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Infectious Disease Considerations for the Operating Room
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THE RABBIT HOLE THAT IS THE PERIOPERATIVE ENVIRONMENT is not well understood by the majority of our general pediatric colleagues. Similarly, the rabbit hole of the primary care clinic or the pediatric inpatient ward is not well understood by the majority of our anesthesiology colleagues. A pediatric patient may repeatedly enter the rabbit hole over the course of a hospital admission, a journey fraught with dangers of airway mishaps, respiratory and/or cardiac arrests, hemorrhage, profound anxiety and stress experienced by the young patient and his or her family, as well as infection risks.1

Anesthesiologists have long been patient safety advocates. It is not surprising that anesthesia providers in the 21st century have taken on increasing responsibility for preventing health care–associated infections (HAIs), including surgical site infections (SSIs). Anesthesia providers practice in a nonsterile environment within the operating room (OR) and frequently contact areas of the patient known to have a high rate of contamination such as the axilla, nares, and pharynx. There are two recognized but poorly implemented interventions: preoperative patient skin and other bacterial reservoir decontamination and hand hygiene by anesthesia providers.2

Anesthesia providers have an impact on bacterial transmission and infection rates. Specifically, anesthesiologists are known to contaminate their work environment within the OR. Contamination of the work environment includes contamination of intravenous (IV) access ports. Without encouragement, anesthesiologists perform hand hygiene less frequently than once per hour during a case, but with reminders, the rate of hand hygiene is more frequent. Improved hand hygiene reduces contamination of the work area and IV access ports from 32% to 8%, which in turn significantly reduces HAIs.3,4

The transmission of infection depends on the presence of three interconnected elements: a causative agent, a source, and a mode of transmission (Fig. 50.1). Understanding the characteristics of each element provides the practicing anesthesiologist with methods to protect susceptible patients and themselves to avoid spreading infection.

There has always been concern about the transmission of infectious agents to the patient from the anesthesiologist and vice versa.5 In addition, there are many sites within the hospital environment where moist or desiccated organic material with the ability to host potentially pathogenic microbes may survive for extended periods of time (Table 50.1) 6,7; some may even resist the usual cleaning and disinfection techniques.8 Their transmission from the source to the host may occur via indirect nonapparent mechanisms (e.g., most commonly through hand contact).

Causative Agent

The infectious vector may be any microorganism capable of causing infection. The pathogenicity is the ability to induce disease, which is characterized by its virulence (infection severity, determined by the germ morbidity and mortality rates) and the level of invasiveness (capacity to invade tissues). No microorganism is completely avirulent. An organism may have a very low level of virulence, but if the host (i.e., patient or health care provider) is highly susceptible, infection by the organism may cause disease. The risk of infection increases with the infecting dose (the number of organisms available to induce disease), the reservoir (the site where the organisms reside and multiply), and the infection source (the site from where it is transmitted to a susceptible host either directly or indirectly through an intermediary object). The infection source may be a human (e.g., health care providers, children, visitors, housekeeping personnel) with a symptomatic or an asymptomatic infection during the incubation period. The source may also be temporarily or permanently colonized (the most frequently colonized tissues are the skin, digestive, and respiratory tracts).

Host

The presence of a susceptible host is an important element in the chain of infection that paradoxically results from advances in current medical therapies and technology (e.g., children undergoing organ transplantation or chemotherapy, or extremely premature neonates) and the presence of children with diseases that compromise their immune systems (e.g., AIDS, tuberculosis, malnutrition, or burns). The organism may enter the host through the skin, mucous membranes, lungs, gastrointestinal tract, genitourinary tract, or the bloodstream via IV solutions, after laryngoscopy, or from surgical wounds. Organisms may also infect the individual because of work accidents with cutting or piercing devices. The development of

| Causative Agent | Strategy for Preventing Infection Transmission in Health Care Institutions |
|-----------------|---------------------------------------------------------------------|
| Host            | Measures for Prevention of Infection Transmission in the Operating Room |
| Methods of Transmission | Prevention of Airborne Pathogen Transmission                  |
| Air Transmission | Standard Precautions                                                   |
| Contact Transmission | Antimicrobial Prophylaxis                                       |

Accidents With Cutting or Piercing Devices
infection is influenced by the host defense mechanisms that may be classified as either nonspecific or specific:

- **Nonspecific defense mechanisms** include the skin, mucous membranes, secretions, excretions, enzymes, inflammatory responses, genetic factors, hormonal responses, nutritional status, behavior patterns, and the presence of other diseases.
- **Specific defense mechanisms or immunity** may occur because of exposure to an infectious agent (antibody formation) or through placental transfer of antibodies; artificial defenses may be acquired through vaccines, toxoids, or exogenously administered immunoglobulins.

**Methods of Transmission**

Microorganisms are transmitted in the hospital environment through a number of different routes; the same microorganism may also be transmitted via more than one route. In the OR, the three main routes of transmission are through the air and by direct and indirect contact.

**AIR TRANSMISSION**

Airborne infections that may infect susceptible hosts are transmitted via two mechanisms: droplets and droplet nuclei.

**Droplets**

Droplet contamination is considered a direct transmission of organisms because there is a direct transfer of microorganisms from the colonized or infected person to the host. This generally occurs with particles whose diameters are greater than 5 µm that are expelled from an individual’s mouth or nose, mainly during sneezing, coughing, talking, or during procedures such as suction, laryngoscopy, and bronchoscopy (Fig. 50.2). Transmission occurs when the microorganism-containing droplets, expelled or shed by the infected person (source), are propelled a short distance (usually not exceeding 60 cm or about 2 feet through the air) and deposited on the host’s conjunctivae or oral or nasal mucous membranes. Droplets remain suspended for only a short duration and distance from the source, but this may be affected by temperature, humidity, force of expulsion, and air currents. Larger particle sizes contact the mucosa of the upper airway, whereas aerosols are capable of penetrating into the lower respiratory tract. Infectious agents vary in their affinity for receptors in different regions of the respiratory tract. When a person coughs, the exhaled air may reach a speed of up to 965 km/hour (600 mph). However, because the droplets are relatively large, they tend to descend quickly and remain suspended in the air for a very brief period, thus obviating the need for special handling procedures for the OR air. Examples of droplet-borne diseases include influenza, respiratory syncytial virus (RSV), severe acute respiratory syndrome (SARS), diphtheria, *Haemophilus influenzae*, *Neisseria meningitidis*, mumps, pertussis, rhinovirus, rubella, and Ebola. Droplet precautions include communication of infectious risk

**TABLE 50.1** Nosocomial Pathogens and Environmental Contamination

| Pathogen                          | Types of Environmental Contamination                                                                 | Organism Survival Time  |
|----------------------------------|------------------------------------------------------------------------------------------------------|-------------------------|
| Influenza virus                  | Aerosolization after cleaning; fomites                                                                 | ≤24–48 hours on nonporous surfaces |
| Parainfluenza virus              | Clothes and nonporous surfaces                                                                       | 10 hours on nonporous surfaces; 6 hours on clothes  |
| Norovirus                        | Extensive environmental contamination, possible aerosolization                                        | ≤14 days on fecal specimens, ≤12 days on carpets |
| Hepatitis B virus                | Environmental contamination with blood                                                                 | 7 days                  |
| Coronavirus-SARS                 | Possible results from emergency department specimens; superspreading events                          | 24–72 hours on fomites and fecal specimens |
| Candida                          | Fomite contamination                                                                                        | 3 days for Candida albicans and 14 days for Candida parapsilosis |
| Clostridium difficile            | Extensive environmental contamination                                                                | 5 months on hospital floors |
| Pseudomonas aeruginosa           | Drain sink contamination                                                                                 | 7 hours on glass slides |
| Acinetobacter baumannii          | Extensive environmental contamination                                                                | 33 hours on laminated plastic surfaces |
| MRSA                             | Extensively contaminated burn units                                                                    | ≤9 weeks after drying; 2 days on laminated plastic surfaces |
| VRE                              | Extensive environmental contamination                                                                | ≤58 days on working surfaces |

**MRSA**, Methicillin-resistant *Staphylococcus aureus*; **SARS**, severe acute respiratory syndrome; **VRE**, vancomycin-resistant enterococci.

