Lessons learned: Protection of healthcare workers from infectious disease risks

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Objective: **To summarize current concepts on preventing occupationally acquired infections in healthcare workers.**

Design: **Review of the pertinent medical literature.**

Settings: **Focus on healthcare workers practicing in acute care hospitals, especially intensive care units.**

Subjects: **Healthcare workers.**

Measurements and Main Results: **Key components of an effective infection control program include the following: 1) preexposure immunization with vaccines to prevent mumps, measles, rubella, varicella, pertussis, hepatitis B, and viral influenza; 2) adherence to standard precautions when providing patient care, especially the performance of hand hygiene before and after patient care; 3) rapid evaluation and initiation of appropriate isolation precautions for patients with potentially communicable diseases; 4) proper use of personal protective equipment such as masks, N95 respirators, eye protection, and gowns when caring for patients with potentially communicable diseases; and 5) evaluation of personnel with exposure to communicable diseases for receipt of postexposure prophylaxis.**

Conclusions: **Risks of acquisition of infectious diseases by healthcare workers can be minimized by adherence to current infection control guidelines. (Crit Care Med 2010; 38[Suppl.]:S306–S314)**

KEY WORDS: occupational health; healthcare workers; bloodborne pathogens; isolation precautions; postexposure prophylaxis

Despite major advances in the prevention and treatment of infectious diseases (1), infectious diseases still remain a common reason for admission to U.S. hospitals (2). Further, healthcare-associated infections are a frequent cause of morbidity and mortality among hospitalized patients. The Centers for Disease Control and Prevention estimates that healthcare-associated infections account for 1.7 million infections and 99,000 associated deaths each year (3). The risk of acquisition of an infectious disease during the care of a patient is a major reason physicians have been held in such high regard by the public. While this risk can be minimized by adherence to infection control guidelines, it cannot be entirely eliminated. For example, more than 20% of persons who acquired severe acute respiratory syndrome were healthcare workers (4). In Vietnam, Canada, and Singapore, healthcare workers accounted for 57%, 43%, and 41% of severe acute respiratory syndrome patients, respectively (4).

Protection of healthcare workers from acquisition of infectious diseases can be achieved by adherence to established infection control guidelines including the following. 1) Assuring healthcare workers are immune to vaccine-preventable diseases including mumps, measles, rubella, varicella, pertussis, hepatitis B, and viral influenza (5–9). 2) Adherence to standard precautions (10) when providing patient care, especially the performance of hand hygiene before and after patient care (11). 3) Rapid evaluation and appropriate isolation of patients with potentially communicable diseases (10). 4) Proper use of personal protective equipment such as masks, N95 respirators, eye protection, and gowns when caring for patients with potentially communicable diseases (10). 5) Evaluation of personnel with exposure to communicable diseases for receipt of postexposure prophylaxis (6–8).

This paper will review the infection control recommendations for preventing and managing infectious disease exposures with a focus on critical care units.

Pre-Exposure Prophylaxis: Assuring Immunity to Vaccine-Preventable Diseases

Immunity to vaccine-preventable diseases for which transmission has been shown in healthcare facilities (Table 1) is recommended by the Centers for Disease Control and Prevention (5–7), the Healthcare Infection Control Practices Advisory Committee (5–7), the Advisory Committee on Immunization Practices (5, 7), the American Academy of Pediatrics (8), and infection control experts (9). Failure to assure immunity to vaccine-preventable diseases has led to large institutional outbreaks in healthcare facilities, morbidity and mortality among hospitalized patients, and even morbidity and mortality among healthcare workers (9). Healthcare workers have become infected with vaccine-preventable diseases through patient care but have also served to initiate or propagate hospital outbreaks.

Occupational health physicians responsible for the care of healthcare workers should be familiar with the general guidelines for immunization of healthcare workers (5–8) and with vaccine-specific recommendations of the Advisory Committee on Immunization Practices. Healthcare workers should be broadly defined to include all persons working within a healthcare facility, whether or not they provide direct patient care (e.g., physicians, nurses, ancillary personnel, students, contractors, and other

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Table 1. Vaccine-preventable diseases for which immunity should be assured

Mumps
Measles
Rubella
Varicella
Pertussis
Hepatitis B (personnel with potential exposure to blood or contaminated body fluids)
Influenza

support personnel). Written documentation of previous immunizations should always be required. Persons who do not have such documentation should be serologically evaluated for immunity, which can be done for mumps, measles, rubella, varicella (serology will detect wild-type infection but is not accurate for demonstrating vaccine-induced immunity), and hepatitis B, or they should receive appropriate immunization. Healthcare facilities should consider making demonstration of immunity a condition of employment.

Mumps, measles, and rubella

Mumps, measles, and rubella were once common infectious diseases of children in the United States. However, routine use of mumps, measles, and rubella vaccine (MMR) has resulted in the near elimination of these diseases in the United States. The Centers for Disease Control and Prevention reported the following numbers of infections in 2008: mumps 545, measles 140 (115 indigenous, 25 imported), and rubella 16 (12). Despite the near elimination of these diseases, community outbreaks of mumps (13, 14) and measles (15, 16) have continued to occur, especially among persons with religious or personal objections to immunizations. These community outbreaks have resulted in nosocomial transmission of infection (16).

