Microbiology for Radiologists: How to Minimize Infection Transmission in the Radiology Department[1]

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Abbreviations: CDC = Centers for Disease Control and Prevention, CSF = cerebrospinal fluid, WHO = World Health Organization.

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SA-CME LEARNING OBJECTIVES

After completing this journal-based SA-CME activity, participants will be able to:

- Identify infection control procedures in the health care environment.
- Discuss the decontamination of medical equipment specific to the radiology department.
- Describe the proper protocol in the event of a needlestick injury or other infectious agent exposure.

See www.rsna.org/education/search/RG.

The implementation of standardized infection control and prevention practices is increasingly relevant as modern radiology practice evolves into its more clinical role. Current Centers for Disease Control and Prevention, National Institutes of Health, and World Health Organization guidelines for the proper use of personal protective equipment, decontamination of reusable medical equipment, and appropriate management of bloodborne pathogen exposures will be reviewed. Standard precautions apply to all patients at all times and are the mainstay of infection control. Proper hand hygiene includes washing hands with soap and water when exposed to certain infectious particles, such as *Clostridium difficile* spores, which are not inactivated by alcohol-based hand rubs. The appropriate use of personal protective equipment in accordance with recommendations from the Centers for Disease Control and Prevention includes wearing a surgical mask during lumbar puncture. Because radiologists may perform lumbar punctures for patients with prion disease, it is important to appreciate that incineration is the most effective method of inactivating prion proteins. However, there is currently no consensus recommendation on the decontamination of prion-contaminated reusable items associated with lumbar puncture, and institutional policies should be consulted for directed management. In the event of a needlestick injury, radiology staff must be able to quickly provide appropriate initial management and seek medical attention, including laboratory testing for bloodborne pathogens. *Online supplemental material is available for this article.*

Introduction

Infection control education is lacking among radiologists. According to a 2006–2007 survey of more than 1000 interventional radiologists, only 44% reported participating in infection control training before initiating practice. Approximately 50% of those surveyed consistently used protective eyewear, face masks, or face shields during interventions. Furthermore, only 71% of needlestick injuries were reported to employee health services (1). These data highlight the need for a concise relevant guide to infection control that is pertinent to current radiology practice. The recent importation of Ebola virus–infected patients to the United States further underscores the need for all clinical personnel, including radiologists, to have an understanding of proper infection control practices.

TEACHING POINTS

- Standard precautions are the primary strategy for the prevention of health care–associated infections and apply to all patients at all times. Components of standard precautions include hand hygiene, the use of appropriate personal protective equipment when contact with blood or body fluid is anticipated, respiratory hygiene and cough etiquette, safe injection practices, and infection control practices for special lumbar procedures.
- Hand washing with soap and water is required for patients under contact special precautions because certain infectious agents (eg, *C difficile* spores and, possibly, norovirus strains) are not inactivated by alcohol-based hand rubs.
- A CDC review of eight cases of meningitis after myelography established that patient blood and/or cerebrospinal fluid (CSF) was contaminated with oropharyngeal flora from health care workers. Face masks were not worn during the procedures. This review, in conjunction with prior data linking bacterial meningitis to spinal procedures, prompted the recommendation that face masks should be worn by all health care workers during catheter placement or injection into the spinal or epidural space. The use of face masks is also recommended during the placement of central venous catheters.
- Unlike bacteria and viruses, prions are unusually resistant to standard decontamination methods and are most reliably destroyed by incineration.
- All bloodborne pathogen exposures should be reported immediately to the appropriate health care provider as designated by your institution (typically, employee health services during business hours or the emergency department after hours).

Exposure of patients and health care workers to infectious agents and environmental contamination may occur when infected individuals visit the radiology department. This may take place in common waiting areas, procedure holding areas, and examination rooms and on the procedure units (eg, radiography or fluoroscopy table or computed tomography [CT] scanner). Exposure to infectious organisms is not limited to clinical staff such as radiologists, technologists, and nurses; receptionists and transport and monitoring personnel are also at risk.

We will describe routes of disease transmission, the application of standard and transmission-based precautions, appropriate use of personal protective equipment, safe handling of specimens obtained during radiologic procedures, decontamination of reusable items and commonly exposed surfaces, special considerations for prion diseases, and the management of exposure to bloodborne pathogens. Sterile technique is not the focus of this discussion and may be reviewed elsewhere (2).