Modified from Hota B. Contamination, disinfection, and cross-colonization: are hospital surfaces reservoirs for nosocomial infection? *Clin Infect Dis.* 2004;39(8):1182–1189.
between caregivers, single room isolation, gown, glove, mask, and eye protection. Patients undergoing surgery must be brought directly to the OR and recover in isolation. Some medical interventions (intubation, extubation, biphasic airway pressure [BiPAP], continuous positive airway pressure [CPAP], bronchoscopy, sputum induction, open airway suction) are categorized as aerosol-generating procedures. When performing an aerosol-generating procedure on a patient with an infectious disease that can be transmitted through droplets, the recommendation is to maximize protection by using airborne precautions.10

Droplet Nuclei
Droplet nuclei result from the evaporation of droplets while suspended in the air. Unlike droplets, the nuclei have an outer layer of desiccated organic material and a very small diameter (1–5 μm) and remain suspended in air indefinitely. The microorganisms contained within these nuclei may be spread by air drafts over great distances, depending on the environmental conditions (dry and cold atmosphere, with limited or no exposure to sunlight favoring the spread).12 In contrast to droplets, which are deposited on mucous membranes, droplet nuclei may enter the susceptible host by inhalation; examples of droplet nuclei–borne diseases include tuberculosis, varicella, and measles, zoster, smallpox, SARS, and Middle Eastern respiratory syndrome.10

CONTACT TRANSMISSION
Direct and indirect contacts are the most significant and frequent methods of hospital infection transmission.

Direct Contact
This type of disease transmission involves direct physical contact between two individuals. The physical transfer of microorganisms from an infected or colonized person to a susceptible host may occur from child to health care provider or from health care provider to child during professional practice (e.g., venous cannulation, laryngoscopy, burn care, or suction of secretions). Health care providers working in the OR may be exposed to skin contamination by body fluids. This is an issue of grave concern because of the potential exposure of health care providers to patients with unrecognized infections, especially hepatitis B virus (HBV), hepatitis C virus (HCV), and human immunodeficiency virus (HIV). Hepatitis B is a highly infectious virus that requires a small amount of blood (10−7–10−9 mL) to transmit the disease. The incidence of skin contamination of anesthesiologists and related personnel by blood and saliva is substantial. One study examined 270 anesthetic procedures during 7 consecutive days. The blood of 35 patients (14%) contaminated the skin of 65 anesthesiologists in 46 incidents. Of these contamination events, 28 (61%) occurred during venous cannulation. Of anesthesiologists who had been contaminated by blood, 5 of 65 (8%) had cuts in the skin of their hands.13 The importance of this observation is that seroconversion of health care providers has been reported after skin contamination by infected blood from HIV carriers14 and HBV infection after blood splashing into health care workers’ (HCWs’) eyes.15 Scabies, pediculosis, and herpes simplex are among the diseases most frequently transmitted by direct contact.16–23 Meticulous hand washing before and after every patient contact and routine use of barriers such as gloves and eye protection are essential basic methods for protecting ourselves even during routine procedures such as starting an IV line or performing laryngoscopy.4

Indirect Contact
Indirect contact involves the transmission of microorganisms from a source (animate or inanimate) to a susceptible host by means of a vehicle (e.g., an intermediary object) contaminated by body fluids. Tables 50.2 and 50.3 provide examples of diseases associated with bodily fluids to which HCWs may be exposed. The vehicle for transmission may be the hands of a health care provider who is not wearing gloves or a provider who fails to wash his or her hands after providing care to a child.12–24–26 This type of contact can also come from health care providers who touch (with or without gloves) contaminated monitoring or other patient care devices (e.g., blood pressure cuffs, stethoscopes, electrocardiographic cables, or ventilation systems [respirators, corrugated tubes, Y-pieces, valves]) that are used without proper cleaning or disinfection between each use.27–29

Knowledge about the transmission of the spread of bacteria from patients to HCWs’ hands and to the hospital environment (Fig. 50.3) has driven many interventions that have reduced patient risks for developing HAIs.30

| TABLE 50.2 | Body Fluids and Diseases They May Transmit |
|-------------|------------------------------------------|
| **Body Fluid** | **Disease Transmitted** |
| Blood       | HBV, HIV, HCV, CMV, EBV, NANBH         |
| Seminal fluid | HIV, HBV, CMV                      |
| Vaginal discharge | HIV, HBV, CMV                  |
| Saliva and sputum | HSV, TB, CMV, respiratory diseases |
| Cerebrospinal fluid | Encephalopathic organisms (see Table 50.5), HIV |
| Breast milk | HIV, HBV, CMV                      |
| Urine       | CMV, EBV, HBV                      |
| Feces and intestinal fluid | HAV, gastrointestinal diseases (see Table 50.5) |

**CMV**, Cytomegalovirus; **EBV**, Epstein-Barr virus; **HAV**, hepatitis A virus; **HBV**, hepatitis B virus; **HCV**, hepatitis C virus; **HSV**, herpes simplex types I and II; **NANBH**, non-A, non-B hepatitis; **TB**, tuberculosis.

Modified with permission from Browne RA, Chernesky MA. Infectious diseases and the anaesthetist. Can J Anesth. 1988;35(6):655–665.
Infectious Disease Considerations for the Operating Room

### Table 50.3 Infectious Agents That May Be Found in the Operating Room

| Category                  | Agents                                      |
|---------------------------|---------------------------------------------|
| **Viral Hepatitis**       | Hepatitis A virus                            |
|                           | Hepatitis B virus                            |
|                           | Hepatitis C virus                            |
|                           | Hepatitis delta virus                        |
|                           | Non-A, Non-B hepatitis                       |
|                           | Human immunodeficiency virus                 |
|                           | Cytomegalovirus                              |
|                           | Epstein-Barr virus                           |
|                           | Herpes simplex virus                         |
| **Respiratory Bacteria**  | Strepococcus                                 |
|                           | Pneumococcus                                 |
|                           | Meningococcus                                |
|                           | Diphtheria                                   |
|                           | Mycobacterium                               |
|                           | Legionella                                  |
| **Fungi**                 | Candida                                      |
|                           | Nocardia                                     |
|                           | Cryptococcus                                 |
| **Parasites**             | Pneumocystis                                 |
| **Viruses**               | Rhinovirus                                   |
|                           | Influenza                                    |
|                           | Parainfluenza                                |
|                           | Adenovirus                                   |
|                           | Respiratory syncytial virus                  |
|                           | Measles                                      |
|                           | Rubella                                      |
|                           | Cytomegalovirus*                             |
| **Gastrointestinal**      | Viruses: hepatitis A virus, rotavirus, adenovirus, enterovirus |
|                           | Bacteria: Giardia, Cryptosporidium, Isospora |
|                           | Fungi: Candida                               |
| **Central Nervous System**| Viruses: Human immunodeficiency virus, herpes simplex virus, Epstein-Barr virus |
|                           | Parasites: Toxoplasma                        |
|                           | Fungi: Cryptococcus                          |

*Opportunistic infections in immunocompromised patients, especially those with acquired immunodeficiency.

Modified with permission from Browne RA, Chernesky MA. Infectious diseases and the anaesthetist. Can J Anesth. 1988;35(6):655–665.

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**FIGURE 50.3** Epidemiologic links for transmission of multidrug-resistant organisms. (From Munoz-Price LS, Weinstein RA. Fecal patina in the anesthesia work area. Anesth Analg. 2015;120(4):703–705.)

Studies on vancomycin-resistant enterococci established the importance of a domino effect of contamination in intensive care units (ICUs) and inpatient wards: spread of vancomycin-resistant enterococci that colonize patients’ gastrointestinal tracts (“rectal carriage”), to patients’ skin, to the hospital environment, to hands of HCWs, and then to other patients. The skin contamination of patients with enteric organisms inspired the rather graphic description, the patient’s “fecal patina.” Also referred to as a “stool veneer,” this coating with enteric organisms is limited not only to patients’ skin but also extends to surfaces in the surrounding environment that are touched, and thereby contaminated, by patients and by HCWs. The environmental contamination spreads out from the patient in a target-like concentric pattern, with the densest contamination closest to the rectum of patients who have rectal carriage of the problem bacteria. This interplay among organisms on patients’ body surfaces, hospital environment, and HCWs’ hands constitutes the foundation for the development of infection control interventions in the field of hospital epidemiology.

Characterization of the transmission dynamics of frequently encountered gram-negative bacteria in the anesthesia work area environment demonstrates that the spread follows an epidemiologic pattern similar to that seen in ICUs and inpatient wards: from patient, to environment and HCWs’ hands, and to other patients (Fig. 50.4). In this report, provider hands were less likely to serve as a transmitter of infection than contaminated environmental or patient skin surfaces. These findings have clinical implications for the risk of colonization and subsequent HCIs—for example, SSIs. This calls attention to the need to develop and enforce strict hand hygiene guidelines for personnel who are providing anesthesia care, but more importantly the need to increase compliance with environmental disinfection of the OR (between cases and terminal cleaning), and to study further the directions of the spread of pathogens in the OR and anesthesia work areas. This study unequivocally underscores our need to improve cleaning procedures in the OR and equipment surfaces to reduce infection risk.