The Advisory Committee on Immunization Practices recommends that all healthcare personnel have presumptive evidence of immunity to mumps, measles, and rubella (17). Immunity may be demonstrated by documentation of appropriate immunizations (mumps, two doses; measles, two doses; rubella, one dose), laboratory evidence of immunity or laboratory confirmation of disease (mumps, measles, rubella), or birth before 1957 (mumps, measles, rubella). Unless documented immune, women born before 1957 of childbearing potential should receive one dose of rubella vaccine. For unvaccinated personnel born before 1957 who lack laboratory evidence of mumps, measles, and/or rubella immunity or laboratory confirmation of disease, healthcare facilities should consider vaccinating personnel with two doses of MMR. For unvaccinated persons born before 1957 who lack laboratory evidence of mumps, measles, and/or rubella immunity or laboratory confirmation of disease, healthcare facilities should recommend vaccinating personnel with two doses of MMR during an outbreak of mumps or measles and one dose during an outbreak of rubella.

Varicella

The incidence of varicella in the United States has declined substantially since the introduction of the live attenuated varicella vaccine in the United States in 1995 (18). The varicella vaccination program in the United States has reduced disease incidence by 57% to 90%, hospitalizations by 75% to 88%, deaths by greater than 74%, and direct inpatient and outpatient medical expenditures by 74% (19).

Varicella is a highly contagious disease spread by airborne transmission. Multiple outbreaks have occurred in healthcare facilities (9). While generally a benign disease in childhood, varicella has increased morbidity and mortality in immunocompromised patients. Further, infection in pregnant women may lead to the fetal varicella syndrome. Importantly, zoster is also infectious via the airborne route and may lead to acquisition of varicella. For this reason, the Advisory Committee on Immunization Practices recommends that all healthcare workers be immune to varicella (20). Immunity may be assured by administration of two doses of varicella vaccine or a positive serology result. The current Advisory Committee on Immunization Practices Guideline is permissive in allowing institutions to consider as immune personnel with a history of varicella or zoster. However, personnel with a negative or uncertain history should either receive vaccine or be serologically tested for immunity to varicella.

Pertussis

In 2008, 13,278 cases of pertussis were reported to the Centers for Disease Control and Prevention (12). However, it has been estimated that there are between 800,000 and 3.3 million cases of pertussis in the United States each year (21). Children under 1 yr of age are the most likely to develop severe disease requiring hospitalization. However, disease is common in both adolescents and young adults. Studies of prolonged cough illnesses in adolescents and adults revealed that 13% to 20% are a result of *Bordetella pertussis* infection (21). Outbreaks of pertussis in healthcare facilities continue to be reported (22–26) and may involve patients in intensive care units, especially neonatal units (22). Outbreaks have been initiated and propagated by infected healthcare workers.

With the licensure in 2005 of a tetanus toxoid, diphtheria toxoid, and acellular pertussis vaccine (Tdap) formulated for adolescents and adults, immunization of persons aged 11 to 64 yrs became possible. The Advisory Committee on Immunization Practices and the Healthcare Infection Control Practices Advisory Committee both recommend that all healthcare workers receive Tdap if they have no contraindications and have not received a tetanus-diphtheria booster within the previous 2 yrs (27). Previous pertussis disease is not a contraindication to immunization.

Hepatitis B

Hepatitis B is a global public health problem. It is estimated that there are more than 350 million hepatitis B carriers in the world. In the United States, the prevalence of hepatitis B carriers has been reported as 0.30% (28) but this is likely an underestimate due to underrepresentation of high-risk groups such as Asian and Pacific Island populations. Before the widespread use of hepatitis B vaccine among healthcare workers, the prevalence of hepatitis B markers was two- to three-fold higher among healthcare workers than among the general public. The frequency of markers of hepatitis B infection correlated with the number of years spent in health care and the degree of exposure to blood. Healthcare workers are at risk of acquiring hepatitis B from patients as a result of sharp injuries. Data from 2006 have revealed that the overall rate for percutaneous sharp object injuries was 16.88 per 100 occupied beds per year for nonteaching hospitals and 44.32 injuries per 100 occupied beds per year for teaching hospitals (29). Infected healthcare workers pose a risk to their patients. More than 20 reports have documented healthcare

worker-to-patient transmission of hepatitis B (30).