Routes of Disease Transmission

Infectious disease transmission in the radiology department occurs primarily through direct and indirect contact and droplet and airborne routes. Any of these types of exposure, including droplet and airborne exposure, can occur during patient registration, recording of history, clinical examination, transportation, or radiologic examination or in the waiting area. Therefore, it is important to identify individuals who may pose an exposure risk to others and take the appropriate precautions based on the likely transmission route for a particular pathogen (Fig 1). Vector-borne transmission is considered to be rare in the radiology department and is not discussed in this article.

There is an important distinction between droplet and airborne transmission. Droplet transmission can be considered to be a form of direct contact transmission and occurs when respiratory droplets measuring greater than 5 μm carry pathogens directly from the respiratory tract of the infected person to susceptible mucosal surfaces (ie, nasal mucosa, oral mucosa, or conjunctivae) of the recipient. Droplets may travel up to 1.83 m (6 ft) from the source individual. Organisms transmitted through respiratory droplets include influenza virus, *Bordatella pertussis,* and *Neisseria meningitidis*. Airborne transmission involves the dispersion of smaller infectious particles (≤5 μm) by normal air currents. These particles may travel long distances and remain infectious over time. Airborne infectious agents such as *M tuberculosis* may be inhaled by individuals who have not had face-to-face contact with the infectious individual (3) (Table 1).

Transmission-based Precautions

Personal protective equipment is defined as the protective equipment worn to prevent exposure to hazardous chemical or biologic agents. Personal protective equipment can be simple, such as nonsterile examination gloves, or complex, such as positive-pressure isolation suits worn in high-containment laboratories (Fig 2). Requirements for the equipment are tailored to each specific situation based on risk assessment for a particular pathogen and the anticipated exposure. The proper use of personal protective equipment is mandated by and must be performed in compliance with Occupational Health and Safety Administration regulations (12) (Fig 3). Detailed explanations and figures of proper donning and doffing of each item may be found in the "2007 Guideline for Isolation Precautions: Preventing Transmission of Infectious Agents in Health Care Settings" (3).

Standard Precautions

In 2007, the CDC introduced standard precautions, a combination of universal precautions (13) and body substance isolation practices (14). Standard precautions are the primary