There are also reports of equipment, fomites, and drugs (mainly propofol) that have resulted in hospital-acquired infections. Propofol is widely used for both inpatient and outpatient anesthesia. This hypnotic agent is a nutrient-rich drug. It is hypothesized that propofol increases bacterial contamination of IV stopcocks and may compromise safety of IV tubing sets when continued use is therefore recommended. Up to 40% of anesthetic equipment in direct or indirect contact with a child (blood pressure cuffs, cables, oximeters, laryngoscopes, monitors, respirator settings, and horizontal and vertical surfaces) may be contaminated with blood because of inadequate cleansing procedures between uses.

In some institutions, up to 8% of the Bain circuits that were reused without previous sterilization were contaminated. Contamination of syringe contents has occurred with glass particles during ampule opening, which in turn may compromise the sterility of the contents, presumably because of the passage of bacteria contained on glass particles into the solution.

IV tubing has both blood contamination as well as contamination by blood from syringes used to inject medications. This can occur with the absence of visible blood reflux in the tubing or syringe. Simply replacing the needle on a syringe that will be reused is ineffective in preventing cross-infection; it is essential to not use the same syringe in multiple patients.

Refilling both glass and plastic syringes several times has also been shown to result in contamination of the contents; single use is therefore recommended.

Some drug formulations, especially propofol, can sustain bacterial growth under certain conditions. Thus great care should be given to aseptic technique when transferring drugs from the vial to a syringe and to use the contents of the syringe within 4 hours. Propofol vials should not be used for multiple patients because of concerns for cross-contamination, particularly since not all countries have added antimicrobials to the propofol emulsion.
ACCIDENTS WITH CUTTING OR PIERCING DEVICES

Percutaneous contamination from a cutting or piercing accident is the most effective means to transmit bloodborne pathogens. Evidence suggests that this is the main route of HIV, HBV, and HCV infection, especially if the injury is caused by hollow-bore needles that were used to draw blood or establish IV access. Over 20 other bloodborne pathogens have been transmitted by this means, including those causing herpes, malaria, and tuberculosis. The risk of exposure to blood and bloodborne pathogens is greater for health care personnel (HCP) than for people who do not work around blood. An exposure to infected blood, tissue, or other potentially infectious body fluids can occur by percutaneous injury or contact with mucous membrane or nonintact skin. The risk of infection after an exposure depends on a number of variables and appears to be greater with exposure to a larger quantity of blood or other infectious fluid; prolonged or extensive exposure of nonintact skin or mucous membrane to blood or other infectious fluid or concentrated virus in a laboratory setting; exposure to the blood of a patient in an advanced disease stage or with a higher HIV viral load; a deep percutaneous injury; a procedure wherein the sharp was in the vein or artery of an infected source patient; an injury with a hollow-bore, blood-filled needle; and limited or delayed access to postexposure prophylaxis. After exposure, the risk of infection varies for specific bloodborne pathogens. For HBV, if the source patient has active HBV and the HCP do not already have immunity, the risk for infection after percutaneous injury is between 1% and 30%. If the source patient has active HCV, the risk of hepatitis C transmission is approximately 1.8% (range 0%–7%) after a percutaneous injury. If the source patient has HIV infection, the risk of HIV transmission is approximately 0.3% after a percutaneous exposure and 0.09% after a mucous membrane exposure. The risk of HIV transmission for an exposure with nonintact skin has not been determined and is estimated to be less than the risk after a mucous membrane exposure.

Anesthesia staff lacking HBV protective antibodies are at great risk for acquiring the disease. These infection rates underscore the need for the use of “safe” needles and the need to advocate the use of “needleless” systems even though they are significantly more expensive. This also emphasizes the need for meticulous handling and disposal of needles and other sharp instruments, as well as the use of special “sharps boxes” designed to minimize accidental needlesticks (e.g., “mailbox”-type boxes that do not allow the hand to enter the disposal area). The U.S. Centers for Disease Control and Prevention (CDC) has estimated that in the United States there are approximately 385,000 cutting and piercing accidents annually among HCP in hospitals; 25% of these occur in the OR. However, the actual prevalence is thought to be much greater, because many of these events are unreported. The distribution of these accidents among anesthesiologists is shown in Fig. 50.5A; the distribution of the items most frequently associated with cutting and piercing injuries in health care providers is shown in Fig. 50.5B. Should such an accident occur (e.g., needle puncture, exposure to nonintact skin, or mucous membrane...
Strategy for Preventing Infection Transmission in Health Care Institutions

Institutional administrative measures aimed at developing, implementing, and monitoring specifically designed accident prevention policies and procedures are important for reducing and preventing transmission of infectious agents in health care centers. To this end, centers should consider the following:

- Include infection control as a major goal in the organizational mission statement and implement safety programs, both for patients and HCWs.
- Provide sufficient administrative and financial support to carry out this mission.
- Provide sufficient administrative and financial support for the microbiology laboratory and implement an infection surveillance plan, especially for postsurgical infections.
- Establish a multidiscipline cross-functional team (e.g., a team manager, an epidemiologist, a representative from industrial health, and a person trained in quality control) to identify health and safety issues within the institution, analyze trends, assess outcomes, implement interventions, and make recommendations to other members of the organization.
- Provide sufficient administrative and financial support to develop and implement education programs for health care providers, patients, and their families. One positive example of such education is that anesthesiologists who have read the CDC’s Universal Precaution Guidelines for the Prevention of Occupational Transmission of HIV and HBV have developed better hygienic practices.
- Provide HCWs with hepatitis A and B vaccine and document that an appropriate immunologic response was achieved. Provide hepatitis A and B immune globulins (HAIG, HBIG) for those exposed who do not have established immunity.
- Provide a health care service for employees for counseling and postexposure prophylaxis should an exposure to HIV occur.
- Provide regular surveillance of HCWs to determine established immunity to infectious diseases such as tuberculosis, measles, mumps, rubella, and chickenpox. Lack of immunity may require immunization; several studies have demonstrated the cost-effectiveness of immunization (for prevention of disease) versus the cost of replacement of HCWs who have become infected.

Measures for Prevention of Infection Transmission in the Operating Room

**PREVENTION OF AIRBORNE PATHOGEN TRANSMISSION**

Airborne pathogens may be transmitted through the OR heating, ventilation, and air conditioning systems. It is vital to have in place proper systems to (1) remove contaminated air, (2) facilitate air management requirements to protect susceptible health care providers and children against hospital-related airborne pathogens, and (3) minimize the risk of airborne pathogens being transmitted by children. Many regulatory institutions, such as the National Institute for Occupational Safety and Health; the American Society of Heating, Refrigerating and Air-Conditioning Engineers; the CDC; and the American Institute of Architects (AIA), have developed standards and guidelines for OR ventilation systems. As in any other environment, ventilation in the OR is an important issue to control infection from microbiologic pollutants. Most
ventilation is used for protective environments (e.g., ORs and isolation rooms for tuberculosis patients), and positive-pressure ventilation is used for highly infective rooms in the hospital (e.g., the OR to the outside (positive pressure). Negative-pressure ventilation is used for areas with immunocompromised patients). Most hospital ORs are currently designed with high-efficiency particulate air (HEPA) filtration systems to maximize removal of airborne contaminants. OR ventilation systems should operate at all times, except during maintenance. During unoccupied hours, air exchange can be reduced as long as positive pressure is maintained in each OR. Air is delivered to each OR from the ceiling, with downward movement toward several exhaust or return ducts near the floor. This design helps provide steady movement of clean air through the breathing and working zones.