Because healthcare workers were at higher risk for hepatitis B than the general public, the Occupational and Safety Health Administration in 1991 required that all healthcare workers with reasonably anticipated exposure to blood be offered hepatitis B vaccine (31). Recent studies suggest that this strategy has been highly successful in reducing hepatitis B infection among healthcare workers, with a 95% decline in the incidence of hepatitis B infection between 1983 and 1995. However, a recent survey demonstrated that only about 75% of healthcare workers have been vaccinated against hepatitis B (32). All healthcare workers with potential exposure to blood or contaminated body fluids should receive hepatitis B vaccine (33). Adequate immunization consists of three doses of hepatitis B vaccine. One to 2 mos (acceptable range, 1–6 mos) following the 3rd dose of vaccine, an anti-HBsAg level should be determined using a quantitative test. Persons can be considered immune if their anti-HBsAg level is $\geq$10 mIU/mL. Persons who do not respond adequately to three doses of vaccine should be reimmunized with another three doses of hepatitis B vaccine and have their anti-HBsAg level retested. Nonresponders (i.e., anti-HBsAg $<$10 mIU/mL) should be tested for the presence of active hepatitis B by assessing HBsAg. Nonresponders who are not chronic hepatitis B carriers should be counseled that they may receive hepatitis B immunoglobulin for postexposure prophylaxis if they have a contaminated sharp injury from a patient with chronic hepatitis B.

Influenza

Influenza infection causes an average of 36,000 excess deaths and nearly 226,000 excess hospitalizations annually in the United States (34). Contributing to this disease burden is the fact that influenza can be transmitted in healthcare settings from patient to patient, from visitor to patient, from patient to healthcare worker, and from healthcare worker to patient (35). Healthcare-associated transmission of influenza has been documented in many different patient populations and clinical settings, including neonatal intensive care units, pediatric wards, adult and pediatric transplant units, infectious disease units, general medical wards, geriatric wards, oncology units, and emergency departments (35). In many of the healthcare-associated outbreaks, infections occurred in unvaccinated healthcare workers and healthcare workers were linked epidemiologically to the transmission of influenza.

Effective measures that can reduce the risk of healthcare-associated influenza during influenza season include adherence to universal respiratory and cough hygiene, placement of patients with influenza-like illness on droplet precautions at the point of first encounter, use of rapid diagnostic tests for patients and healthcare workers with suspected influenza, prompt treatment of hospitalized patients diagnosed with influenza, provision of antiviral chemoprophylaxis for healthcare workers and patients under selected conditions, and restriction of ill healthcare workers from patient care (35). However, the most effective way to prevent healthcare-associated transmission of influenza is vaccination of all healthcare workers annually with influenza vaccine (34). Either inactivated or live-attenuated vaccine may be used, but workers receiving live-attenuated vaccine should not work with patients housed in a protected environment (i.e., a stem cell transplant unit) for 7 days after immunization (34).

Recently, a novel H1N1 strain has emerged, resulting in a worldwide influenza pandemic (36, 37) All healthcare workers should also receive one of the recently released 2009 H1N1 vaccines as per recommendations of the Advisory Committee on Immunization Practices (38, 39). Thus, for the 2009–2010 influenza season, healthcare workers should receive the trivalent seasonal influenza vaccine and the monovalent H1N1 2009 vaccine. For the 2010–2011 influenza season, it is likely that only a single dose of a multivalent influenza vaccine will be recommended.

Isolation Precautions to Prevent Transmission of Infectious Agents

Standard precautions

Standard precautions are used with every patient during the delivery of health care. They are based on the assumption that every person is potentially infected or colonized with an organism that could be transmitted in the healthcare setting. Hand hygiene and use of protective personal equipment are the key elements of standard precautions.

Hand hygiene should be performed before and after direct contact with a patient (10, 11). Hand hygiene should also be performed after contact with a potentially contaminated environmental surface (e.g., inanimate object in the immediate vicinity of the patient), contact with body fluids (i.e., blood, excretions, secretions), or moving from a contaminated body site to a clean body site during patient care. Hands should be washed with soap and water (or an antimicrobial soap and water) when visibly dirty, contaminated with proteinaceous material, or visibly soiled with blood or body fluids. If hands are not visibly soiled, hand hygiene may be performed using an alcohol-based product. Multiple studies have validated that alcohol-based hand products are more effective in removing transient flora than soap and water (40, 41). Fifteen seconds of hand hygiene provides adequate decontamination (41, 42). Because alcohol is ineffective in inactivating spores, soap and water (or an antimicrobial soap and water) should be used if the hands are potentially contaminated with spores (e.g., *Clostridium difficile*, *Bacillus anthracis*) (43, 44). Alcohol may also have reduced effectiveness for eliminating nonenveloped viruses, so soap and water (or an antimicrobial soap and water) should be considered if the hands are potentially contaminated with norovirus (45).

Personnel protective equipment consists of gloves, gowns, surgical masks, N95 respirators, and eye shields. The proper use of personal protective equipment is thoroughly described in the current Centers for Disease Control and Prevention Guideline on Isolation Precautions (10). Gloves should be worn whenever it can be reasonably anticipated that contact with blood or other potentially infectious materials, mucous membranes, nonintact skin, or potentially intact skin (e.g., of a patient incontinent of stool or urine) could occur. Gloves should be removed following patient contact using proper technique to prevent hand contamination. Hand hygiene should be performed after glove removal. Gloves should always be changed between care of different patients.

