INTRODUCTION

Infection control is a key factor in protecting the health care worker (HCW) from infections that may be transmitted during patient care. This involves a complex interaction between patients, HCWs, and the hospital environment, and requires the use of specific measures to reduce the spread of infectious agents. In this chapter, we will review infection control guidelines as outlined by the Centers for Disease Control and Prevention (CDC), recommendations for vaccination in HCWs, and the application of these measures as they apply to common bacterial and viral agents in the health care setting.

HISTORICAL PERSPECTIVE

One of the pioneers of infection control was the Hungarian obstetrician Ignaz Semmelweis (1). While working on the obstetric wards at Allegemeines Krankenhaus in Vienna he became alarmed by the high rates of puerperal sepsis (“childbed fever”). He noted that the mortality rate on the delivery ward attended by midwives was much lower than the ward attended by physicians. Semmelweis postulated that women likely became ill when cared for by physicians who came directly to the obstetric ward after performing autopsies on women who had died of puerperal fever. However, autopsies were never performed by midwives. A colleague of Semmelweis, Jacob Kolletschka, died after he sustained a scalpel injury while performing an autopsy on a puerperal fever patient. His autopsy showed similar pathologic features to those patients. Semmelweis concluded that contact with infected autopsy tissue was the cause of puerperal fever when it was carried to the obstetrical patients on the physician ward. Semmelweis then implemented a simple measure asking the physicians to wash their hands with a chlorine solution after performing autopsies and prior to attending to obstetrical patients. Subsequent to this, the rates of puerperal fever decreased on the physician obstetric ward. To this day, hand hygiene is the central tenet for preventing the spread of infection. Further observations and advances have led to the modern era of infection control.

RECOMMENDED VACCINES FOR HCWS

A key component of protecting the HCW is vaccination. The Advisory Committee on Immunization Practices (ACIP) is a group of medical and public health experts that develops recommendations on how to use vaccines to control diseases in the United States. HCWs are at risk for exposure to serious, and sometimes deadly, diseases. The CDC and ACIP have published a list of recommended vaccines for HCWs (Table 10.1). These are general recommendations for HCWs who are not immunocompromised. If an HCW is pregnant or plans to become pregnant, all vaccine decisions should be discussed with her health care provider first. HCWs should not become
TABLE 10.1 CDC-Recommended Vaccines for Health Care Workers

<table>
<thead>
<tr>
<th>Vaccine</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hepatitis B</td>
<td>HCWs lacking documented evidence of a 3-dose vaccine series and evidence of protective immunity defined as a HBsAg titer ≥10 mIU/mL should:</td>
</tr>
<tr>
<td></td>
<td>• Receive the 3-dose vaccine series</td>
</tr>
<tr>
<td></td>
<td>• Obtain a HBsAg titer 1–2 mo after the 3rd dose</td>
</tr>
<tr>
<td>Influenza</td>
<td>Annual vaccination with an inactivated (intramuscular) influenza vaccine</td>
</tr>
<tr>
<td>Measles, mumps, rubella (MMR)</td>
<td>*HCWs who have not had the MMR vaccine series, or those lacking serologic evidence of immunity should receive 2 doses of MMR</td>
</tr>
<tr>
<td></td>
<td>*MMR vaccine should not be administered to HCWs known to be pregnant or attempting to become pregnant or to immunocompromised HCWs</td>
</tr>
<tr>
<td>Varicella (chickenpox)</td>
<td>HCWs who have not had chickenpox, received the varicella vaccine, or lack serologic evidence of immunity should receive 2 doses of the varicella vaccine</td>
</tr>
<tr>
<td></td>
<td>*Varicella vaccine should not be administered to HCWs known to be pregnant or attempting to become pregnant or to immunocompromised HCWs</td>
</tr>
<tr>
<td></td>
<td>Td vaccine should receive one dose of Td</td>
</tr>
<tr>
<td></td>
<td>All HCWs should receive Td boosters every 10 yrs</td>
</tr>
<tr>
<td></td>
<td>Pregnant HCWs should receive a dose of Td during each pregnancy</td>
</tr>
<tr>
<td></td>
<td>Meningococcal</td>
</tr>
<tr>
<td></td>
<td>HCWs who are routinely exposed to isolates of N. meningitidis should receive one dose</td>
</tr>
</tbody>
</table>

*Some health care institutions opt not to vaccinate HCWs born prior to 1957 based on the presumption of immunity from natural infection.

*HCWs should not become pregnant for at least 28 d after each dose of varicella vaccine, MMR vaccine, or any of the components of the MMR vaccine.


In order to decrease pathogens that can be transmitted on HCW clothing, there are now HCW clothing restrictions in Britain including the elimination of ties, except bow ties, and white coats with long sleeves. While these HCW clothing restriction proposals are not currently being practiced in the United States, some ICUs have instituted policies that HCWs wear only surgical scrubs while providing patient care and that white coats be removed prior to entering ICU rooms. At this time, these recommendations are not part of the CDC’s standard precautions, but may become so in the future.

**Gloves**

Clean, nonsterile gloves are appropriate when contact with blood, body fluids, secretions, excretions, broken skin, mucous membranes, and items visibly contaminated by these fluids are expected. Gloves should be changed between tasks and

**PRECAUTIONS**

In addition to vaccination, several types of precautions for use in patient care settings are critical to protecting the HCW. Making sense of them and knowing when to implement each can be confusing. The CDC has published guidelines outlining the recommended approach to infection control as well as the definition and application of the various precautions, including the specific personal protective equipment (PPE) to be used for each category. There are four types of precautions recommended in the CDC guidelines (3):

1. **Standard** (previously termed universal)
2. **Contact**
3. **Droplet**
4. **Airborne**
procedures on the same patient if contact with material containing a high concentration of microorganisms occurs and between different anatomic sites on the same patient. Gloves should be removed immediately after use and hand hygiene performed before contact with the environment to avoid contamination of surfaces. Between contact with the next patient, hand hygiene must always be performed and new gloves donned if indicated; failure to do so is an infection control hazard (6). According to CDC guidelines, the use of gloves does not replace the need for hand hygiene. Gloves may have small, unapparent perforations or may be torn during use. Also, hands can become contaminated during removal of gloves (6) and clean gloves may be contaminated with dirty hands prior to donning making hand hygiene after glove removal critical.