The AIA has specific guidelines for the location of outside fresh air inlets to minimize contamination from exhaust systems and noxious fumes. A greater air inflow rate and a larger air-inlet area are desirable for contaminant control, but these approaches are detrimental to the thermal comfort of the staff and patient.108 The AIA recommends an air-change rate in an OR of 20 to 25 air changes per hour (ACH) for ceiling heights between 9 feet

### TABLE 50.4: Guide to Postexposure Prophylaxis and Prevention of Infection Transmission

| PEP Step 1: Treat Exposure Site | PEP Step 4: Evaluate the Exposure Source |
|---------------------------------|-----------------------------------------|
| • Use soap and water to wash areas exposed to potentially infectious fluids as soon as possible after exposure. | **When source patient is known:** |
| • Flush exposed mucous membranes with water. | • Test source patient for HBsAg, HCV antibody, and HIV antibody. |
| • Flush exposed eyes with water or saline solution. | • Use a rapid HIV antibody test. Use of fourth-generation HIV antigen/antibody testing is recommended if available. |
| • Do NOT apply caustic agents, or inject antiseptics or disinfectants into the wound. | • HIV viral load assessment for routine screening of source patient is NOT recommended. |
| **PEP Step 2: Report and Document** | • If the source person is NOT infected with a bloodborne pathogen, further follow-up testing of the exposed HCP is not necessary. Follow state regulations related to informed consent and confidentiality. |
| • Details of the incident: where and how the exposure occurred, exposure site(s) on HCP’s body, if related to sharp device, the type and brand of device. | • For patients who cannot be tested, consider medical diagnoses, clinical symptoms, and history of risk behaviors. |
| • Details of the exposure: type and amount of fluid or material, severity of exposure. | **When source patient is NOT known/unable to be tested immediately:** |
| • Documentation of counseling following exposure and postexposure management plan. | • Evaluate the likelihood of high-risk exposure: |
| • Details about the exposure source: If the source patient is known or unknown: whether the source material contained HIV, HBV, or HCV; if the source patient is HIV-infected, determine stage of disease, CD4 cell count, HIV viral load, history of antiretroviral therapy, and antiretroviral resistance information as available. | • Consider the likelihood of bloodborne pathogen infections among patients in the exposure setting: What is the community infection rate? Does the clinic/hospital unit care for a large number of HIV-, HBV-, or HCV-infected or at-risk patients? |
| • Details about the exposed HCP: hepatitis B vaccination and vaccination response status (HBsAb titer); other medical conditions that may influence choice of prophylactic agent(s) if needed; current medications, and drug allergies; pregnancy status or lactation status. | • Is there a high suspicion for HIV infection and the patient is unable to be tested immediately? |
| • The exposure should be evaluated for the potential to transmit HBV, HCV, or HIV based on the type of body substance involved, the route, severity and frequency of exposure. | • Do not test discarded needles for bloodborne pathogens; the reliability of these findings is not known. |
| • Significant exposures to any of the following may pose a risk for bloodborne pathogen transmission and require further evaluation: blood, semen, vaginal secretions, cerebrospinal fluid, synovial fluid, pleural fluid, peritoneal fluid, pericardial fluid, amniotic fluid. | **The “window period”:** |
| • Body fluids that do NOT pose a risk of bloodborne pathogen transmission unless visibly contaminated with blood include: urine, stool, tears, saliva, gastric secretions or vomitus, sweat, nonpurulent sputum, nasal discharge. | • To date, there has not been a documented case of occupational HIV transmission from a source patient with a negative HIV antibody test result with risk factors for HIV acquisition. |
| **PEP Step 3: Evaluate the Exposure** | • Postexposure prophylaxis should be considered only if the source patient has risk factors and has been determined to have symptoms consistent with acute HIV infection. |

**Source:** HBV, hepatitis B virus; HBsAg, hepatitis B surface antigen; HCV, hepatitis C virus; HCP, health care personnel; HIV, human immunodeficiency virus.
From Mountain Plains AIDS Education and Training Center. PEP Steps, A Quick Guide to Postexposure Prophylaxis in the Health Care Setting (April 2006); PEP Steps: A Quick Guide to Postexposure Prophylaxis in the Health Care Setting (March 2014).
Factors to Consider in Assessing the Need for Follow-Up After Occupational Exposure

| Type of Exposure | Considerations |
|------------------|----------------|
| Percutaneous injury | Requires evaluation of needlestick or puncture wound |
| Mucous membrane exposure | Requires evaluation of exposure to mucous membranes |
| Nonintact skin exposure | Requires evaluation of exposure to nonintact skin |
| Bites resulting in blood exposure | Requires evaluation of exposure to bites |

| Type and Amount of Fluid/Tissue | Considerations |
|-------------------------------|----------------|
| Blood | Requires blood testing for exposure |
| Fluids containing blood | Requires fluid testing for exposure |
| Potentially infectious fluid or tissue | Requires tissue testing for exposure |
| Direct contact with concentrated virus | Requires testing for exposure to concentrated virus |

Infection Status of Source Patient

- If positive for HBSAg testing for exposed person’s vaccination status.
- If positive for HCV antibody, consider measuring HCV viral load.
- If positive for HIV antibody, consider obtaining HIV viral load testing, and evaluating clinical status of patient.

Susceptibility of Exposed HCP

- Hepatitis B vaccine and vaccine response status
- HBV, HCV, and HIV status—baseline testing for HbsAb, anti-HCV, and HIV antibody should be completed as early as possible (preferably within 72 hours)

Accessibility of PEP and Follow-Up

- PEP should be initiated within 2 hours of the exposure.
- The efficacy of PEP initiation is thought to diminish after 24 to 36 hours following an exposure.

Laboratory Tests Used for Evaluation

- If the fourth-generation combination HIV Ag/Ab assay is used to test the source patient, HIV follow-up testing can be completed 4 months after exposure.

**STANDARD PRECAUTIONS**

Standard precautions assume that any person or patient is potentially infected or colonized by microorganisms that could be transmitted and cause an infectious process. Standard precautions must be implemented with all patients and include the following:

- **Universal precautions**—blood and body fluid precautions, developed to reduce bloodborne pathogen transmission.
- **Body substance isolation**, designed to reduce the risk of pathogen transmission by moist body substances.

Standard precautions are used to reduce the transmission of all infectious agents from one person to another, thus protecting health care providers and children against exposure to the most common microorganisms. Standard precautions are implemented for any contact with blood and body fluids, secretions, and excretions (except sweat), whether or not they contain visible blood, as well as for any contact with nonintact skin, mucous membranes, and intact skin that is visibly soiled with blood and/or body fluids. Prevention is primary. All HCPs should be familiar with standard precautions: wash hands frequently and thoroughly before and after patient care; use personal protective equipment: gloves, gowns, boots, shoe covers, eyewear, masks, and shields, as appropriate for the patient care situation; gloves must be worn when any kind of venous or arterial access is being performed; use sharps with caution: plan ahead (use sharps in a safe environment with a sharps container nearby), dispose of used sharps in puncture-proof receptacles immediately after use, do not recap needles, and use safety devices if available. All HCPs should be vaccinated with the hepatitis B vaccine series and should undergo testing for HbsAb response after completion of the series to document adequate protection. Employees who have not gone through the vaccination series previously should be offered the hepatitis B series through their employer at no cost.

Summaries of standard precautions, droplet precautions, airborne precautions, and contact precautions are available on line.

**Hand Washing**

Overall hand hygiene compliance across health care providers remains less than 50%, with anesthesia providers identified as a particularly noncompliant group (one study found a compliance rate of only 23%). Bacterial contamination of anesthesia providers has been directly linked to high-risk bacterial transmission events to IV stopcocks and 30-day postoperative infections.

The vast majority of SSIs are caused by *Staphylococcus aureus*. Transmission of specific staphylococcal phenotypes within and between patients is a major contributor to SSIs and HAIs. The role of anesthesia-provider hand contamination in transmission of *Enterococcus* to the workstation and patient biome is concerning, even though it was not associated with actual infection, because of rising rates of antibiotic-resistant organisms and the observation that *Enterococcus* is becoming a more prevalent pathogen.

Two approaches are indicated: improved methods of patient reservoir decontamination and more effective and frequent decontamination of provider hands. Hand hygiene is a well-known and effective solution to the problem of bacterial transmission within and across patients. Compliance with the current “5 moments” World Health Organization guidelines could make a major inroad into reducing provider hand and workspace contamination. One study found that only 20% of anesthesia providers demonstrated complete knowledge regarding WHO hand hygiene guidelines. Failure of providers to recognize prior contact with the environment and prior contact with the patient as hand hygiene opportunities contributed to this low percentage. Several cognitive factors were associated...
TABLE 50.6  Recommended HIV Postexposure Prophylaxis for Percutaneous Injuries

| Exposure Type | HIV-Positive Class 1 | HIV-Positive Class 2 | Source of Unknown HIV Status | Unknown Source | HIV-Negative |
|---------------|---------------------|---------------------|----------------------------|----------------|--------------|
| Less severe"  | Recommend basic 2-drug PEP | Recommend expanded ≥3-drug PEP | In general, no PEP warranted; however, consider basic 2-drug PEP for source with HIV risk factors" | In general, no PEP warranted; however, consider basic 2-drug PEP in settings in which exposure to HIV-infected persons is likely | No PEP warranted |
| More severe"  | Recommend expanded 3-drug PEP | Recommend expanded ≥3-drug PEP | In general, no PEP warranted; however, consider basic 2-drug PEP for source with HIV risk factors" | In general, no PEP warranted; however, consider basic 2-drug PEP in settings in which exposure to HIV-infected persons is likely | No PEP warranted |

HIV, human immunodeficiency virus; PEP, postexposure prophylaxis.

