended.

Table 2-5 lists the three categories of isolation based on routes of transmission and the necessary components. Table 2-6 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 (e.g., pandemic influenza), droplet precautions (with use of surgical mask) is appropriate; however, during an aerosol-producing procedure, N95 or higher respirators are indicated (www.pandemicflu.gov/plan/healthcare/maskguidancehc.html).

ENVIRONMENTAL MEASURES

Contaminated environmental surfaces and noncritical medical items have been implicated in transmission of several HAIs, including VRE, *C. difficile, Acinetobacter* sp., MRSA, and RSV.[1,51,52] Pathogens on surfaces are transferred to the hands of HCP and then transferred to patients or items. Most often, the failure to follow recommended procedures for cleaning and disinfection contributes more than the specific pathogen to the environmental reservoir during outbreaks. Education of environmental services personnel combined with observations of cleaning procedures and feedback has been associated with a persistent decrease in the acquisition of VRE in a medical ICU;[52] monitoring for adherence to recommended environmental cleaning practices is an important determinant of success. Certain infectious agents (e.g., rotavirus, noroviruses, *C. difficile*) can 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.[80] Pediatric facilities should use disinfectants active against rotavirus.

TABLE 2-5. Transmission-Based Precautions[2,a]

Component	Contact	Droplet	Airborne
Hand hygiene	Per Standard Precautions. 5 moments of hand hygiene,[47] and ***upon entry*** into room. Soap and water preferred over alcohol handrub for *Clostridium difficile, Bacillus anthracis* spores	Per Standard Precautions. 5 moments of hand hygiene, and ***upon entry*** into room	Per Standard Precautions. 5 moments of hand hygiene, and ***upon entry*** into room
Gown	Yes. Don before or ***upon entry*** into room	Per Standard Precautions. Add to droplet precautions for infants, young children, and/or presence of diarrhea	Per Standard Precautions and, if infectious, draining skin lesions present
Gloves	Yes. Don before or ***upon entry*** into room	Per Standard Precautions. Add for infants, young children and/or presence of diarrhea	Per Standard Precautions. Add for infants, young children and/or presence of diarrhea
Mask	Per Standard Precautions	Yes. Don before or ***upon entry*** into room	Don N95 particulate respirator or higher ***before entry*** into room
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 Always don ***before entry*** into room	When aerosol-producing procedures performed for influenza, SARS[b], VHF[c]	When aerosol-producing procedures performed for influenza, SARS, VHF	Yes. Don before entry into room
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. Bleach for VRE, *C.difficilie,* norovirus	Routine	Routine
Transport	Mask patient if coughing. Cover infectious skin lesions. PPE not routinely required for transporter	Mask patient	Mask patient. Cover infectious skin lesions

[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.*

[b]*SARS, severe acute respiratory syndrome.*

[c]*VHF, viral hemorrhagic fever.*

VISITATION POLICIES

Since acquisition of a seemingly innocuous viral infection in neonates and in children with underlying diseases can result in unnecessary evaluations and empiric therapies for suspected 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 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 required during a community outbreak (e.g., SARS, pandemic influenza). For patients requiring Contact Precautions, the use of PPE 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 families.

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[81] and that bacterial colonization[82,83] or subsequent infection[84] 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 should not be allowed to visit if they are delinquent in recommended vaccines, have fever or symptoms of an acute illness, or are within the incubation period following exposure to a known infectious disease. 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 recently were exposed to varicella but who previously were 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 staff members.
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

Pets can be of substantial clinical benefit to the child hospitalized for prolonged periods of time; therefore it is important for healthcare facilities to provide guidance for safe visitation. Many zoonoses and infections are attributable to animal exposure (see Chapter 91, Infections Related to Pets and Exotic Animals). Most infections result from inoculation of animal flora through a bite

TABLE 2-6. 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*	Droplet Precautions for first 24 hours of antimicrobial therapy; mask and face protection for intubation
	Enteroviruses	Contact Precautions for infants and children
	Mycobacterium tuberculosis	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)	*Neisseria meningitidis*	Droplet Precautions for first 24 hours of antimicrobial therapy
If traveled in an area with an ongoing outbreak of VHF in the 10 days before onset of fever	Ebola, Lassa, Marburg viruses	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 until *M. tuberculosis* ruled out; Droplet if respiratory viruses most likely
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.