Mask, Eye Protection, and Face Shield
The mucous membranes of the HCW, including those of the eyes, nose, and mouth, are at risk for exposure when performing procedures or patient care tasks that may generate aerosols or droplets. Bronchoscopy, open suctioning, and intubation are examples of aerosol-generating procedures (AGPs). Masks, goggles (eye protection), or face shields should be worn to protect the mucous membranes of the HCW.

Gowns
A clean, nonsterile gown that is fluid resistant or impermeable should be used during procedures and patient care activities when the clothing or skin of an HCW may be at risk for exposure or contamination. A gown should be worn if the patient is incontinent of urine or stool, has an ileostomy, colostomy, or wound drainage not covered, or contained by a dressing. Gowns should be removed immediately after patient contact and should not be worn outside of the patient’s room. Hands may be contaminated during gown removal and hand hygiene should be performed prior to contact with the environment or other patients.

Patient Care Equipment and Linen
If patient care equipment is soiled with blood, body fluids, secretions, and excretions, the HCW should don appropriate PPE to prevent skin and mucous membrane exposures, contamination of HCW clothing, and transfer of microorganisms to other patients and the environment. Multi-use equipment should be appropriately cleaned or processed prior to being used for the care of another patient. Single-use items should be disposed of in the appropriate manner. Adequate procedures for the routine cleaning and disinfection of environmental surfaces, beds, bedrails, bedside equipment, and other high-touch surfaces should be established. Soiled linen should be handled and transported in a manner that prevents skin and mucous membrane exposure and contamination of HCW clothing (7).

Contact Precautions
Contact precautions are designed to reduce the risk of transmission of epidemiologically important microorganisms and certain infestations caused by lice or scabies. Transmission of these organisms or conditions may take place either by direct or indirect contact. Direct contact transmission from patient to staff includes physical transfer of microorganisms to the HCW from an infected or colonized patient. This usually takes place via skin-to-skin contact during patient care activities. Indirect transmission occurs when an HCW comes into contact with a contaminated intermediate object in the patient’s environment, particularly high-touch surfaces such as monitors, medication pumps, bedrails, bedside tables, commodes, and sinks. Pathogenic organisms that can remain viable on the surfaces in the patient’s environment for extended periods of time include methicillin-resistant Staphylococcus aureus (MRSA), vancomycin-resistant enterococcus (VRE), Gram-negative organisms such as Pseudomonas spp. and Acinetobacter spp., and C. difficile (6).

Contact precautions involve appropriate patient placement, hand hygiene, gloves, gowning, and precautions when transporting patients and when using patient care equipment. Patients should be placed in a private room if possible; however, the door to the room may be left open. When a private room is not available, the patient can be placed in a room with a patient who has colonization or active infection with the same microorganism but no other infection (cohorting). If a private room is not available or the HCW has been exposed to an immunocompromised patient in the same room as a patient with a resistant organism.

Contact precautions should be used as with standard precautions, and gowns should be used if there will be any contact with the patient, environmental surfaces, or items in a patient’s room. Therefore, many hospitals require a gown and gloves be worn upon entry to the room even if substantial contact with the patient or environment is not anticipated. Patient transport should be limited only to essential purposes, and if the patient is transferred out of the room, care should be taken to ensure minimal risk of transmission to other patients and environmental surfaces or equipment. Patient care equipment such as stethoscopes, thermometers, and intravenous pumps should be dedicated to a single patient (or cohort) to avoid sharing between patients, minimizing transfer of organisms.

Droplet Precautions
Droplet precautions aim to reduce the risk of spreading infectious agents when droplets formed by secretions are expelled from the respiratory tract during sneezing, coughing, talking, and open suctioning. Transmission in this manner occurs when infectious droplets greater than 5 μm in size come into contact with the mucous membranes (conjunctiva, nose, mouth) of an HCW. Droplet transmission requires close contact between the infected patient and the HCW, as droplets do not remain suspended in the air and generally travel only short distances, usually less than 3 feet. However, data from experimental studies with smallpox and experience during the severe adult respiratory syndrome (SARS) outbreak showed that droplets containing these viruses could reach persons up to 6 feet away. Because of this, the CDC suggests that masks and face protection be donned 6 to 10 feet from a source patient requiring droplet precautions. According to CDC recommendations, because droplets do not remain suspended in the air, special air handling and ventilation are not required to prevent droplet transmission, and the door to the patient’s room may remain open (3).
Droplet precautions apply to any patient known or suspected to be infected with epidemiologically important pathogens that can be transmitted by infectious droplets, such as *Neisseria meningitidis*, influenza, *Bordetella pertussis*, rhinovirus, rubella, *Haemophilus influenzae* type B, adenovirus, *Mycoplasma pneumoniae*, and parvovirus B19. Patients should be placed in a private room or cohorted. Transport should be limited to essential purposes only. If transport becomes necessary, a surgical mask should be placed on the patient to minimize dispersal by droplets.

Hospitals should implement programs that encourage respiratory etiquette among patients, visitors, and HCWs. This includes covering sneezes and coughs with tissues which are then disposed of immediately, followed by hand hygiene. If tissues are not available sneezes or coughs should be covered by the upper arm or elbow and not directed into the hands. Visitors and patients may be asked to wear masks if they are experiencing upper respiratory symptoms (7). To prevent transmission to both patients and other HCWs, many hospitals require that HCWs with respiratory illnesses be medically evaluated prior to patient contact.

**Airborne Precautions**

Airborne precautions are designed to reduce the risk of transmission of respiratory infectious agents which are carried in airborne droplets less than or equal to 5 μm in size (droplet nuclei) or can attach to dust particles in the environment. Airborne transmission occurs by dissemination and inhalation of these droplet nuclei and dust particles which can be dispersed widely by air currents or may travel through ventilation systems. They may be inhaled by a susceptible host within the same room or by a patient several rooms or floors away from the source patient because a single ventilation system often serves multiple patient rooms. Therefore, special air handling and ventilation are required to prevent airborne transmission. Airborne precautions apply to patients known or suspected to be infected with epidemiologically important pathogens such as *Mycobacterium tuberculosis* (MTb), rubeola virus (measles), and varicella-zoster virus (VZV, chickenpox) (8).