"HIV-positive class 1: asymptomatic HIV infection or known low viral load (e.g., <1500 ribonucleic acid copies/mL). HIV-positive class 2: symptomatic HIV infection, AIDS seroconversion, or known high viral load. If drug resistance is a concern, obtain expert consultation. Initiation of PEP should be delayed pending expert consultation, and because expert consultation alone cannot substitute for face-to-face counseling, resources should be available to provide immediate evaluation and follow-up care for all exposures.

"For example, deceased source person with no samples available for HIV testing.

"The recommendation "consider PEP" indicates that PEP is optional; a decision to initiate PEP should be based on a discussion between the exposed person and the treating clinician regarding the risks versus benefits of PEP.

If PEP is offered and administered and the source is later determined to be HIV-negative, PEP should be discontinued.

"For example, large-bore hollow needle, deep puncture, visible blood on device, or needle used in patient’s artery or vein.

From Centers for Disease Control and Prevention. Updated U.S. Public Health Service guidelines for the management of occupational exposures to HBV, HCV, and HIV and recommendations for postexposure prophylaxis. MMWR Recommendations and Reports 2001;50(RR11):1–42. Available at http://www.cdc.gov/mmwr/PDF/rr/rr5011.pdf.

TABLE 50.7  Recommended HIV Postexposure Prophylaxis for Mucous Membrane Exposures and Nonintact Skin Exposures

| Exposure Type | HIV-Positive Class 1 | HIV-Positive Class 2 | Source of Unknown HIV Status | Unknown Source | HIV-Negative |
|---------------|---------------------|---------------------|----------------------------|----------------|--------------|
| Small volume" | Consider basic 2-drug PEP | Recommend basic 2-drug PEP | In general, no PEP warranted" | In general, no PEP warranted | No PEP warranted |
| Large volume" | Recommend basic 2-drug PEP | Recommend expanded ≥3-drug PEP | In general, no PEP warranted; however, consider basic 2-drug PEP for source with HIV risk factors" | In general, no PEP warranted; however, consider basic 2-drug PEP in settings in which exposure to HIV-infected persons is likely | No PEP warranted |

PEP, postexposure prophylaxis.

"For skin exposures, follow-up is indicated only if evidence exists of compromised skin integrity (e.g., dermatitis, abrasion, or open wound).

"HIV-positive class 1: asymptomatic HIV infection or known low viral load (e.g., <1500 ribonucleic acid copies/mL). HIV-positive class 2: symptomatic HIV infection, acquired immunodeficiency syndrome, acute seroconversion, or known high viral load. If drug resistance is a concern, obtain expert consultation. Initiation of PEP should be delayed pending expert consultation, and because expert consultation alone cannot substitute for face-to-face counseling, resources should be available to provide immediate evaluation and follow-up care for all exposures.

"For example, deceased source person with no samples available for HIV testing.

"For example, splash from inappropriately disposed blood.

"For example, a few drops.

"The recommendation "consider PEP" indicates that PEP is optional; a decision to initiate PEP should be based on a discussion between the exposed person and the treating clinician regarding the risks versus benefits of PEP.

"If PEP is offered and administered and the source is later determined to be HIV-negative, PEP should be discontinued.

"For example, a major blood splash.

From Centers for Disease Control and Prevention. Updated U.S. Public Health Service guidelines for the management of occupational exposures to HBV, HCV, and HIV and recommendations for postexposure prophylaxis. MMWR Recommendations and Reports 2001;50(RR11):1–42. Available at http://www.cdc.gov/mmwr/PDF/rr/rr5011.pdf.

with a reduced risk of incomplete knowledge, including providers responding positively to washing their hands after contact with the environment, disinfecting their environment during patient care, believing that they can influence their colleagues, and intending to adhere to guidelines. These results suggest that anesthesia providers have knowledge deficits pertaining to opportunity-based hand hygiene in the intraoperative arena—specifically, after interactions with patient skin surfaces and the surrounding environment, the two most important reservoirs of intraoperative bacterial transmission.

Hand washing is considered the most important and cost-effective individual intervention in the prevention of HAIs in children and health care providers. Its importance in medical practice had not been universally accepted, despite the pioneering work by Oliver Wendell Holmes (1843) and Ignaz Semmelweis.
TABLE 50.8 Ventilation System Specifications for the Operating Room

- Minimize the circulation of people during surgeries. It has been proved that the level of microbes in the operating room air is directly proportional to the number of people moving inside the room.
- Maintain humidity under 68% and temperature control to prevent environmental conditions that favor the development of germs.
- Maintain positive pressure compared with corridors and surrounding areas to prevent microorganisms from entering the operating room.
- Provide at least 15 air changes per hour in the operating room, 20% of which should be fresh air. Air should be recirculated through a high-efficiency particulate air (HEPA) filter.
- Air should be introduced at ceiling level and disposed of at ground level.

From Centers for Disease Control and Prevention. Guidelines for environmental infection control in health-care facilities: recommendations of CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC). MMWR Recommendations and Reports 2003;52(RR10):1–42. Available at http://www.cdc.gov/mmwr/preview/mmwrhtml/rr52i10al.htm.

TABLE 50.9 Precautionary Procedures for Patients with Infectious Tuberculosis

Follow Precautionary Procedures for Infectious TB Patients Who Also Require Emergency Surgery. Category IB, IC

1. Use an N95 respirator approved by the National Institute for Occupational Safety and Health without exhalation valves in the operating room. Category IC
2. Intubate the patient in either the AI room or the operating room; if intubating the patient in the operating room, do not allow the doors to open until 99% of the airborne contaminants are removed. Category IB
3. When anesthetizing a patient with confirmed or suspected TB, place a bacterial filter between the anesthesia circuit and the patient’s airway to prevent contamination of anesthesia equipment or discharge of tubercle bacilli into the ambient air. Category IB
4. Exhale and allow the patient to recover in an AI room.
5. If the patient has to be exhaled in the operating room, allow adequate time for ACH to clean 99% of airborne particles from the air, because exhalation is a cough-producing procedure. Category IB

Use Portable, Industrial-Grade HEPA Filters Temporarily for Supplemental Air Cleaning During Intubation and Extubation for TB Patients Who Require Surgery. Category II

1. Position the units appropriately so that all room air passes through the filter; obtain engineering consultation to determine the appropriate placements. Category II
2. Switch the portable unit off during the surgical procedure. Category II
3. Provide fresh air as per ventilation standards for operating rooms; portable units do not meet the requirements for the number of fresh ACH. Category II

If possible, schedule TB patients as the last surgical cases of the day to maximize the time available for removal of airborne contamination. Category II

No recommendation is offered for performing orthopedic implant operations in rooms supplied with laminar airflow. Unresolved issue

Maintain backup ventilation equipment (e.g., portable units for fans or filters) for emergency ventilation of operating rooms, and take immediate steps to restore the fixed ventilation system. Category IB, IC (AIA: 5.1)

ACH, air changes per hour; AI, airborne infection isolation; HEPA, high-efficiency particulate air.

Centers for Disease Control and Prevention. Guidelines for environmental infection control in health-care facilities: recommendations of CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC). 2003. http://apps.who.int/iris/bitstream/10665/44102/1/9789241597906_eng.pdf