or scratch or self-inoculation after contact with the animal, the animal's secretions or excretions, or contaminated environment. Although there are few data to support a true evidence-based guideline for pet visitation in healthcare facilities, recommendations are provided in the Guidelines for Environmental Infection Control in Health-Care Facilities[80] to guide institutional policies. Additionally, a guideline has been developed by the Association for Professionals in Infection Control and Epidemiology (APIC) that provides rationale, evidence-based recommendations (when possible), and consensus opinion.[85]

Prudent visitation policies should limit visitation to animals who: (1) are domesticated; (2) do not require a water

environment; (3) do not bite or scratch; (4) can be brought to the hospital in a carrier or easily walked on a leash; (5) are trained to defecate and urinate outside or in appropriate litter boxes; (6) can be bathed before visitation; and (7) are known to be free of respiratory, dermatologic, and gastrointestinal tract disease. Despite the established risk of salmonellosis associated with reptiles (e.g., turtles, iguanas), there continue to be many reports of outbreaks of invasive disease associated with reptiles; reptiles should be excluded from pet visitation programs and families should be advised not to have pet reptiles in the home with young infants or immunocompromised individuals.[86,87] Exotic animals that are imported should be excluded because of unpredictable behavior and the potential for transmission of unusual pathogens (e.g., monkey-pox in the U.S. in 2003).[88] Visitation should be limited to short periods of time and confined to designated areas. Visiting pets need to 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

Disinfection and sterilization as they relate to infection prevention and control have been reviewed[89] and comprehensive guidelines were made by the CDC in 2008.[90] *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 reduces the effectiveness of these processes. *Disinfection* is a process that eliminates all forms of microbial life except the endospore. Disinfection usually requires liquid chemicals. Disinfection of an inanimate surface or object is affected adversely by the presence of organic matter; a high level of microbial contamination; use of 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. The Spaulding classification of patient care equipment as *critical*, *semicritical*, and *noncritical* items with regard to sterilization and disinfection is used by the CDC.[90] *Critical items* require sterilization because they enter sterile body tissues and carry a high risk of causing infection if contaminated; *semicritical items* 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 between uses. 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.[91] 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 are considered and regulated as "manufacturers." 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).

Deficiencies in disinfection and sterilization leading to infection have resulted either from failure to adhere to scientifically based guidelines or failures in the disinfection or sterilization processes. When such failures are discovered, an investigation must be completed including notification of patients and, in some cases, testing for infectious agents. Rutala and Weber[92] have published an excellent guidance document for risk assessment and communication to patients in such situations.

Healthcare facility waste is all biologic or nonbiologic waste that is discarded and not intended for further use. *Medical waste* is 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 infectious waste. 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 are available.[80]

OCCUPATIONAL HEALTH

Occupational health (OH) and student health collaboration with the IPC Department of a healthcare facility is required by OSHA[77] and is essential for a successful program. The OH program is of paramount importance in hospitals caring for children because HCP are at increased risk of infection because: (1) children have a high incidence of infectious diseases; (2) personnel may be susceptible to many pediatric pathogens; (3) pediatric care requires close contact; (4) children lack good personal hygiene; (5) infected children can be asymptomatic; and (6) HCP are exposed to multiple family members who also can be infected.

The OH Department is an educational resource for information on infectious pathogens in the healthcare workplace. In concert with the IPC service, OH provides pre-employment education and respirator fit testing; annual retraining for all employees regarding routine health maintenance, available recommended and required vaccines, standard precautions and isolation categories, and exposure plans. Screening for tuberculosis at regular intervals, as determined by the facility's risk assessment, may use either tuberculin skin testing (TST) or interferon-γ release assays (IGRAs).[93] 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 IPC and know where and what services, equipment, and therapies are available for HCP.

All HCP 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 toxoid, HBV, influenza (yearly), mumps, poliomyelitis, rubella, rubeola, varicella, adult pertussis vaccine (Tdap). The 2006 Advisory Committee on Immunization Practices (ACIP) recommendation to provide HCP with a single dose of Tdap vaccine was amended in 2011 to have no restriction based on age or on the time since the last Td dose. Providing vaccines at no cost to HCP increases acceptance.