A gown appropriate to the task should be worn to protect skin and prevent soiling or contamination of clothing during procedures and patient care activities when contact with blood, body fluids, se-

cretions, or excretions is anticipated. Gowns should be removed before leaving the patient's environment. Masks, and if needed eye shields, should be used to protect the mucous membranes of the eyes, nose, and mouth during procedures and patient care activities that are likely to generate splashes or sprays of blood, body fluids, secretions, and excretions. One should select masks, goggles, face shields, and combinations of each according to the need anticipated by the task performed. During aerosol-generating procedures (e.g., bronchoscopy) in patients not suspected of being infected with an agent for which respiratory protection is otherwise recommended (e.g., *Mycobacterium tuberculosis*), wear one of the following: a face shield that fully covers the front and sides of the face, a mask with attached shield, or a mask and goggles (in addition to gloves and gowns).

Transmission-based precautions

Rapid institution of isolation precautions coupled with the use of personal protective equipment by healthcare personnel is a key element in preventing patient-to-patient transmission of infectious diseases and acquisition of infectious diseases by healthcare workers (Table 2). The currently recommended isolation precautions are based on the mode of transmission of the infectious pathogen (10).

Patients with airborne transmitted diseases (e.g., tuberculosis, measles, varicella) are placed on airborne isolation. This consists of a private room under negative pressure (i.e., air flows from the corridor into the room) with direct outexhausted air. In existing facilities, it is recommended that such rooms have at least six air exchanges per hour, while new or renovated rooms should have at least 12 air exchanges per hour. The door should be kept closed to maintain the air pressure differentials. If patients on airborne precautions must leave their room for necessary medical procedures, they should be instructed to wear a surgical mask and observe respiratory hygiene/cough etiquette. Personnel entering an airborne isolation room of a patient with tuberculosis (infectious pulmonary or laryngeal tuberculosis), smallpox, or viral hemorrhagic fevers should wear a fit-tested National Institute for Occupational Safety and Health-approved N95 or higher level respirator for respiratory protection. Healthcare workers entering the room of a patient with other airborne transmitted diseases (e.g., measles, varicella, disseminated zoster) may wear either an N95 respirator or a surgical mask.

Patients with droplet-transmitted diseases (e.g., pertussis, invasive meningococcal infection) should be placed in a single room when available. Ideally, the room should be negative or even pressure. Personnel should don a mask before entry into the patient's room or cubicle. For patients with severe acute respiratory disease syndrome, avian influenza, or pandemic influ-

Table 2. Recommended isolation precautions for selected diseases

Abscess: draining, major (contact)
Abscess: draining, minor or limited (standard)
Aspergillosis (standard)
Cellulitis (standard)
Closed cavity infection: with or within open drain in place (standard)
Conjunctivitis: acute bacterial including gonococcal (standard)
Creutzfeld-Jakob disease: including CJD and vCJD (standard)
Cytomegalovirus infection: including neonates and immunocompromised persons (standard)
Epstein-Barr infection (standard)
Furunculosis: adult, staphylococcal (standard)
Furunculosis: infants and children, staphylococcal (contact)
Gangrene: gas gangrene (standard)
Gastroenteritis: adenovirus, *Campylobacter*, *Salmonella*, *Shigella*, cholera, *Escherichia coli* O157:H7, rotavirus (standard but use contact precautions for diapered or incontinent persons or to control institutional outbreaks)
Gastroenteritis: *Clostridium difficile* (contact)
Hepatitis A (standard but use contact precautions for diapered or incontinent persons)
Hepatitis B: acute or chronic (standard)
Hepatitis C: acute or chronic (standard)
Herpes simplex: encephalitis (standard)
Herpes simplex: mucocutaneous, disseminated or primary, severe (contact)
Herpes simplex: recurrent oral, skin or genital (standard)
Herpes zoster: disseminated or localized disease in an immunocompromised person (contact, airborne)
Herpes zoster: localized disease in a person with intact immune system and with lesions that can be contained/covered (standard)
Influenza: seasonal (droplet)
Legionnaires disease (standard)
Lice: head, pediculosis (contact)
Lice: body or pubic (contact)
Lyme disease (standard)
Malaria (standard)
Measles (airborne)
Mycobacterium tuberculosis: active pulmonary disease, laryngeal, draining lesion (airborne)
Mycobacterium tuberculosis: nonpulmonary sites, latent infection (standard)
Multidrug resistant organisms: methicillin-resistant *Staphylococcus aureus*, vancomycin-resistant *Enterococcus* spp., ESBL-producing Gram-negative bacilli, multidrug-resistant Gram-negative bacilli (contact for both colonization and infection)
Mumps (droplet)
Nontuberculous mycobacteria (standard)
Parvovirus B19 (droplet)
Pneumonia: *Haemophilus influenzae* type b in infants and children, meningococcal, *Mycoplasma*, group A streptococcal (droplet)
Pneumonia: adenovirus (droplet, contact)
Pneumonia: respiratory syncytial virus, *Burkholderia cepacia* in patients with cystic fibrosis (contact)
Pertussis (droplet)
Rickettsial diseases (standard)
Rubella (droplet)
Streptococcal disease, group A: skin, wound or burn, major (contact, droplet)
Streptococcal disease, group A: skin, wound or burn, minor or limited (standard)
Syphilis (standard)
Tularemia (standard)
Varicella (airborne, contact)
Viral hemorrhagic fevers: Lassa, Ebola, Marburg, Crimean-Congo (standard, contact, airborne)
Zygomycosis: phycomycosis, mucomycosis (standard)

CJD, Creutzfeld-Jakob disease; vCJD, variant Creutzfeld-Jakob disease; ESBL, extended-spectrum beta-lactamase.