(1846), who separately recognized that the contaminated hands of physicians performing autopsies were the vectors responsible for the spread of puerperal fever caused by streptococci. They demonstrated that hand washing before delivering a baby reduced the risk of infectious transmission and maternal mortality by 90%! Unfortunately, the scientific basis for hand washing was not established until the introduction of the germ theory of disease by Louis Pasteur and the discovery of the microorganism that caused anthrax (Bacillus anthracis) by Robert Koch in the late 19th century. More than one-and-a-half centuries later, and with strong evidence that health care providers are a leading source of hospital acquired infections, the average frequency of hand hygiene episodes fluctuates with the method used for monitoring and the setting where the observations are conducted. Hand washing per hour may vary over 30-fold. On the other hand, the average number of opportunities for hand hygiene per HCW varies markedly between hospital wards; nurses in pediatric wards, for example, had an average of eight opportunities for hand hygiene per hour of patient care, compared with an average of 30 for ICU nurses. In some acute clinical situations, the patient is cared for by several HCWs contemporaneously and, on average, as many hand hygiene opportunities per patient per hour of care have been observed per provider as in a postanesthesia care unit (PACU) admission. The number of opportunities for hand hygiene depends largely on the process of care provided: revision of protocols for patient care may reduce unnecessary contacts and, consequently, improve hand hygiene opportunities. In 11 observational studies, the duration of hand cleansing episodes by HCWs ranged, on average, from as little as 6.6 seconds to 30 seconds. In 10 of these studies, the hand hygiene technique monitored was hand washing, while handrubbing was monitored in one study. In addition to washing their hands for very short time periods, HCWs often failed to cover all surfaces of their hands and fingers. Therefore the number of hand hygiene opportunities per hour of care may be very large and, even if the hand hygiene compliance rate is large, the applied cleansing technique may be inadequate. Adherence of HCWs to recommended hand hygiene procedures varies from unacceptably poor (5%) to relatively good (89%) with an overall mean rate of 38.7% in the ICU, OR, and PACU. A number of investigators reported improved adherence after implementing various interventions, but most studies had only short follow-up. Few studies have reported sustained improvement. There are hospital-wide predictors of poor adherence to recommended hand hygiene measures during routine patient care. These include professional category, hospital ward, time of day/week, and type and intensity of patient care, defined as the number of opportunities for hand hygiene per hour of patient care. Nonadherence was the least among nurses and during weekends. Nonadherence was greater in ICUs compared with internal medicine, during procedures that carried a substantial risk of bacterial contamination, and when intensity of patient care was high. In other words, the greater the demand for hand hygiene, the poorer the adherence. The poorest adherence rate (36%) was found in ICUs, where indications for hand hygiene were typically
more frequent (on average, 22 opportunities per patient-hour). The greatest adherence rate (59%) was observed in pediatrics, where the average intensity of patient care was smaller than elsewhere (on average, 8 opportunities per patient-hour). The results suggest that full adherence to guidelines is unrealistic and that easy access to hand hygiene at the point of patient care, (i.e., in particular, alcohol-based handrubbing) could help improve adherence to hand hygiene.

Perceived barriers to adherence with hand hygiene practice recommendations include skin irritation caused by hand hygiene agents, inaccessible hand hygiene supplies, interference with HCW–patient relationships, patient needs perceived as a priority over hand hygiene, wearing of gloves, forgetfulness, lack of knowledge of guidelines, insufficient time for hand hygiene, high workload and understaffing, and the lack of scientific information showing a definitive impact of improved hand hygiene on HAI rates. Lack of knowledge of guidelines for hand hygiene, lack of recognition of hand hygiene opportunities during patient care, and lack of awareness of the risk of cross-transmission of pathogens are barriers to good hand hygiene practices. Furthermore, some HCWs believed that they washed their hands when necessary even when observations indicated that they did not. The risk of pathogen transmission via the hands is proportional to the power of the number of times a child is touched. Table 50.10 presents a summary of the indications for and the strength of supporting evidence for hand washing and antisepsis.

Recommendations for surgical hand preparation are as follows: remove rings, wristwatch, and bracelets before beginning surgical hand preparation (II); artificial nails are prohibited (IB); sinks should be designed to reduce the risk of splashes (II); if hands are visibly soiled, wash hands with plain soap before surgical hand preparation (II); remove debris from underneath fingernails using a nail cleaner, preferably under running water (II); brushes are not recommended for surgical hand preparation (IB); surgical hand antisepsis should be performed using either a suitable antimicrobial soap or suitable alcohol-based handrub, preferably with a product ensuring sustained activity, before donning sterile gloves (IB); if the quality of water is not assured in the operating theatre, surgical hand antisepsis using an alcohol-based handrub is recommended before donning sterile gloves when performing surgical procedures (II); when performing surgical hand antisepsis using an antimicrobial soap, scrub hands and forearms for the length of time recommended by the manufacturer, typically 2–5 minutes. Long scrub times (e.g., 10 minutes) are not necessary (IB); when using an alcohol-based surgical handrub product with sustained activity, follow the manufacturer’s instructions for application times. Apply the product to dry hands only (IB); do not combine surgical hand scrub and surgical handrub with alcohol-based products sequentially (II); when using an alcohol-based handrub, use sufficient product to keep hands and forearms wet with the handrub throughout the surgical hand preparation procedure (IB); after application of the alcohol-based handrub as recommended, allow hands and forearms to dry thoroughly before donning sterile gloves (IB).

At present, alcohol-based handrubs are the only known means for rapidly and effectively inactivating a wide array of potentially harmful microorganisms on hands. The WHO recommends alcohol-based handrubs based on the following factors: evidence-based, intrinsic advantages of fast-acting and broad-spectrum microbicidal activity with a minimal risk of generating resistance to antimicrobial agents; suitability for use in resource-limited or remote areas with lack of accessibility to sinks or other facilities for hand hygiene (including clean water, towels, and so on); capacity to promote improved compliance with hand hygiene by making the process faster and more convenient; economic benefit by reducing annual costs for hand hygiene, representing approximately 1% of extra costs generated by an HCI; minimization of risks from adverse events because of increased safety associated with better acceptability and tolerance than other products.

After hand washing, it is very important to dry the hands properly with appropriate paper towels, hot air flow, or both, because the level of pathogen transmission from a HCW’s hands to a patient is greatly increased if the hands are wet. Sterile cloth towels are most frequently used in ORs to dry wet hands after surgical hand antisepsis. Several methods of drying have been tested without significant differences between techniques.

Transmission may also occur from patients’ wet sites, such as groins or armpits, or when a HCW gets his or her hands wet when opening parenteral solutions. It is critical for health institutions to establish written procedures and protocols to support adherence to the recommended hand hygiene practices.

### Gloves

Wearing clean or sterile gloves while caring for children is an effective means of reducing HAIs. Gloves remain a supplementary barrier to infection that should not replace proper hand hygiene.
Indications for Gloving and Glove Removal

Gloves protect patients by reducing health care provider hand contamination and the subsequent transmission of pathogens to other children, provided the gloves are changed after providing care to each child. Additionally, when the use of gloves is combined with CDC standard precautions, they protect the health care provider against exposure to bloodborne infections or infections transmitted by any other body fluids, such as excretions, secretions (except sweat), mucous membranes, and nonintact skin. Examination gloves are single-use and usually nonsterile. Sterile surgical gloves are required for surgical interventions. Some nonsurgical care procedures, such as central vascular catheter insertion, also require surgical glove use. In addition to their sterile properties, these gloves have characteristics of thickness, elasticity, and strength that differ from other medical gloves.

The use of gloves in situations when their use is not indicated represents a waste of resources without necessarily reducing cross-transmission. The wide-ranging recommendations for glove use have led to very frequent and inappropriate use. Indications for gloving and glove removal are shown in Table 50.11. Situations that require and that do not require glove use are presented in Fig. 50.6.

Ranked consensus recommendations for the use of gloves, categorized according to the CDC/HICPAC system, include the following:

- Wear gloves in case of contact with blood or any other potentially infecting body fluid, such as excretions, secretions (except sweat), mucous membranes, and nonintact skin (IC).
- Remove the gloves immediately after providing care to a child. Staff should not wear the same pair of gloves to take care of more than one child, nor should they touch the surfaces of any equipment, monitoring devices, or even light switches. Contaminated gloves can pass blood or other body fluids to working surfaces and are vectors for hepatitis transmission (IB).72
- Change gloves when taking care of a child if you must move from a contaminated to a clean body site (II).
- Apply hand hygiene measures immediately after removing the gloves because, despite the use of gloves, hands may get contaminated through small (microscopic) holes in the gloves.131,144,145 Microbial contamination of hands and possible infection transmission have been reported even with the use of gloves.146
- Remove the gloves by using an appropriate technique (so as not to contaminate your hands with the contaminated surface of the gloves).

| TABLE 50.11 | Indications for Gloving and Glove Removal |
|--------------|------------------------------------------|
| **Indication** | **Glove Use** |
| 1. Before a sterile condition | 1. |
| 2. Anticipation of a contact with blood or another body fluid, regardless of the existence of sterile conditions and including contact with non-intact skin and mucous membrane | 2. |
| 3. Contact with a patient (and his/her immediate surroundings) during contact precautions | 3. |
| **Glove Removal** | 4. |
| 1. As soon as gloves are damaged (or non-integrity suspected) | |
| 2. When contact with blood, another body fluid, nonintact skin, and mucous membrane has occurred and has ended | |
| 3. When contact with a single patient and his or her surroundings, or a contaminated body site on a patient has ended | |
| 4. When there is an indication for hand hygiene | |

From *WHO Guidelines on Hand Hygiene in Health Care: First Global Patient Safety Challenge Clean Care Is Safer Care. Geneva: World Health Organization; 2009.*

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**STERILE GLOVES INDICATED**

Any surgical procedure; vaginal delivery; invasive radiological procedures; performing vascular access and procedures (central lines); preparing total parental nutrition and chemotherapeutic agents.