The patient should be placed in an airborne infection isolation (AII) room that has monitored negative air pressure in relation to the surrounding areas, 6 to 12 air exchanges per hour, and appropriate discharge of air outdoors or monitored high-efficiency filtration of room air before the air is recirculated to other areas in the hospital. The room door should be kept closed and the patient should remain in the room except for medically necessary tests. If a private AII room is not available, the patient should be cohorted with a patient infected with the same microorganism but with no other infection. Consultation with infection prevention and control professionals is advised before patient placement in the event no AII rooms are available (3).

An N95 or higher respirator must be worn to provide an adequate barrier to airborne microorganisms including *M. tuberculosis* (9,10). Powered air-purifying respirators (PAPRs) may be used in these settings as well. PAPRs do not require fit testing and may be worn by HCWs with facial hair. Per CDC, HCWs with documented immunity to measles or chickenpox need not wear respiratory protection. However, hospital policies may dictate all HCWs wear respiratory protection regardless of immune status. Susceptible persons should not enter the room of patients known or suspected to have rubeola or VZV if immune caregivers are available. If susceptible persons must enter the room of a patient known or suspected to be infected with rubeola or VZV, they should wear an N95 respirator or PAPR.

Patient transport should be limited to the movement and transport of the patient from the room for essential purposes only. If transport or movement is necessary, minimize patient dispersal of droplet nuclei by placing a surgical mask on the patient. The patient is not required to wear an N95 respirator or PAPR during transport (3).

**BLOOD-BORNE PATHOGENS**

Handling of sharps (needles, scalpels, sutures and other sharp instruments or devices) during use, cleaning, or disposal should be done with extreme care to avoid percutaneous injury. Blood-borne pathogen training is mandatory for HCWs who have exposure to blood and body fluids per the Occupational Safety and Health Administration (OSHA) Blood-borne Pathogen Standard (11). Safe practices include never recapping any needle, avoiding manipulation of sharps using both hands, avoiding hand-off of a sharp from one HCW to another or using techniques that involve the point of a needle being directed toward any part of an HCW’s body. Used needles should not be removed from disposable syringes by hand. Bending, breaking, or otherwise manipulating used needles should not be done. Used disposable syringes and needles, scalpel blades, and other sharp items should be placed in an appropriate puncture-resistant container which should be located as close as practical to the area in which the items are being used. Reusable sharps can be placed in a puncture-resistant container for transport to a reprocessing area. The Needlestick Safety and Prevention Act of 2000 directs employers to evaluate their medical devices on an ongoing basis and make efforts to convert as many devices as possible to safer products (11).

**Human Immunodeficiency Virus**

Human immunodeficiency virus (HIV) is the etiologic agent of acquired immunodeficiency syndrome (AIDS). Two species of HIV, HIV-1 and HIV-2, infect humans. HIV is transmitted primarily by exposure to blood and other body fluids from an HIV-infected patient. The three primary methods of transmission are via unprotected sexual intercourse, vertical transmission (mother to child), and contaminated needles (either occupational exposure or with the use of intravenous drugs of abuse). In the United States, blood products are screened for HIV, and transfusion-associated transmission essentially has been eliminated. Potentially infectious fluids include blood and blood-containing fluids; fluids from other sites such as semen, vaginal secretions, and cerebrospinal fluid (CSF); and, synovial, pleural, peritoneal, pericardial, and amniotic fluids.

After percutaneous or mucosal exposure, HIV replicates within dendritic cells and spreads via lymphatics to the bloodstream where CD4+ cells become infected. The delay in systemic spread leaves a “window of opportunity” for postexposure prophylaxis (PEP) using antiretroviral drugs. The most common HCW exposure is via percutaneous injury. Other types of exposures among HCWs include mucous membrane
Several factors may affect the risk of HIV transmission after an occupational exposure. Increased risk is associated with a larger quantity of blood from the source patient such as contained in a hollow bore needle, percutaneous injury that occurs during a procedure involving a needle placed directly into a vein or artery of the source patient, a deep tissue injury in the HCW and blood exposure from a patient with a high HIV viral load.

**HIV Postexposure Management**

Occupational exposures to HIV require urgent medical evaluation. The goal of postexposure management is to deliver HIV PEP to the HCW with a high-risk exposure within 2 hours. A number of occupational HIV PEP guidelines have been published (17,18). The initial step following an occupational exposure to blood and body fluids is prompt treatment of the exposure site including washing wounds and skin sites with soap and water and flushing mucous membranes with water. Squeezing the injured area to expel blood should not be done. The use of local antiseptics at the injury site is not contraindicated, although there is no evidence of efficacy.

The HCW should immediately report the exposure to facilitate rapid testing of the source patient for HIV, hepatitis B (HBV), and hepatitis C (HCV). PEP should be initiated for the HCW if indicated. The source patient should be tested for HIV immediately. FDA-approved rapid tests can produce HIV test results within 30 minutes, with sensitivities and specificities similar to those of first- and second-generation enzyme immunoassays (EIAs). Third-generation chemiluminescent immunoassays can detect HIV-specific antibodies 2 weeks sooner than conventional EIAs and generate test results in an hour or less. Fourth-generation combination p24 antigen—HIV antibody (Ag/Ab) tests produce both rapid and accurate results, and p24 antigen detection allows identification of most infections during the window period (the time period between HIV infection and the development of detectable HIV antibodies). Rapid determination of source patient HIV status provides essential information about the need to initiate and/or continue PEP. As per the U.S. Public Health Service Guidelines, regardless of which type of HIV testing is employed, all of the above tests are acceptable for determination of source patient HIV status (17). It is not necessary to investigate whether the source patient is in the window period unless acute antiretroviral syndrome is suspected (17). HIV RNA polymerase chain reaction (PCR) testing for routine screening of source patients is not recommended. As per the CDC, if the source patient is HIV negative, no further testing of the HCW is indicated. However, other guidelines recommend that if the source patient has been at risk for HIV exposure in the preceding 6 weeks, then an HIV RNA PCR should be performed on the source patient. Depending on the results, PEP is either continued or stopped (Figure 10.1) (18).