Adapted from reference 10. See reference 10 for additional diseases and complete information on isolation precautions and duration of isolation.

Table 3. Diseases for which postexposure prophylaxis is available

Animal bite (antibiotics, tetanus vaccine if indicated)
Anthrax (doxycycline, ciprofloxacin, vaccine?)
Diphtheria (penicillin G benzathine, or erythromycin)
Hepatitis A (vaccine, IG)
Hepatitis B (vaccine, HBIG)
Human bite (antibiotics, tetanus vaccine if indicated)
Human immunodeficiency virus (antivirals)
Influenza A, seasonal and novel H1N1, and B (oseltamivir, zanamivir, or rimantadine)
Measles (vaccine, IG)
Meningococcal disease (ceftriaxone, rifampin, ciprofloxacin, or azithromycin)
Pertussis (azithromycin, clarithromycin, erythromycin, or trimethoprim-sulfamethoxazole)
Plague (doxycycline, ciprofloxacin)
Rabies (vaccine, HRIG)
Smallpox (also monkeypox)(vaccine, VIG?)
Syphilis (penicillin G benzathine)
Tuberculosis (antibiotics for PPD conversion)
Varicella (vaccine, VariZIG if available and indicated, IG, acyclovir?)
Zoster (vaccine, VariZIG if available and indicated, IG, acyclovir?)

IG, serum immunoglobulin; HBIG, hepatitis B immunoglobulin; HRIG, human rabies immunoglobulin; VIG, vaccinia immunoglobulin; PPD, purified protein derivative; VariZIG, varicella immunoglobulin (FFF Enterprises, Temecula, CA).

Postexposure prophylaxis should only be used after a complete evaluation. Some diseases require prophylaxis with multiple agents.

enza, healthcare providers should refer to the latest recommendations on the web page for the Centers for Disease Control and Prevention (www.cdc.gov). A recent study demonstrated that surgical masks are as effective as an N95 respirator in preventing nosocomial acquisition of seasonal influenza (46).

Contact precautions are used for patients with known or suspected infections or evidence of syndromes that represent an increased risk for contact transmission (e.g., respiratory syncytial virus, methicillin-resistant *Staphylococcus aureus* [MRSA]). Healthcare workers should don gloves and a gown before entering the room of a patient on contact precautions. Hand hygiene should also follow glove removal. Specific recommendations on the use of contact precautions in patients with multidrug-resistant pathogens are available (47).

Postexposure Prophylaxis

Postexposure prophylaxis is available for many diseases (Table 3) (6, 48, 49). Unfortunately, postexposure prophylaxis is not available for hepatitis C, mumps, parvovirus B19, rubella, and severe acute respiratory syndrome. Postexposure prophylaxis is provided depending on the disease by an antimicrobial, vaccine, or immunoglobulin preparation. For some diseases, more than one prophylactic agent may be recommended. However, it is important to remember that prevention (i.e., pre-exposure immunization and use of personal protective equipment) is superior to postexposure prophylaxis.

Any healthcare worker with a potential exposure to a communicable disease should be evaluated by their occupational health provider. Employees generally need to complete an incident report in order to be covered by their worker's compensation program. Key elements of an exposure evaluation include the following. First, whether the source patient is infected and infectious at the time of exposure is evaluated. Thus, a patient with varicella would not be considered infectious once the skin lesions were dried and crusted. Exposure to a patient with tuberculous disease confined to a closed organ space (e.g., bone, testes, adrenals, brain) would not be considered capable of transmitting infection. Second, whether transmission was possible is evaluated. If the "exposed" healthcare worker was wearing appropriate personal protective equipment (e.g., mask for a patient with measles) then infection could not result. Some diseases (e.g., pertussis and invasive meningococcal disease) are spread by large droplets, and direct contact with infectious secretions must occur for transmission (e.g., intubation or suctioning of the patient without wearing a mask for N95 respirator). For these diseases, merely being in vicinity would not constitute an exposure. Third, employee susceptibility to the disease of concern is determined. Demonstration of adequate immunization for mumps, measles, rubella, and varicella would make it highly unlikely that the healthcare worker could acquire disease. If the occupational health records did not provide adequate evidence of immunity, serological testing could be performed. However, for some pathogens (e.g., *Neisseria meningitidis*, *Bordetella pertussis*), appropriate immunizations are not considered proof of immunity, and postexposure antimicrobial prophylaxis should be offered regardless of immunization history. Fourth, an assessment is made whether prophylaxis is available and appropriate. For some diseases (e.g., varicella), postexposure prophylaxis is recommended only for susceptible healthcare workers at high risk for complications if they acquire disease (e.g., pregnant, immunocompromised). Fifth, if multiple prophylactic therapies are available (e.g., for invasive meningococcal infection, adequate prophylaxis can be provided by ciprofloxacin, ceftriaxone, or rifampin), then an assessment should be made as to what therapy is the most effective and safest based on the healthcare worker's medical history. Finally, appropriate follow-up should be provided.