**EXAMINATION GLOVES INDICATED IN CLINICAL SITUATIONS**

Potential for touching blood, body fluids, secretions, excretions, and items visibly soiled by body fluids

**DIRECT PATIENT EXPOSURE:** contact with blood; contact with mucous membrane and with nonintact skin; potential presence of highly infectious and dangerous organism; epidemic; or emergency situations; IV insertion and removal; drawing blood; discontinuation of venous line; pelvic and vaginal examination; suctioning nonclosed systems of endotracheal tubes.

**INDIRECT PATIENT EXPOSURE:** emptying emesis basins; handling/cleaning instruments; handling waste; cleaning up spills of body fluids.

**GLOVES NOT INDICATED (except for CONTACT precautions)**

No potential for exposure to blood or body fluids, or contaminated environment

**DIRECT PATIENT EXPOSURE:** taking blood pressure; temperature and pulse; performing SC and IM injections; bathing and dressing the patient; transporting patient; caring for eyes and ears (without secretions); any vascular line manipulation in absence of blood leakage.

**INDIRECT PATIENT EXPOSURE:** using the telephone, writing the patient’s chart; giving oral medications; distributing or collecting patient dietary trays; removing and replacing linen for patient bed; placing noninvasive ventilation equipment and oxygen cannula; moving patient furniture.

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**FIGURE 50.6** Situations requiring and not requiring glove use. IM, intramuscular; SC, subcutaneous. (Adapted from *WHO Guidelines on Hand Hygiene in Health Care: First Global Patient Safety Challenge Clean Care Is Safer Care. Geneva: World Health Organization; 2009.*)
Alcohol-based handrub dispensers and clean glove boxes (at least two sizes) should be in place near every patient care site (e.g., on top of every anesthesia cart, medication cart, or in the nursing station).

Disposable gloves should not be washed, resterilized, or disinfected (IB). If gloves are reused, appropriate reprocessing methods should be in place to ensure the physical integrity of the gloves and their full decontamination (II).

Sterile gloves are much more expensive than clean, disposable gloves and should be used only for certain procedures, such as when hands are in contact with normally sterile body areas or when inserting intravascular or urinary catheters. Clean gloves should be used during any other procedure, including wound dressing.

Latex-free gloves should be worn when caring for children at risk for latex allergy.

ANTIMICROBIAL PROPHYLAXIS

Surgical antimicrobial prophylaxis is an essential tool to reduce the risk of postoperative infections, and the anesthesia team plays a central role in ensuring the proper timing of drug administration. The aim of the perioperative administration of antibiotics is to obtain plasma and tissue drug concentrations exceeding the minimal inhibitory concentration of those organisms most likely to cause an infection. This will reduce the microbial load of the intraoperative contamination; it is not the intent to cover all possible pathogens, because this can lead to the selection of drug-resistant bacteria.

There have been few studies regarding the effectiveness of prophylactic guidelines for prevention of SSIs in children. Currently, prophylactic antibiotic guidelines exist for certain subsets of the pediatric surgical population, but there are no global recommendations, and the guidelines that exist are mostly based on studies from adults or from expert opinion. A retrospective study suggested that the appropriate use of antibiotic prophylaxis was a vital modifiable risk factor and may be the easiest factor to influence. Primary failure to administer the correct dose of antibiotics at the appropriate time resulted in an almost 2-fold increase in the risk of developing an SSI. The importance of correct antibiotic usage and dosing plays a major role in reducing the risk of SSIs in children. Recommendations are provided for adult (age ≥19 years) and pediatric (age 1–18 years) patients. The guidelines do not specifically address newborn (premature and full-term) infants (Table 50.12).

Selection of the Antimicrobial Agent

Although pediatric-specific prophylaxis data are sparse, available data have been evaluated for specific procedures. Selection of antimicrobial prophylactic agents mirrors that in adult guidelines, with the agents of choice being first- and second-generation cephalosporins, reserving the use of vancomycin, alone or in combination with other antimicrobials, for routine perioperative antimicrobial prophylaxis in institutions that have a high prevalence of methicillin-resistant S. aureus (MRSA). Vancomycin may be considered in children known to be colonized with MRSA and decreases MRSA infections. Mupirocin is effective in children colonized with MRSA, but drug-resistant bacteria.

| Antimicrobial | Pediatric Recommended Dosea | Recommended Redosing Interval (From Initiation of Preoperative Dose), hoursb |
|---------------|-----------------------------|--------------------------------------------------------------------------|
| Ampicillin-sulbactam | 50 mg/kg of the ampicillin component (up to 3 g) | 2 |
| Ampicillin | 50 mg/kg (up to 2 g) | 2 |
| Aztreonam | 30 mg/kg (up to 2 g) | 4 |
| Cefazolin | 30 mg/kg (up to 2 g, 3 g if >120 kg) | 4 |
| Cefuroxime | 50 mg/kg (up to 1.5 g) | 4 |
| Cefotaxime | 50 mg/kg (up to 1 g) | 3 |
| Cefotetan | 40 mg/kg (up to 2 g) | 2 |
| Ceftazidime | 40 mg/kg (up to 2 g) | 6 |
| Ceftriaxone | 50–75 mg/kg (up to 2 g) | N/A |
| Ciprofloxacin† | 10 mg/kg (up to 400 mg) | N/A |
| Clindamycin | 10 mg/kg (up to 900 mg) | 6 |
| Ertapenem | 15 mg/kg (up to 1 g) | N/A |
| Fluconazole | 6 mg/kg (up to 400 mg) | N/A |
| Gentamicin‡ | 2.5 mg/kg based on dosing weight | N/A |
| Levofloxacin‡ | 10 mg/kg (up to 500 mg) | N/A |
| Metronidazole | 15 mg/kg (up to 500 mg) | N/A |
| Piperacillin-tazobactam | Infants 2–9 months: 80 mg/kg of the piperacillin component (up to 3.375 g) Children >9 months and ≤40 kg: 100 mg/kg of the piperacillin component | 2 |
| Vancomycin | 15 mg/kg | N/A |
| Erythromycin base | 20 mg/kg (up to 1 g) | N/A |
| Metronidazole | 15 mg/kg (up to 1 g) | N/A |
| Neomycin | 15 mg/kg (up to 1 g) | N/A |

†The maximum pediatric dose should not exceed the usual adult dose.
‡For antimicrobials with a short half-life (e.g., cefazolin, cefoxitin) used before long procedures, redosing in the operating room is recommended at an interval of approximately two times the half-life of the agent in patients with normal renal function. Recommended redosing intervals marked as “not applicable” (N/A) are based on typical case length; for unusually long procedures, redosing may be needed.
§While fluoroquinolones have been associated with an increased risk of tendinitis/tendon rupture in all ages, use of these agents for single-dose prophylaxis is generally safe.
¶In general, gentamicin for surgical antibiotics prophylaxis should be limited to a single dose given preoperatively. Dosing is based on the patient’s actual body weight. If the patient’s actual weight is more than 20% above ideal body weight (IBW), the dosing weight (DW) can be determined as follows: DW = IBW + 0.4 (actual weight − IBW). Adapted from Bratzler DW, Dellinger EP, Olsen KM, et al. Clinical practice guidelines for antimicrobial prophylaxis in surgery. Am J Health Syst Pharm. 2013;70(3):195–283.
there are limited data supporting its use perioperatively. Most recommendations for adults are the same for pediatric patients. Dosing recommendations in pediatric patients are limited and have been extrapolated from adult data; therefore nearly all pediatric recommendations are based on expert opinion. Pediatric efficacy data are few. Fluoroquinolones should not be routinely used for surgical prophylaxis in pediatric patients because of the potential for toxicity in this population. The same principle of preoperative dosing within 60 minutes before incision has been applied to pediatric patients. Additional intraoperative dosing may be needed if the duration of the procedure exceeds two half-lives of the antimicrobial agent or there is excessive blood loss during the procedure. As with adult patients, single-dose prophylaxis is usually sufficient. If antimicrobial prophylaxis is continued postoperatively, the duration should be less than 24 hours, regardless of the presence of intravascular catheters or indwelling drains. There are sufficient pharmacokinetic studies of most agents to recommend pediatric dosages that provide adequate systemic exposure and, presumably, efficacy comparable to that demonstrated in adults. Therefore the pediatric dosages recommended in guidelines are based largely on pharmacokinetic data and the extrapolation of adult efficacy data to pediatric patients. Because few clinical trials have been conducted in pediatric surgical patients, strength of evidence criteria have not been applied to these recommendations. With few exceptions (e.g., aminoglycoside dosages), pediatric doses should not exceed the maximum adult recommended dosages. Generally, if a dose is calculated on a milligram-per-kilogram basis for children weighing more than 40 kg, the calculated dosage will likely exceed the maximum recommended dose for adults; adult dosages should therefore be used for larger children.