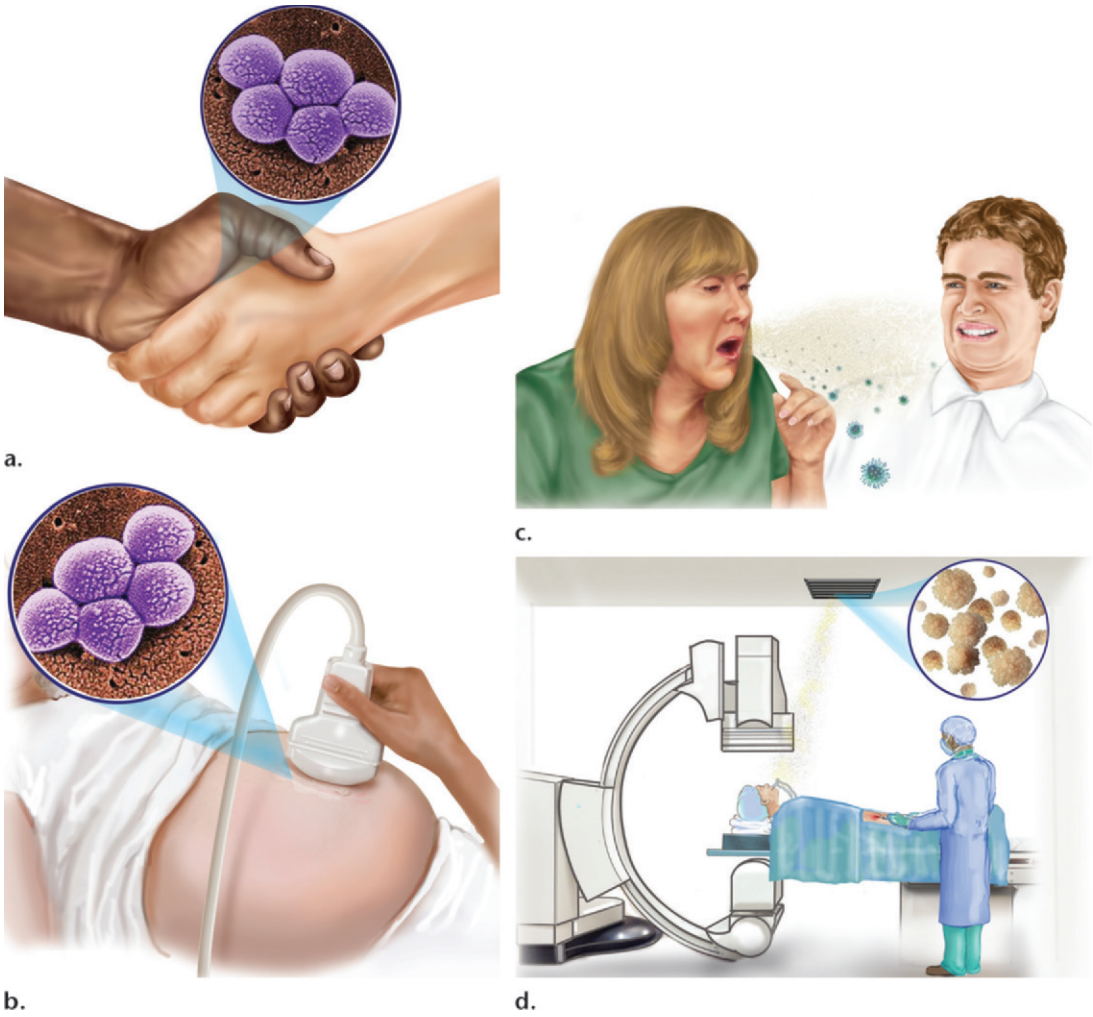


Figure 1. Routes of disease transmission. **(a)** Direct contact transmission involves the transfer of microorganisms from one infected person to another without an intermediate object or surface. This includes skin-to-skin, blood-to–broken skin, and blood-to–mucous membrane contact. **(b)** Indirect contact transmission requires a contaminated intermediate object for microorganism transfer (eg, the transfer of methicillin-resistant *Staphylococcus aureus* via personal protective equipment or hospital equipment such as an ultrasound probe). **(c, d)** In droplet **(c)** and airborne **(d)** transmission, droplet and airborne pathogens (eg, *Mycobacterium tuberculosis*), respectively, are encountered during airway suctioning, endotracheal intubation, cardiopulmonary resuscitation, talking, coughing, and sneezing (3).

Table 1: Microorganisms that May Be Encountered in the Radiology Department, by Route of Transmission

Direct contact
Ebola virus, hepatitis B virus, hepatitis C virus, human immunodeficiency virus, herpes simplex virus, rabies virus, varicella-zoster virus, *Bacillus anthracis*
Indirect contact
Ebola virus, norovirus, respiratory syncytial virus, varicella-zoster virus, *Clostridium difficile*, methicillin-resistant *S aureus*, *Pseudomonas aeruginosa*, vancomycin-resistant *Enterococcus* species
Droplet
Ebola virus, adenovirus, influenza virus, rhinovirus, severe acute respiratory syndrome coronavirus, *B pertussis*, group A streptococci, *Mycoplasma pneumoniae*, *N meningitidis*, *S aureus*
Airborne
Influenza virus,* measles virus, norovirus,* severe acute respiratory syndrome coronavirus,* varicella-zoster virus, *M tuberculosis*, *Aspergillus* species

Source.—References 3 and 4.
Note.—This list is not exhaustive, and many organisms may be transmitted through multiple routes.
*Possible.

Type of PPE	Specifications	Purpose	Comments
 Gloves	Latex and nitrile (in the case of latex allergy) are preferred due to higher failure rates with vinyl (5–9).	Prevent direct and indirect contact transmission. Use for anticipated body fluid exposure, contact with mucous membranes or broken skin, and as part of contact precautions.	When using gloves in conjunction with a gown, make sure that the cuffs of the gloves overlap the cuffs of the gown.
 Isolation Gown	Various materials and gown coatings provide different levels of fluid and microbe imperviousness.	Choose the appropriate level of fluid imperviousness for the anticipated body fluid contact.	Laboratory coats are not acceptable substitutes for isolation gowns (3).
 Face mask and/or face shield	Provides varying degrees of particulate filtration and fluid imperviousness. Surgical, procedure, and isolation facemasks are fluid-resistant by U.S. Food and Drug Administration requirement (10).	Use as part of droplet precautions and during sterile procedures as well as anticipated body fluid exposure to the mouth, nose, and eyes.	The face mask does not provide protection against small particulates (≤ 5 μm) unless specified. The face mask with attached face shield also provides eye and nose protection.
 Particulate respirator	Filters small particulates (≤5 μm). Provides varying degrees of fluid resistance.	Use as part of airborne precautions.	The commonly used N95 respirator does not provide the same degree of fluid resistance as a surgical mask. The *surgical N95* model provides *both* airborne protection and splash protection (11).
 PAPR	A half mask, full facepiece or helmet/hood attached to a battery pack that forces room air through a filter.	Use as part of airborne precautions by individuals who cannot wear a particulate respirator due to medical comorbidities or inadequate seal, including the presence of facial hair.	Requires additional training for use.
 Eye protection	Includes goggles, safety glasses or face shield (may be attached to or worn in conjunction with a face mask).	Protect the eyes from body fluid and chemical splashes.	Eyeglasses and contact lenses are not considered eye protection.