Healthcare workers for whom postexposure prophylaxis is recommended should be advised about the risk of disease acquisition if they decline postexposure prophylaxis, including the risk of transmitting infection to their close contacts. They should also be informed of the risks (i.e., potential side effects) and benefits (i.e., degree of protection) of the recommended postexposure regimen and of any alternative regimens. Finally, any follow-up medical evaluations that can reduce the risks should be described.

Susceptible healthcare workers who are exposed to selected infectious diseases may have to be furloughed to prevent the possibility of their initiating an outbreak in the medical facility. Diseases for which furlough of susceptible healthcare workers should be considered include measles, mumps, rubella, and varicella. Healthcare workers with communicable diseases (e.g., mumps, measles, rubella, varicella, influenza, pertussis, group A streptococcal pharyngitis, tuberculous disease, and invasive meningococcal infection) should be furloughed until noninfectious.

Bloodborne pathogens

More than 30 different pathogens have caused documented occupational infection following exposure to blood or body

fluids in healthcare workers (50). The most important of these are hepatitis B virus (HBV), human immunodeficiency virus (HIV), and HCV. Following a percutaneous sharp injury, the risks of transmitting these diseases if the source is infected and employee susceptible are as follows: hepatitis B, 1% to 31%, depending on hepatitis B "e" antigen (or HBV DNA viral load) status of the source patient; HIV, 0.3%; and hepatitis C, 1.8% (51). Pre- and postexposure prophylaxis is available to prevent hepatitis B and postexposure prophylaxis is available to prevent HIV. However, there is no currently available vaccine to prevent hepatitis C, and no therapy (e.g., immunoglobulin) has demonstrated value to prevent hepatitis C after an exposure.

Minimizing risks to healthcare workers for the acquisition of bloodborne pathogens should be an integral part of the infection control and occupational health programs in all healthcare facilities and is the personal responsibility of all healthcare personnel. Healthcare workers should use validated engineering controls to minimize the risk of sharp injuries, including needleless connectors and infusion sets, safety needles (e.g., self-sheathing needles), double gloving when there is a high risk of glove puncture (e.g., orthopedic surgery), blunted suture needles for closing fascia, and plastic rather than glass capillary tubes. Healthcare workers should also use work practice controls (e.g., never recap syringes) and personal protective equipment (e.g., gloves, masks, face shields, gowns) to prevent percutaneous injuries and exposure of nonintact skin or mucous membranes to blood or other potentially infectious body fluids.

The risk that a healthcare worker will acquire a bloodborne pathogen as the result of an occupational exposure will depend upon several things, including the following: 1) the prevalence of the infectious agent in the general population and within the patient population served by the healthcare facility; 2) the frequency of exposures capable of transmitting the infectious agent; 3) the nature of the exposure and efficiency of transmission for that exposure (i.e., exposure via percutaneous, mucosal, or nonintact skin); 4) which virus(es) is present in the contaminated fluid and the titer of virus (viral load) in that fluid; and 5) the availability and efficacy of pre- and postexposure prophylaxis.

Exposures to blood or other body fluids that may place a healthcare worker at risk for infection from a bloodborne pathogen and therefore require consideration of postexposure prophylaxis are as follows: a percutaneous injury (e.g., a needlestick or cut with a sharp object), or contact of mucous membrane or nonintact skin (e.g., exposed skin that is chapped, abraded, or afflicted with dermatitis). Body fluids demonstrated to transmit HIV include semen, vaginal secretions, other body fluids contaminated with visible blood. Potentially infectious (undetermined risk for transmitting HIV) body fluids include cerebrospinal, synovial, pleural, peritoneal, pericardial, and amniotic fluids. Fluids that are not considered infectious unless they contain blood include feces, nasal secretions, saliva, sputum, sweat, tears, urine, and vomitus. The same classification is used to determine the need for postexposure evaluations for hepatitis B.

Any healthcare worker exposed to blood or a potentially contaminated body fluid should immediately cleanse the exposed site. For skin exposures, the area should be washed with soap and water. Small wounds and punctures may be cleansed with an antiseptic such as an alcohol-based hand hygiene agent, since alcohol is virucidal to HIV, HBV, and HCV; persons should be warned that the alcohol may sting. Other antiseptics, including iodophors, chloroxylenol, and chlorhexidine gluconate, also inactivate HIV. For mucosal surface exposure, the exposed mucous membranes should be flushed with copious amounts of water. Eyes should be irrigated with saline or water. There is no evidence that expressing fluid by squeezing the wound will further reduce the risk of bloodborne pathogen transmission. Following initial first aid, the exposed healthcare worker should report the exposure to their occupational health provider for more definitive care and follow-up (see below).