The severity of exposure is no longer used to determine the number of drugs to be offered in an HIV PEP regimen. A regimen of three or more antiretroviral drugs is now recommended for all occupational exposures to HIV. The drug regimen selected should have a favorable side-effect profile as well as a convenient dosing schedule to facilitate both adherence to the regimen and completion of the recommended 4-week course of PEP. As of 2015, the preferred HIV PEP regimen includes emtricitabine plus tenofovir with either raltegravir or dolutegravir. This once-a-day regimen is tolerated, potent, and conveniently administered, and it has been associated with minimal drug interactions (17). Expert consultation for HIV PEP is recommended for an exposure report delayed more than 72 hours, unknown source (needle in sharps disposal container or laundry), known or suspected pregnancy in the HCW, breastfeeding in the HCW, known or suspected resistance of the source HIV to antiretroviral agents, toxicity of the initial PEP regimen, or significant underlying illness in the HCW. HCWs should have follow-up within 72 hours of the occupational exposure regardless of whether they take PEP or not. If local expert consultation is not available, the National Clinicians’ Post-Exposure Hotline (PEPline) can be consulted at 888-448-4911.

**Hepatitis Viruses**

Several hepatitis viruses have been described, including hepatitis A, B, C, D, E, and G. Hepatitis A and E are transmitted by the fecal/oral route, usually by contaminated food. They cause acute hepatitis that is generally self-limited and confers immunity to future infections. In a small percentage of cases, hepatitis E can develop into an acute severe liver disease that is often fatal, especially in pregnant women. Hepatitis D is caused by delta virus and can only replicate in the presence of HBV. By far, HBV and HCV pose the greatest threat to HCWs.

**Hepatitis B**

HBV is endemic in many parts of the world, causes both acute and chronic hepatitis, and is a major cause of hepatocellular carcinoma. The virus is transmitted through exposure to blood and body fluids. Routes of transmission include unprotected sexual contact, blood transfusions, use of contaminated needles and syringes, vertical transmission, and occupational exposure including needlesticks and mucous membrane exposure. As with many blood-borne viral pathogens, the risk of transmission from a blood and body fluid exposure is closely related to the volume of blood and the number of copies of virus present in the blood of the source patient. The percutaneous injury site should be washed with soap and water, and the mucous membrane flushed with water. Squeezing the injured area to expel blood should not be done.

Per the CDC guidelines, risk of transmission of HBV is also related to the HBV envelope antigen (HBeAg) status of the source patient. In patients who were both hepatitis B surface antigen (HBsAg) and HBeAg positive, the risk of developing clinical hepatitis from a needle injury was 22% to 31%. The risk of developing serologic evidence of infection was 36% to 62%. If the source patient was HBsAg positive with a negative HBeAg, the risk of developing clinical hepatitis from a needle injury was 1% to 6%, and the risk of developing serologic evidence of HBV infection was 23% to 37% (19). Blood exposure and percutaneous injuries are among the most efficient
modes of transmitting HBV since blood has the highest titers of HBV compared to other body fluids. HBsAg is also found in several other body fluids, including breast milk, CSF, stool, nasopharyngeal washings, saliva, semen, sweat, and synovial fluid (20). When investigations of outbreaks were performed, most infected HCWs could not recall a percutaneous injury but rather recalled caring for a patient who was HBsAg positive (21–24). HBV has been shown to survive in dried blood at room temperature for at least 1 week (25), and it is possible that contact with environmental surfaces is a potential risk for HBV transmission as has been shown in hemodialysis units (23,26–28).

The key factor in preventing HBV infection in the health care setting is vaccination. The OSHA Blood-borne Pathogen Standard requires employers to offer the HBV vaccine series to all employees who have exposure to blood-borne pathogens (11). The worker may opt out of the series but they can change their mind at any time and be given the vaccination series.

HBV vaccination is part of the routine immunization schedule for infants and children in the United States; by the age of 18 months, children who are up to date on their vaccinations have been fully immunized for HBV. As with childhood vaccination, the protocol for adult immunization consists of three doses of the vaccine given intramuscularly in the deltoid muscle. For those whose HBV vaccination series is interrupted, there is no need to restart the series over again. Vaccination can resume based on where in the series the patient was at the time of the interruption. Follow-up testing to document

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**FIGURE 10.1** Health care worker HIV postexposure prophylaxis. The strategy for source patient evaluation and PEP recommended by the CDC is shown by the blue pathway. The orange pathway details additional steps recommended by other guidelines (18) when the source patient’s rapid HIV test is negative. For both pathways, the choice of antiretrovirals for PEP (gray box) should be verified at www.aidsinfo.nih.gov, since the regimens change as new antiretrovirals become available.
The early detection of HCV infection and prevention of occupational exposure to HCV-infected blood, nor is there a report of immune globulin after an injury or mucous membrane exposure, washing the area with soap and water or flushing the mucous membrane site should be done immediately. Although data are limited on the survival of HCV in the environment, one study has suggested that HCV-RNA is resistant to drying at room temperature for at least 48 hours (32).

HCV is an RNA virus causing both acute and chronic hepatitis and is a risk factor for development of hepatocellular carcinoma. The virus is transmitted by direct contact with blood via percutaneous injury or mucous membrane exposure. Various routes of transmission have been identified. Intravenous drug abusers have the highest incidence of developing HCV. Sexual transmission occurs through blood exposure, not body fluids such as semen or vaginal secretions. Vertical transmission is also possible, although this occurs infrequently. Mucous membranes or skin exposures, both intact and nonintact, rarely result in transmission of HCV. As with any percutaneous injury or mucous membrane exposure, washing the area with soap and water or flushing the mucous membrane site should be done immediately. Although data are limited on the survival of HCV in the environment, one study has suggested that HCV-RNA is resistant to drying at room temperature for at least 48 hours (32).

The average incidence of HCV seroconversion after percutaneous injury from an HCV-positive source is 1.8% (0% to 7%) (33,34). There is no vaccine for HCV, and antibodies which form after infection are not protective. Studies have shown no beneficial effect of immune globulin after an occupational exposure to HCV-infected blood, nor is there a recommendation for HCV PEP with new HCV protease inhibitor agents (35,36). Postexposure management is aimed at the early detection of HCV infection and prevention of active disease (37). The source patient should be tested for HCV antibody and the HCW should be tested for both HCV antibody and ALT. Further management is dependent upon the results (Table 10.3). While it has been suggested that no further testing or follow-up is indicated for the HCW when the source patient is HCV-antibody positive and HCV RNA negative (38), given the lack of data for this specific clinical scenario, consultation with an HCV specialist should be considered.