The failure to increase influenza vaccine coverage above an average of 60% using novel strategies and signed declination forms led to the recommendation by many professional societies to implement a mandatory influenza vaccine program for all employees who work in a facility where healthcare is delivered.[94,95] Publications from several large institutions, including children's hospitals, indicate that mandatory programs with only medical and religious exemptions are well received with only rare employees being terminated for failure to be vaccinated.[96,97]

Special Concerns of Healthcare Personnel

HCP who have common underlying medical conditions should be able to obtain general information on wellness and screening when needed from the OH service. HCP with direct patient contact who have infants <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-zoster virus (VZV) does not become a silent "carrier" of VZV. 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 and other respiratory viruses, rotavirus, and tuberculosis. Important preventive procedures for HCP with infants at home are: (1) consistent observance of Standard Precautions, Transmission-based Precautions, and hand hygiene according to published recommendations;[2,47] (2) annual influenza and one-time Tdap immunization; (3) routine tuberculosis screening; (4) assurance of immunity or immunization against poliomyelitis, measles, mumps, hepatitis B, and rubella; (5) early medical evaluation for infectious illnesses; (6) routine, on-time immunization of infants; and (7) prompt initiation of prophylaxis/therapy following exposure/development of certain infections.

HCP who are, could be, or anticipate becoming pregnant should feel comfortable working in the healthcare workplace. In fact, with Standard Precautions and appropriate adherence to environmental cleaning and isolation precautions, vigilant HCP 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 pregnant HCP include cytomegalovirus, HBV, influenza, measles, mumps, parvovirus B19, rubella, VZV, and *M. tuberculosis.* Important preventive procedures include documentation of immunity or immunization before pregnancy for rubella, mumps, measles, poliomyelitis, and HBV; 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. In 2011, the CDC recommended universal immunization with Tdap (if previously not immunized with Tdap) for pregnant women after 20 weeks of gestation.[98] 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 2-7 summarizes the

TABLE 2-7. 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. Restriction from care of known CMV patient not required
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 during pregnancy and at delivery	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

Continued

TABLE 2-7. The Pregnant Healthcare Worker: Guide to Management of Occupational Exposure to Selected Infectious Agents—cont'd

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 >10000 (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 post partum for 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). Severe disease in pregnant women, especially with 2009 influenza A (H1N1)	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
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
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
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
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.[d] 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.*

information about infectious agents that are relevant to the pregnant woman, and a comprehensive review has been published.[99]

INFECTION PREVENTION AND CONTROL IN THE AMBULATORY SETTING

The risk of HAIs in ambulatory settings has been reviewed,[100,101] is substantial, and is associated with lack of adherence to routine IPC practices and procedures, especially recommended safe injection practices, disinfection and sterilization, and hand hygiene.[78,102] Respiratory viral agents and *M. tuberculosis* are noteworthy infectious agents transmitted in ambulatory settings. Transmission of RSV in an HSCT outpatient clinic has been demonstrated using molecular techniques.[103] Crowded waiting rooms, toys, furniture, lack of isolation of children, unwell children, contaminated hands, contaminated secretions, and susceptible HCP are only some of the factors that result in sporadic and epidemic illness in outpatient settings. The association of CA-MRSA in HCP working in an outpatient HIV clinic with environmental CA-MRSA contamination of that clinic indicates the potential for transmission in this setting.[104] Patient-to-patient transmission of *Burkholderia* species and *P. aeruginosa* in outpatient clinics for people with cystic fibrosis has been confirmed and prevented by implementing recommended IPC methods.[105,106] IPC guidelines and policies for pediatric outpatient settings have been published.[101] Prevention strategies include definition of policies, education, and strict adherence to guidelines. In pediatrics, one of the most important interventions is segregation of children with respiratory tract illnesses and consistent implementation of respiratory etiquette/cough hygiene. A guideline for infection prevention and control for outpatient settings with a checklist was posted on the CDC website in July, 2011: www.cdc.gov/HAI/pdfs/guidelines/standatds-of-ambulatory-care-7-2011.pdf.

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