Figure 2. Specifications and purpose of personal protective equipment *(PPE)* commonly used in the radiology department. Personal protective equipment is made from various materials and may have different degrees of fluid imperviousness and/or particulate filtration as decreed by the Association for the Advancement of Medical Instrumentation and American Society for Testing and Materials International. The appropriate level of protection should be selected for the anticipated exposure. *PAPR* = power air-purifying respirator.

strategy for the prevention of health care–associated infections and apply to all patients at all times. Components of standard precautions include hand hygiene, the use of appropriate personal protective equipment when contact with blood or body fluid is anticipated, respiratory hygiene and cough etiquette, safe injection practices, and infection control practices for special lumbar procedures. Safe injection practices are not discussed here.

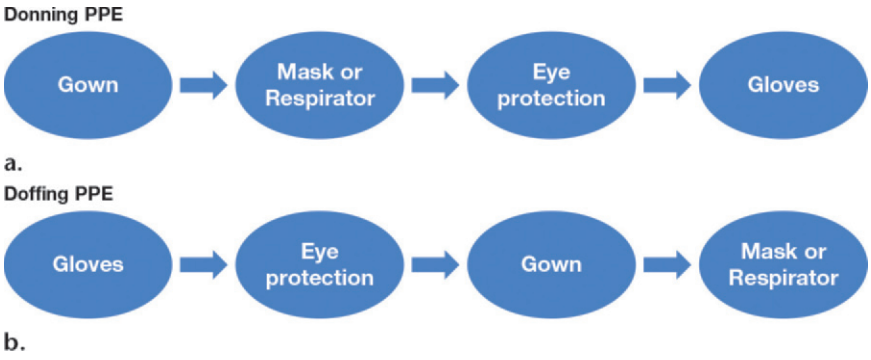


Figure 3. The recommended sequences for donning **(a)** and doffing **(b)** personal protective equipment according to the Centers for Disease Control and Prevention (CDC) (3). Hand hygiene must be performed before and after the use of personal protective equipment. To minimize infection transmission, used personal protective equipment should be disposed of in the patient environment and must be changed between patient encounters.

Figure 4. Hand hygiene. Wash hands with soap and water for 15–20 seconds or use alcohol-based hand sanitizer both before and after patient contact and before and after use of personal protective equipment.

Hand hygiene (Fig 4) must be performed both before and after patient contact and before and after use of personal protective equipment (including gloves). To properly use alcohol-based hand rubs, apply enough product to thoroughly wet both hands and then rub briskly until dry. Hand washing with soap and water is required for patients under contact special precautions because certain infectious agents (eg, *C difficile* spores and, possibly, norovirus strains) are not inactivated by alcohol-based hand rubs (3,15).

Respiratory hygiene and cough etiquette (Fig 5) can reduce the transmission of droplet and airborne pathogens and applies to coughing or sneezing individuals (both patients and health care workers). Signs depicting proper respiratory hygiene and cough etiquette may facilitate the education of health care workers, patients, and visitors (3) about this topic.

Finally, the CDC advocates infection control practices for special lumbar procedures as a part of standard precautions. A CDC review of eight cases of meningitis after myelography established that patient blood and/or cerebrospinal fluid (CSF) was contaminated with oropharyngeal flora from health care workers. Face masks were not worn during the procedures. This review, in conjunction with prior data (16–25) linking bacterial meningitis to spinal procedures, prompted the recommendation that face masks should be worn by all health care workers during catheter placement or injection into the spinal or epidural space. The use of face masks is also recommended during the placement of central venous catheters (3).