**Herpes Viruses**

Human herpes viruses (HHVs) are DNA viruses that cause a variety of diseases in humans. HHVs include herpes simplex virus type 1 (HSV-1), herpes simplex virus type 2 (HSV-2), varicella-zoster virus (VZV), Epstein-Barr virus (EBV), cytomegalovirus (CMV), human herpes virus 6 (HHV-6), human herpes virus 7 (HHV-7), and human herpes virus 8 (HHV-8, HHV-9).

**TABLE 10.3 Health Care Worker Postexposure Management for Hepatitis C**

<table>
<thead>
<tr>
<th>Clinical Scenario</th>
<th>Recommended Follow-up for the HCW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source patient is HCV-antibody negative</td>
<td>No further testing or follow up</td>
</tr>
<tr>
<td>Source patient is unavailable or refuses testing</td>
<td>Follow up HCV antibody at 3 and 6 mo*</td>
</tr>
<tr>
<td>Source patient is HCV-antibody positive and HCV RNA negative</td>
<td>No further testing or follow-up*</td>
</tr>
<tr>
<td>Source patient is positive for both HCV antibody and HCV RNA and</td>
<td></td>
</tr>
<tr>
<td>Exposed worker is HCV-antibody negative</td>
<td>Consultation with an HCV specialist is recommended</td>
</tr>
<tr>
<td>Exposed worker tests positive for both HCV antibody and HCV RNA</td>
<td>Consultation with an HCV specialist is recommended</td>
</tr>
</tbody>
</table>

*HCV RNA should be measured in an exposed HCW if at any time the serum ALT becomes elevated to assess for acute HCV infection.

*Due to a lack of data for this clinical scenario, consultation with an HCV specialist should be considered.

**TABLE 10.2 Health Care Worker Postexposure Prophylaxis for Hepatitis B**

<table>
<thead>
<tr>
<th>Vaccination and/or Antibody Status of the Exposed HCW</th>
<th>Recommended Treatment When the Source Patient Is:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unvaccinated, incompletely vaccinated or nonimmune</td>
<td>HBsAg POSITIVE</td>
</tr>
<tr>
<td>Previously vaccinated, known responder</td>
<td>HBsAg NEGATIVE</td>
</tr>
<tr>
<td>Previously vaccinated, known nonresponder</td>
<td>Initiate or complete HBV vaccine series</td>
</tr>
<tr>
<td>Previously vaccinated, antibody response unknown</td>
<td>No treatment</td>
</tr>
<tr>
<td></td>
<td>HBIG &lt;2 separated by one month</td>
</tr>
<tr>
<td></td>
<td>HBIG &gt;1 and initiate revaccination</td>
</tr>
</tbody>
</table>

*Vaccinated with 3 or more doses.
*Based on available information on presentation. Responders are persons with previously documented adequate levels of serum antibody to HBsAg (≥10 mIU/mL).

**c**

*Nonresponders are persons with previously documented inadequate response to vaccination (serum anti-HBs <10 mIU/mL). Decision-making should not be delayed while awaiting anti-HBs test results at presentation.

*Vaccinated with 6 doses.

also known as Kaposi sarcoma–associated virus). In the United States, the seroprevalence of HHVs varies. CMV seroprevalence has been documented to be 60% to 90% in the adult population. EBV and VZV seroprevalence is in the 80% to 95% range, while HSV-1 and HSV-2 antibodies are found in 50% to 70% and 30% to 50% of the adult population, respectively. Several HHVs cause similar clinical syndromes including vesicular skin lesions as well as organ involvement. After resolution of the primary infection, all members of the herpesvirus family establish and maintain latency and can reactivate to cause asymptomatic viremia or clinically significant infection.

HSV-1 and HSV-2 cause vesicles either in the oral or genital area. Standard precautions are indicated for HSV-1 and HSV-2 except in the case of severe infection when contact precautions are indicated. HSV-1 and HSV-2 can be transmitted to the HCW by direct contact with the lesions when standard precautions have not been followed. Primary infection with VZV causes chickenpox and VZV reactivation causes herpes zoster (shingles). VZV can be transmitted both by direct contact with the vesicles of chickenpox and shingles as well as via respiratory secretions during disseminated VZV infection. The recommended approach to patients with chickenpox includes contact and airborne isolation. For patients with a localized shingles eruption, standard precautions should be used. Patients with disseminated herpes zoster infection should be placed on contact and airborne precautions. VZV-susceptible HCWs should not care for patients with VZV infections if immune HCWs are available (3).

One issue that arises in the clinical setting is the exposure of the nonimmune pregnant HCW to patients with CMV or VZV disease, as primary infection with either virus during pregnancy can be devastating to both mother and fetus. The transmission of CMV requires prolonged or recurrent close contact with any patient who is shedding the virus in body fluids and respiratory secretions. While there have been no conclusive recommendations regarding the precautions to be used by nonimmune pregnant HCWs with respect to patients with CMV, it would seem prudent to identify patients with active CMV infection so that these HCWs can be aware of the risk or be assigned to another patient. It must be recognized, however, that any patient can be shedding CMV without clinical signs or symptoms. This is the foundation for the CDC’s strong recommendation of meticulous adherence to hand hygiene and standard precautions when providing care for any patient in any health care setting at any time as the best way to prevent CMV transmission. In patients with proven or suspected CMV pneumonitis, mask and eye protection may be a consideration in the nonimmune pregnant HCW.

A vaccine is available for VZV; it is a live, attenuated vaccine that is given in two doses spaced 4 to 8 weeks apart and is 70% to 90% effective in preventing infection and 95% effective in preventing severe disease up to 10 years after administration. For PEP, the VZV vaccine should be given to nonimmune exposed HCWs as soon as possible, but certainly within 120 hours. For nonimmune exposed HCWs for whom the VZV vaccine is contraindicated (immunocompromised or pregnant HCWs), provide VZV immune globulin (VZIG) within 96 hours. If VZIG is unavailable, intravenous immune globulin may be substituted. The vaccine is recommended for nonpregnant women of childbearing age, but not for pregnant women, with a further stipulation that women should not become pregnant for at least 1 month after each dose of the vaccine (39).