Hepatitis B. HBV is the most infectious agent of the common bloodborne viruses. It has been transmitted by percutaneous and mucosal exposures and human bites. It has also been transmitted by fomites such as finger-stick devices used to obtain blood for glucose measurements, multidose medication vials, jet gun injectors, and endoscopes (52). Importantly, HBV is environmentally stable and can survive on countertops for 7 days and remain capable of causing infection.

Postexposure prophylaxis for hepatitis B should be considered for any percutaneous, ocular, or mucous membrane exposure to HBsAg-positive blood (or potentially infectious body fluid) in the workplace. The need for prophylaxis is determined by assessing the type of exposure (i.e., percutaneous, mucous membrane, nonintact skin), the HBsAg status of the source patient, and the vaccination and vaccine response status of the exposed person (51). If the exposed person had an adequate antibody response (>10 mIU/mL) documented after completion of an HBV vaccination series, no testing or treatment is needed, although some experts would consider administration of a booster dose of vaccine. If the source patient is HBsAg-positive and the exposed person is unvaccinated, hepatitis B immunoglobulin should be administered as soon as possible after the exposure (preferably within 24 hrs) and the hepatitis B vaccine series started. The effectiveness of hepatitis B immunoglobulin when administered more than 7 days after percutaneous or permucosal exposures is unknown.

HIV. The risk of disease transmission of HIV following a contaminated sharp injury is lower than for either hepatitis B or hepatitis C. Nevertheless, as of June 2004, 57 healthcare workers in the United States had acquired HIV infection as an occupational injury, most commonly due to a percutaneous exposure (53). Only limited data are available on the factors associated with the risk of a healthcare worker developing HIV following an exposure. A case-control study of needlestick injuries from an HIV-infected source by the Centers for Disease Control and Prevention reported that the following factors were related to an increased risk of HIV acquisition (odds ratios [ORs]): deep injury (OR 15), a device visibly contaminated with the patient's blood (OR 6.2), needle placement in a vein or artery (OR 4.3), and terminal illness in the source patient (OR 5.6). The latter risk factor is now thought to be a surrogate for high HIV viral load. Postexposure prophylaxis with antivirals is likely highly effective in reducing the risk of HIV acquisition.

Occupational health providers should adhere to the published recommendations of the Centers for Disease Control and Prevention, which are based on the type of exposure (i.e., percutaneous or mucous membrane/nonintact skin), the likelihood that the source is HIV-in-

fected, and if there is infection, the source's viral load (54). Postexposure prophylaxis should be initiated as quickly as possible. The goal is to start within 1 to 2 hrs or earlier after exposure, often using a "starter pack" with appropriate drugs that are immediately available. Current guidelines recommend two or three antiretroviral drugs for HIV postexposure prophylaxis. Choice of the specific drugs depends, in part, on an analysis of possible drug resistance in the source patient. Exposed healthcare workers should be counseled regarding the risks and benefits of specific drug regimens, and the occupational providers should have experience in the use of these medications. The usual course of postexposure prophylaxis is 4 wks. Healthcare workers should receive appropriate follow-up to assess for possible drug side effects and to obtain additional testing for HIV conversion.

Airborne-transmitted diseases

Tuberculosis. Patients with active pulmonary or laryngeal tuberculosis may transmit infection via the airborne route. Less well appreciated is that tuberculosis may be acquired from irrigating tuberculous abscesses or other activities that aerosolize *M. tuberculosis* (e.g., autopsies). Patients with tuberculosis confined to a close organ space (e.g., bone, brain) are not infectious.

The decision to evaluate a healthcare worker for tuberculous exposure depends, in part, on the nature and duration of the exposure (55). For exposed healthcare workers, a tuberculin skin test (i.e., purified protein derivative) should be performed immediately and again at 8 to 10 wks postexposure. If the employee has symptoms of active tuberculosis (e.g., prolonged cough, fever, weight loss, hemoptysis), the employee should be removed from work and evaluated for active tuberculosis with a chest radiograph and sputum samples for smear and culture. Employees with evidence of latent tuberculous infection should be offered preventive therapy (56), and those with tuberculous disease should be provided standard therapy for tuberculosis (57).

Measles. Persons with measles are considered infectious from 1 day before the beginning of the prodromal period (about 4 days before the rash appears) to 4 days after rash appearance; minimally after the second day of rash. For a susceptible person, exposure is defined as face-to-face contact or being in a confined space (e.g., a room) with a patient with measles during their infectious period. Importantly, persons have acquired measles after entering a confined space (e.g., waiting room) up to 75 mins after the contagious person has left the room.

Exposure to measles is not a contraindication to immunization. Available evidence suggests that measles vaccine, if given within 72 hrs of measles exposure, will provide protection in some cases. Immunoglobulin can be given intramuscularly to prevent or modify measles in a susceptible person within 6 days of exposure. The usual recommended dose is 0.25 mL/kg given intramuscularly (maximum dose, 15 mL). In adults, immunoglobulin is indicated for exposed susceptible persons, i.e., pregnant women and immunocompromised persons.