The Timing of Antibiotic Prophylaxis

The 2013 revised policy paper on prophylactic antibiotics developed jointly by the American Society of Health-System Pharmacists (ASHP), the Infectious Disease Society of America, the Surgical Infection Society, and the Society for Healthcare Epidemiology of America states:

Successful prophylaxis requires the delivery of the antimicrobial to the operative site before contamination occurs. Thus, the antimicrobial agent should be administered at such a time to provide serum and tissue concentrations exceeding the minimum inhibitory concentration (MIC) for the probable organisms associated with the procedure, at the time of incision, and for the duration of the procedure.

Current evidence suggests that for most β-lactams, a bolus dose at 15 to 45 minutes before incision is ideal and provides maximum interstitial fluid concentrations at the time of initial bacterial seeding (see Table 50.12). Because diffusion distances from capillary to pathogen are greater in obese patients, for this patient subset initiating antibiotic infusion 30 minutes or longer before incision is warranted on theoretical grounds. The initial β-lactam bolus dose should be followed by additional doses at every 1 to 2 half-lives per the ASHP guidelines. The use of a SSI prevention bundle in pediatric patients improves compliance with preincision antibiotic administration and decreases the SSI infection rate.

Allergy to β-Lactams

Several studies have shown that the true incidence of allergy to antibiotics is less than that reflected in medical charts. For surgical procedures where cephalosporins are the prophylaxis of choice, alternative antibiotics should be administered to those children at risk of anaphylaxis to β-lactams, based on their history or diagnostic tests (e.g., skin testing). However, the incidence of severe allergic reactions to first-generation cephalosporins in children with reported allergy to penicillin is rare (but not zero); furthermore, skin testing does not reliably predict the likelihood of adverse reactions to cephalosporins in those with reported allergy to penicillin. There is no evidence of any risk of cross-reactivity between penicillin and second- and third-generation cephalosporins. For the most part, “allergies” to oral antibiotics that appear on children’s charts (rash, vomiting, gastrointestinal disturbances) are reactions to the additives in the antibiotic formulation, including food dyes, fillers, and other compounds, or a manifestation of the underlying infection. IV administration of small test doses of the pure antibiotic in a fully monitored (and anesthetized) child will determine whether the child is at risk for an allergic reaction to the antibiotic. In the case of surgical procedures where antibiotic prophylaxis is mainly directed at gram-positive cocci, children who are truly allergic to β-lactams (cephalosporins) should receive either vancomycin or clindamycin. However, in those children where the history is consistent with either an IgE-mediated penicillin allergy (urticaria, angioedema, anaphylaxis, bronchospasm) or a severe non–IgE-mediated reaction (interstitial nephritis, toxic epidermal necrolysis, hemolytic anemia, or Stevens-Johnson syndrome) it is advisable to switch out the cefazolin. Cross-sensitivity occurs when the RI side chains of the penicillins and cephalosporins are similar, which perhaps surprisingly is not the case with cefazolin. Cephalosporins with RI side chains similar to penicillins include cephalaxin, cefaclor, and cefadroxil. The risk associated with use of first- or second-generation cephalosporins with dissimilar side chains, or third- or fourth-generation cephalosporins, appears to be very low in patients with mild-to-moderate reactions to penicillin G, ampicillin, or amoxicillin. Dismissing cefazolin use when there is a vague history of any penicillin allergy should be reconsidered.

Indications for Prophylactic Antibiotics

Surgical wounds are classified into four categories (Table 50.13). The use of antibiotic prophylaxis for postoperative infections is well established for clean-contaminated procedures. Within the clean category, prophylaxis has been traditionally reserved for surgical procedures involving a foreign body implantation or for any surgical procedure where an SSI would be catastrophic (e.g., cardiac surgery or neurosurgical procedures). However, there is evidence that postoperative infections resulting from procedures not involving prosthetic elements are underreported; estimates show that more than 50% of all complications occur after the patient is discharged and are thus unrecognized by the surgical team. Therefore antibiotic prophylaxis is also recommended for certain procedures, such as herniorrhaphy. The direct and indirect costs of these complications may not affect the hospital budget; however, they represent a substantial cost for the community at large. In the case of contaminated or dirty procedures, bacterial contamination or infection is established before the procedure begins. Accordingly, the perioperative administration of antibiotics is a therapeutic, not a prophylactic, measure. The use of antibiotics in children has implications not only for the response to the current treatment but also to future treatments. Thus all medical professionals are jointly responsible for the rational use of antibiotics.

Protocols, although effective, require continuous feedback on their acceptance and SSI results. No surgical protocol can replace
TABLE 50.13  Wound Classification System

| Wound Category                        | Description                                                                 |
|---------------------------------------|-----------------------------------------------------------------------------|
| Class I/clean                         | Uninfected wound with no inflammation, and the respiratory, alimentary, genital, or uninfected urinary tract is not entered. Clean wounds primarily are closed and drained, when necessary, with closed drainage. Operative wounds after blunt trauma may be included in this category if they meet criteria. |
| Class II/clean contaminated            | Operative wound in which the respiratory, alimentary, genital, or urinary tract is entered under controlled conditions and without unusual contamination. Specifically, operations involving the biliary tract, appendix, vagina, and oropharynx are included in the category, provided no evidence of infection or major break in technique is encountered. |
| Class III/contaminated                 | Open, fresh, accidental wounds; operations with major breaks in sterile technique (e.g., open cardiac massage) or gross spillage from the gastrointestinal tract; and incisions in which acute, nonpurulent inflammation is encountered. |
| Class IV/dirty-infected                | Old traumatic wounds with retained devitalized tissue and those that involve existing clinical infection or perforated viscera, suggesting that the organisms causing postoperative infection were present in the operative field before operation. |

From Neville HL, Lally KP. Pediatric surgical wound infections. Semin Pediatr Infect Dis. 2001;12:124–129.

the judgment of the medical professional; clinical reasoning must be tailored to the individual circumstances. Finally, children with congenital heart disease and a subgroup of those with repaired congenital heart disease may require bacterial endocarditis prophylaxis (see also Tables 16.2 and 16.3).167

ANNOTATED REFERENCES

Fernandez PG, Lofrus RW, Dodds TM, et al. Hand hygiene knowledge and perceptions among anesthesia providers. Anesth Analg. 2015;120(4):837-843.

Anesthesiologists have long been patient safety advocates. It is not surprising that anesthesia providers have taken on increasing responsibility for preventing health care–associated infections. However, the overall hand hygiene compliance across health care providers remains less than 50%, with anesthesia providers identified as a particularly noncompliant group. In this paper, the authors identified risk factors for knowledge deficits among anesthesia providers and characterized anesthesia provider perceptions, attitudes, awareness of individual group performance, workload and type, and accessibility of hand hygiene agents.

Lofrus RW, Brown JR, Koff MD, et al. Multiple reservoirs contribute to intraoperative bacterial transmission. Anesth Analg. 2012;114(6):1236-1248.

Bacterial cross-contamination is thought to play an important role in the development of health care–associated infections, but the relative importance of the known hospital bacterial reservoirs (health care providers’ hands, patient, and environment, including health care equipment) in this process is unknown. A better understanding of how bacterial cross-contamination occurs can provide the basis for the development of evidence-based preventive measures. This paper examined the relative contributions of anesthesia providers’ hands, the patient, and the patient environment to stopcock contamination.

Rizzo M. Striving to eliminate catheter-related bloodstream infections: a literature review of evidence-based strategies. Semin Anesth Perioper Med Pain. 2005;24(4):214-225.

This paper reviews and emphasizes the need for preventive measures that could help to avoid or reduce most nosocomial catheter-related infections. The use of evidence-based standardized protocols will result in “best practices” and markedly reduce such infections.

Sagoe-Moses CH, Pearson R, Perry J, Jagger J. Risks to health care workers in developing countries. N Engl J Med. 2001;345(7):538-541.

Protecting HCWS in developing countries from exposure to bloodborne pathogens will involve some cost. HCWS are a crucial resource in the health care systems of developing nations. In many countries, including those in sub-Saharan Africa, workers are at increased risk for preventable, life-threatening occupational infections. This paper expands on the need for improved support of HCWS throughout the world with appropriate supplies of gloves, barriers, sharps disposal, and the need for accident education programs.

A complete reference list can be found online at ExpertConsult.com.
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