EMERGING PATHOGENS

Emerging pathogens are defined as agents of infectious diseases whose incidence is rising or threatens to rise in a defined time period and location. Such microorganisms may be entirely new, such as HIV; a known organism that has changed, such as pandemic influenza or the SARS coronavirus; or, a known organism that has spread to a new region, such as chikungunya virus in the U.S. Regardless of the pathogen, the type of PPE necessary to prevent the HCW from becoming infected with or transmitting the organism depends on two factors: (1) the organism’s mode of transmission, and (2) the type of procedure(s) expected to be performed on the patient.

Ebola Viral Disease

Ebola is a filovirus, and the etiologic agent of EVD, first recognized during a 1976 outbreak in the Democratic Republic of Congo. More than 20 outbreaks have occurred since, mostly in central African countries. In 2014 to 2015, the largest recorded outbreak occurred in the west African nations of Sierra Leone, Guinea, and Liberia. As with prior outbreaks, many HCWs in the affected African nations contracted Ebola and died, a fact attributed to the difficulties in adhering to recommended infection control practices in a field hospital (40). However, transmission of Ebola to HCWs from an infected patient in an US hospital raised concern about appropriate PPE. Ebola is transmitted by contact with infected fluids or tissue with intact skin or mucous membranes, and by droplets that remained suspended in the air over short distances (<3 feet). By this logic, only contact and droplet precautions would be recommended (gown, gloves, surgical mask with eye protection). However, using this level of PPE, two HCWs in the United States contracted EVD (41). Given the complexity of medical care in acute care hospitals that includes AGPs such as intubation, and the inability to predict which patient will emergently need an AGP, the CDC recommends that HCWs wear an N95 respirator with eye protection or a PAPR in addition to gowns and gloves when caring for a suspected or confirmed EVD patient (40).

The CDC outlines a broad EVD preparedness plan that stresses early recognition as a key component of infection control and recommends four basic steps:

1. Initiate: Consider EVD when approaching a patient.
2. Identify: Assess the patient for EVD risk factors and evaluate for clinical signs and symptoms of EVD.
3. Isolate: If the assessment indicates the possibility of EVD, isolate the patient in a private room, limit staff contact, keep a log of persons who enter and leave the room, and don CDC-recommended PPE. An observer, ideally a trained observer, should be watching the PPE donning and doffing process to ensure that the HCW does not self-contaminate.
4. Inform: Alert hospital administration and the local or state health department.

Full details of the CDC’s plan are available at www.cdc.gov/vhf/ebola/. The CDC also recommends that hospitals develop an EVD preparedness plan based on the Health Care Facility Preparedness Checklist for EVD (42).
Measles

Re-emerging pathogens are those that had been considered eradicated or controlled in the past but, nonetheless, show increasing incidence. An example of this type of pathogen that threatens HCWs is measles, that was declared eliminated in the United States in 2000 (43). However, due to declining vaccination rates in the United States and abroad, and due to the increased number of travelers from measles-endemic part of the world, outbreaks occur annually. Measles is of concern in the health care setting as it spreads via the airborne route and is one of the most infectious organisms known; >85% of nonimmune persons who share living space with a measles patient will contract measles (44). Patients with known or suspected measles should be placed in an AI room. Nonimmune HCWs should not enter the room of a known or suspected measles patient if immune care providers are available. If a nonimmune HCW becomes exposed to measles, vaccination within 72 hours is indicated or immune globulin within 6 days should be given as PEP (45). As a vaccine-preventable disease, the best means of protection for HCWs is to be immunized with two doses of the measles–mumps–rubella (MMR) vaccine (45) (Table 10.1). The MMR vaccine is contraindicated in pregnancy. Exposed nonimmune pregnant HCWs should be offered intramuscular immune globulin of 0.25 mL/kg (40 mg IgG/kg) (2).

Vector-Borne Diseases

Vector-borne diseases are transmitted to humans by rodents and arthropods, usually insects. Several viral illnesses have recently emerged or re-emerged in the United States. The chikungunya virus appeared for the first time in the western hemisphere in 2013 and is now endemic in the Caribbean. Dengue virus is endemic in the Caribbean and Central and South America but was eliminated from the continental United States in 1946, except for sporadic cases along the southeastern border between Texas and Mexico. It re-emerged in Key West, Florida, between 2009 and 2010 (46). The mosquito vectors of chikungunya and dengue viruses are dengue fever in the United States, and local transmission in the southeastern United States was documented (46,47). In 1993, hantavirus, carried by rodents, was identified in residents in the southwestern United States and community as well as hospital settings. Although any patient with a resistant P. aeruginosa also often infects wounds particularly in burn patients (52), and contact precautions are indicated for those patients. All these MDR GNB, however, can gain access to the blood stream, leading to high mortality. For example, the mortality rate for a bloodstream infection with a carbapenem-resistant K. pneumoniae is >50% (53). While adherence to indicated precautions will mitigate against colonization or infection with MDR GNB, the primary means by which HCWs can protect themselves is by 100% compliance with hand hygiene.

Methicillin-Resistant Staphylococcus Aureus

Serious MRSA infections declined in hospitals between 2005 and 2011, but still remain a major problem in both hospital and community settings (54). MRSA infections in the hospital are associated with both longer stays and higher costs (55,56). The U.S. National Healthcare Safety Network (NHSN) 2009–2010 reported that >50% of blood and urinary catheter associated infections caused by S. aureus were MRSA, as well as >40% of ventilator-associated pneumonia and surgical site infections (57). Methicillin resistance is mediated by the acquisition of a staphylococcal cassette chromosome (SCC) that harbors the mecA gene. Expression of the mecA gene leads to an altered penicillin-binding protein, PBP2a, which has a reduced affinity for β-lactam antibiotics.

Prevention of transmission is the most important step in controlling MRSA. Patients with MRSA infection in the hospital should be placed on contact precautions. However, hand hygiene remains a critical factor in preventing spread. HCWs must perform hand hygiene before and after any contact with a patient, even when gloves are worn as part of standard or contact precautions. Mask and eye protection are indicated if aerosols will be generated. Environmental surfaces have been implicated in the transmission of MRSA. In a meta-analysis of 127 investigations with 33,318 HCWs, 4.6% were found to be colonized or infected with MRSA. Poor infection control practices were implicated in both acquisition and transmission of MRSA by HCWs (58).