Varicella Zoster. Persons with varicella are considered infectious from 1 day before onset of their rash until all lesions are dried and crusted. Persons with zoster are considered infectious only after rash onset and until all lesions are dried and crusted. If the zoster lesions are all contained under a dressing, transmission is unlikely. Exposure is defined for a susceptible person as face-to-face contact or being within a confined space (e.g., a room) of a patient with varicella during their infectious period in a susceptible person.

Administration of varicella vaccine to susceptible adults as soon as possible within 72 hrs and possibly up to 120 hrs after varicella exposure may prevent or modify disease and should be considered if there are no contraindications to vaccine use. If varicella vaccine is contraindicated, passive immunoprophylaxis with varicella zoster immunoglobulin (VariZIG) should be considered for healthcare workers who are at increased risk for complications of varicella, e.g., immunocompromised persons or pregnant women. VariZIG is available from the sole authorized U.S. distributor, FFF Enterprises (58). If VariZIG is not available, intravenous immunoglobulin can be used (400 mg/kg IV). The efficacy of intravenous immunoglobulin is unknown. If VariZIG is not available or more than 96 hrs have passed since exposure, some experts recommend prophylaxis with acyclovir (80 mg/kg per day, administered four times per day for 7 days; maximum dose, 800 mg, four times per day) beginning 7 to 10 days after exposure for immunocompromised persons without evidence of immunity.

Droplet-transmitted diseases

Droplet-transmitted diseases are common reasons for both emergency department visits and admissions to the hospital. They include influenza, pertussis, invasive meningococcal disease, epiglottitis due to *Haemophilus influenzae* type b, parvovirus B19, adenoviral pneumonia, rubella, and group A streptococcal pneumonia.

Influenza. Postexposure and seasonal prophylaxis for viral influenza can be provided using rimantadine, oseltamivir, or zanamivir. In general, one of the latter two agents is preferred, as rimantadine prophylaxis is associated with a higher rate of adverse reactions and more frequent development of viral resistance. As oseltamivir resistance is common among seasonal influenza A strains and has been described among novel 2009 H1N1 strains, many would consider zanamivir the preferred prophylactic agent.

As the indications for antiviral prophylaxis are rapidly changing during the current novel H1N1 outbreak, current guidelines for professional societies and the Centers for Disease Control and Prevention should be consulted. Annual immunization of all healthcare workers with influenza vaccine is highly recommended and antiviral prophylaxis should not be considered a substitute for appropriate immunization.

Pertussis. Chemoprophylaxis is recommended for healthcare workers with close contact (contact with oral secretion as with suctioning or intubation) with an infectious patient regardless of vaccine status. Advanced macrolides (i.e., azithromycin 500 mg as a single dose on day 1, then 250 mg as a single dose on days 2 through 5; clarithromycin 1 g/day in two divided doses for 7 days) are considered the drugs of choice for prophylaxis. Erythromycin can also be used. For macrolide-intolerant persons, trimethoprim-sulfamethoxazole (trimethoprim 200 mg/day, sulfamethoxazole 1600 mg/day, in two divided doses for 14 days) is recommended. Asymptomatic exposed healthcare workers who refuse or cannot take prophylaxis should be excluded from their healthcare facility for 21 days.

Invasive Meningococcal Infection. Chemoprophylaxis is recommended for healthcare workers with close contact (contact with oral secretions as with suctioning, intubation, mouth-to-mouth resuscitation) with an infectious patient during 7 days before onset of illness. Recommended chemoprophylactic agents in-

clude ciprofloxacin (single oral dose, 20 mg/kg, maximum 500 mg, use only if fluoroquinolone-resistant strains of *Neisseria meningitidis* have not been identified in the community), azithromycin (single oral dose, 10 mg/kg, maximum 500 mg), ceftriaxone (single intramuscular dose, 250 mg), or rifampin (oral doses, 10 mg/kg, maximum 600 mg, one dose every 12 hrs for 2 days).

Contact-transmitted diseases

Postexposure prophylaxis is *not* recommended following unprotected exposures to ectoparasites (e.g., lice, scabies mites) or to contact with fluids potentially contaminated with cytomegalovirus or herpes simplex.

There is currently no recommendation to routinely test employees for colonization with MRSA (59). Further, there is no current recommendation to provide decolonization therapy to healthcare workers colonized with MRSA. Healthcare workers in the United States, in general, are assessed for MRSA colonization only if they are epidemiologically linked to an outbreak of MRSA among patients and offered decolonization only if their strain of colonizing MRSA is linked to the outbreak strain by molecular typing.

Conclusions

Healthcare workers should rigorously adhere to current infection control guidelines during patient care to prevent acquisition of infectious diseases. A combination of vaccine prevention, work controls, engineering controls, postexposure prophylaxis when indicated, and adherence to isolation precautions and hand hygiene can minimize infectious exposure risks to the healthcare worker.

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