Multidrug-Resistant Gram-Negative Bacteria

The bacteria of concern in this group include Klebsiella pneumoniae, Escherichia coli, Acinetobacter baumannii, Pseudomonas aeruginosa, Salmonella, and Enterobacter spp. Of particular concern are those Gram-negative bacteria (GNB) which have developed resistance to extended-spectrum beta lactam (ESBL) and carbapenem antibiotics (49). Some strains of these bacteria have acquired resistance to every antibiotic currently available in the United States, rendering the infections they cause untreatable. With the exception of P. aeruginosa, MDR GNB of clinical concern are primarily found in the gastrointestinal tract. Therefore, these patients should be placed on contact precautions. P. aeruginosa often infects the respiratory tract, and is a particular threat to cystic fibrosis (CF) patients (50). Although any patient with a resistant P. aeruginosa in a respiratory sample should be placed on droplet precautions, the 2013 Infection Prevention and Control Guideline for Cystic Fibrosis recommends that droplet and contact precautions be implemented when caring for all CF patients, regardless of respiratory tract culture results (51). P. aeruginosa also often infects wounds particularly in burn patients (52), and contact precautions are indicated for those patients. All these MDR GNB, however, can gain access to the blood stream, leading to high mortality. For example, the mortality rate for a bloodstream infection with a carbapenem-resistant K. pneumoniae is >50% (53). While adherence to indicated precautions will mitigate against colonization or infection with MDR GNB, the primary means by which HCWs can protect themselves is by 100% compliance with hand hygiene.

MULTIDRUG-RESISTANT ORGANISMS

Multidrug-resistant organisms (MDROs) are defined as microorganisms, predominantly bacteria, that are resistant to one or more classes of antimicrobial agents. Many are found in the community as well as hospital settings. Although the names of certain MDROs describe resistance to only one agent, such as MRSA or VRE, these pathogens are frequently resistant to additional antimicrobial agents. In 2013, for the first time, the CDC prioritized selected MDROs as “urgent”, “serious” and “concerning” to reflect the danger they represent in the hospital setting (49). However, the risk to HCWs from MDROs has not been well defined. Therefore the careful adherence to standard and isolation precautions by HCWs affords the best means of protection.
Vancomycin-Resistant Enterococcus

Enterococci are Gram-positive, facultative anaerobes that colonize the gastrointestinal tract. Two species in particular are associated with infection: Enterococcus faecalis and Enterococcus faecium. While many strains of enterococci remain susceptible to ampicillin, penicillin, and vancomycin, there has been an increase in the incidence of VRE. The NHSN reported that from 2009 to 2010, >80% of blood and urinary catheter associated infections and ventilator-associated pneumonia caused by E. faecium were resistant to vancomycin, as were >60% of surgical site infections (57). The rate of hospitalization with VRE doubled during the period 2003 to 2006 from 4.6 to 9.48 hospitalizations/100,000 population (59). VRE infections have been associated with adverse outcomes. The mortality rate from invasive VRE infections is significantly higher than infections with vancomycin-sensitive enterococci (60).

Risk factors for VRE colonization and infection include hospitalization longer than 72 hours, presence of significant underlying medical conditions (dialysis, cancer, transplant), previous antimicrobial treatment, care in the intensive care unit, and invasive devices (61). HCWs can become colonized in their gastrointestinal tracts, but the rate appears to be low and transmission to patients from this source has not been demonstrated. Transmission generally occurs from a colonized or infected patient to the hands of HCWs via direct contact with either the patient or contaminated environmental surfaces. VRE can survive from 30 minutes to 7 days on surfaces and equipment including stethoscopes (62). In general, the lack of proper hand hygiene appears to be the major factor in the spread of VRE from patient to HCW and back to other patients. Studies have shown a dramatic decrease in the incidence of VRE with the enforcement of proper hand hygiene, either with alcohol-based hand sanitizers or with routine hand washing (63). Proper environmental cleaning has been shown to also decrease the transmission of VRE (64). Patients who are known to be colonized or infected with VRE should be placed in contact isolation to prevent spread of the organism.

Clostridium Difficile

C. difficile is an anaerobic, spore-forming bacterium that causes pseudomembranous colitis, which manifests as diarrhea and can progress to toxic megacolon, sepsis, and death. An estimated 14,000 to 20,000 death/year are attributable to C. difficile infection (CDI) in the United States (65). CDI occurs when the enteric microbiota is altered by the use of antibiotics. Limiting the use and duration of antibiotics as well as choosing antibiotics with the narrowest appropriate spectrum is critically important to decreasing the risk CDI. The fluoroquinolones are one of the primary precipitating antibiotics, but cephalosporins, ampicillin, and clindamycin remain important predisposing antibiotics as well. However, every antibiotic has been associated with CDI. Suppression of gastric acid, advanced age, and severity of underlying illness are other factors associated with the increased risk (66).

The organism produces two toxins, an enterotoxin (toxin A) and a cytotoxin (toxin B), which are responsible for diarrhea and colonic inflammation. Serologic testing using an enzyme-linked immunosorbent assay (ELISA) for detection of toxin A or B has a sensitivity of only 50% to 70% and is being supplanted by C. difficile toxin B gene PCR; the sensitivity of this PCR test is >95%.
used to decide on discontinuation of isolation. The growth of MTB using specific liquid culture media is significantly faster. The average time-to-growth detection with liquid culture is 10 to 14 days. Newer diagnostic techniques include nucleic acid amplification tests (NAAT) for MTB DNA can be used on both AFB-positive and AFB-negative body fluids. The positive predictive value of NAAT for TB is >95% in AFB smear-positive cases (70,71). The sensitivity for AFB NAAT in smear-negative cases is in the range of 50% to 80%, and it is not sufficiently sensitive to exclude the diagnosis of MTB in smear-negative cases (72).

**Influenza Virus**

Influenza viruses are RNA viruses which cause an acute febrile illness usually occurring during the winter months. However, influenza viruses circulate with low prevalence throughout the year and cause infection at any time. The clinical manifestations include sudden onset of high fever, headache, myalgia, arthralgia, and cough. Transmission occurs via large droplets. Therefore, droplet precautions are used for patients who are admitted to the hospital with active or suspected influenza infection. While droplet precautions prevent spread, the mainstay of disease prevention is annual immunization. The Healthcare Infection Control Practices Advisory Committee (HICPAC) and ACIP recommend that all HCWs be vaccinated annually against influenza. The CDC recommends annual influenza vaccination for all persons aged 6 months and older with rare exceptions. Some hospitals have mandated annual influenza vaccination for all HCWs to prevent nosocomial transmission of influenza from HCWs to patients. For HCWs who opt out of influenza immunization, wearing a surgical mask may be required for all patient contacts during influenza season. There are two types of influenza vaccine. Because the live attenuated influenza vaccine results in replication of the virus in the respiratory epithelium with active viral shedding, the inactivated influenza vaccine is recommended for HCWs with direct patient contact.

Rapid influenza diagnostic test (RIDT) results are available in a little as 15 minutes. However, the sensitivity of RIDT ranges from 30% to 70%, and therefore, cannot exclude influenza infection if the result is negative, especially during periods when influenza disease prevalence is high. If the suspicion for influenza is high in a patient with a negative RIDT result, another respiratory specimen should be sent for influenza reverse transcriptase PCR (RT-PCR) testing if available. While awaiting test results, droplet precautions should be continued and antiviral treatment instituted. If RT-PCR testing is not available, the decision to treat is made on a clinical basis. Many hospitals will continue droplet precautions for any patient with an influenza-like illness to prevent transmission of other respiratory viruses (3).

**Bordetella Pertussis**

Pertussis, a respiratory illness commonly known as whooping cough, is a highly contagious disease caused by the bacterium *Bordetella pertussis*. Pertussis is spread by droplets created when infected person’s cough or sneeze. Therefore, any patient with known or suspected pertussis should be placed in droplet isolation. Neither infection nor immunization produces lifelong immunity to pertussis as they do for diseases such as measles, indicating that previously immunized HCWs may not be fully protected against pertussis. In 2005, 2010, and 2012, substantial pertussis epidemics occurred. Cycles of pertussis occur and it is known that B. pertussis is continuing to circulate in a manner similar to that of the pre-vaccine era (73). Despite the possible limitations of pertussis immunization, the best way to protect against pertussis remains vaccination. PEP with a macrolide or trimethoprim-sulfamethoxazole is recommended for HCWs who have unprotected exposure to pertussis and are likely to expose a patient at risk for severe pertussis, including hospitalized neonates and pregnant women. Other HCWs can receive either PEP or be monitored daily for 21 days after pertussis exposure and treated at the onset of signs and symptoms suggestive of pertussis (2).

**Neisseria Meningitidis**

*Neisseria meningitidis* is the causative agent of meningococcal disease including meningitis and meningococcemia. The organism is transmitted by large droplets and patients with known or suspected meningococcal infection should be placed in droplet isolation. HCW who adhere to droplet precautions do not require antimicrobial chemoprophylaxis. PEP is only advised for HCWs who have had intensive, unprotected contact (not wearing a mask) with infected patients while performing mouth-to-mouth resuscitation, endotracheal intubation, endotracheal tube management, or close examination of the oropharynx. In HCWs who meet criteria for PEP, it is important to begin within less than 24 hours because secondary cases of *N. meningitidis* can occur rapidly after exposure. CDC recommendations for meningococcal PEP in adults, excluding pregnant and lactating women, include oral rifampin or oral ciprofloxacin. Rifampin may affect the reliability of oral contraceptives and female HCWs should be advised to use an alternative contraceptive method while taking rifampin. Pregnant or lactating women can receive a single intramuscular dose of ceftriaxone. Meningococcal vaccine has been used successfully to control community outbreaks but its use is not recommended for PEP in health care settings (74).

**Respiratory Syncytial Virus**

Respiratory syncytial virus (RSV) is a common respiratory virus that usually infects infants and children, resulting in a high rate of immunity in adults (75). RSV primarily causes a cold-like illness with or without fever but can also cause bronchitis, croup, and lower respiratory infections including bronchiolitis and pneumonia. It is spread by droplets and patients with known or suspected RSV infection should be placed in droplet isolation. However, nosocomial transmission appears to be exceedingly rare (76). The CDC recommends HCWs adhere to droplet precautions, and there is no PEP.

**Coronaviruses**

Coronaviruses (CoV) are common infectious agents that cause respiratory tract infection. First identified in the 1960s, there are now six coronaviruses known to infect humans including SARS-CoV (causing severe acute respiratory syndrome or SARS) and MERS-CoV (causing Middle East respiratory syndrome, or MERS). SARS-CoV was first recognized in China in November 2002, causing a worldwide outbreak between 2002 and 2003 with 8,098 probable cases and 774 deaths (77). Since 2004, there have been no reported cases of SARS-CoV infection.
MERS-CoV was first reported in Saudi Arabia in 2012 (78). This novel CoV causes a severe acute respiratory illness with a mortality rate of 30% to 40%. Diagnosis is made by RT-PCR, available in the United States through the CDC (79); no specific treatment is currently available. MERS-CoV, like other CoVs, is thought to spread by respiratory droplets, both large droplet and droplet nuclei, which are generated by infected persons through coughing and sneezing and by AGPs. However, the precise ways the virus spreads are not fully understood. Person-to-person spread of MERS-CoV, usually after close contact, as such caring for or living with an infected person, has been well documented. Infected persons have spread MERS-CoV to others in health care settings, such as hospitals, including to HCWs. These viruses may also be transmitted by touching contaminated objects or surfaces then touching the mouth, nose, or eyes prior to performing hand hygiene. Patients with known or suspected SARS-CoV or MERS-CoV should be placed in an airborne isolation room with contact precautions. N95 or higher respiratory protection (PAPR) should be worn by HCWs and meticulous hand hygiene performed (80).

Key Points

- Hand hygiene is the most important intervention that can be performed to prevent illness in the health care practitioner.
- Standard precautions apply to contact with every patient.
- The CDC designates three levels of precautions in addition to standard precautions: airborne, droplet, and contact, and each delineates the PPE to be used by the health care practitioner.
- Additional precautions may be required based upon the nature of the task being performed and a patient’s colonizing or infecting organism, symptoms, or other conditions.
- Certain vaccinations are recommended for all health care practitioners to prevent illness after exposures to infectious agents.
- Exposed health care practitioners should receive rapid evaluation and receive postexposure prophylaxis (if available) rapidly after a blood or body fluid exposure.

References