Contact Precautions

In addition to the aforementioned standard precautions, transmission-based precautions have been developed to prevent the spread of certain organisms that are known to be associated with significant morbidity and mortality and are propagated in the health care setting. Single-patient rooms are preferred for patients under transmission-based precautions. The individual components of contact precautions, contact special precautions, droplet precautions, and airborne precautions are shown in Figure E1 (online only). Contact precautions are instituted to prevent the transmission of virulent microorganisms by direct or indirect contact with an individual or an individual's environment (eg, methicillin-resistant *S aureus,* vancomycin-resistant *Enterococcus* species, and respiratory syncytial virus) (Table 1, Fig E1a [online only]).

Droplet Precautions

Droplet precautions (Fig E1c) limit the transmission of pathogens such as adenovirus and influenza virus that are spread by close contact of mucous membranes or the respiratory tract with infected respiratory secretions (Table 1). The greatest risk of organism transmission is within 91.44 cm (3 ft) of the source individual (3).

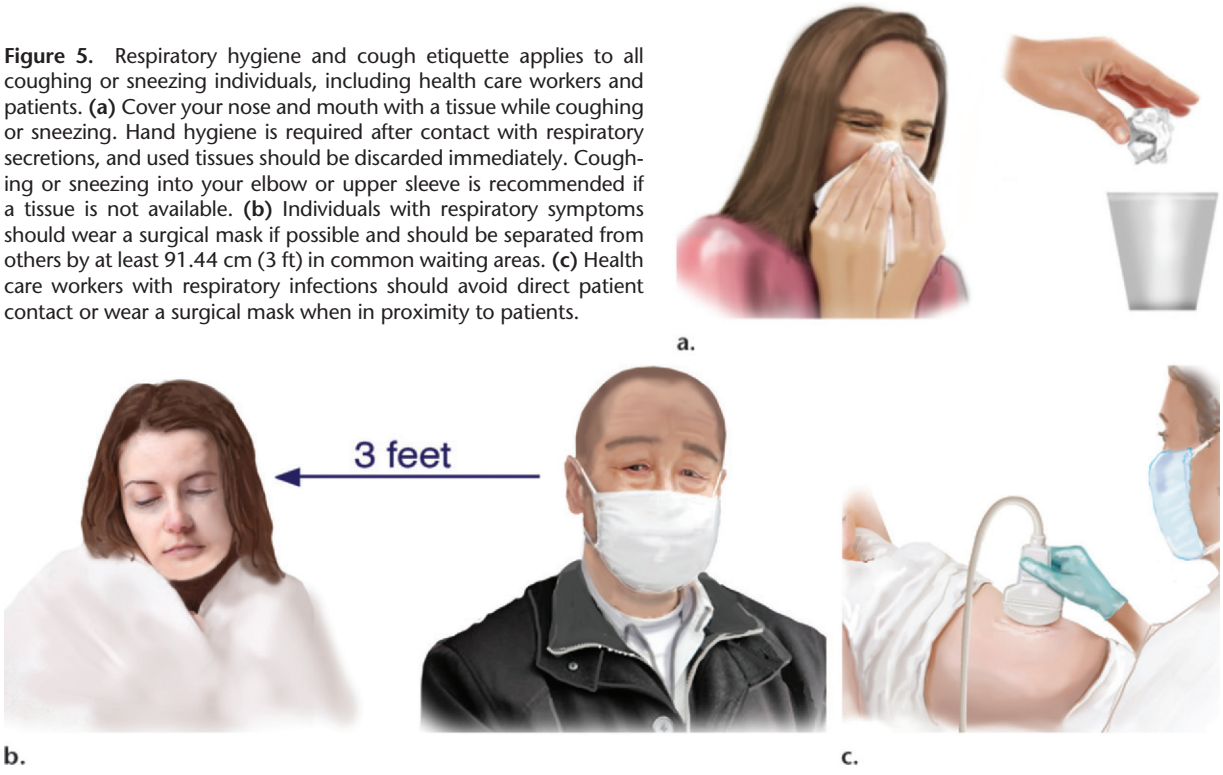


Figure 5. Respiratory hygiene and cough etiquette applies to all coughing or sneezing individuals, including health care workers and patients. **(a)** Cover your nose and mouth with a tissue while coughing or sneezing. Hand hygiene is required after contact with respiratory secretions, and used tissues should be discarded immediately. Coughing or sneezing into your elbow or upper sleeve is recommended if a tissue is not available. **(b)** Individuals with respiratory symptoms should wear a surgical mask if possible and should be separated from others by at least 91.44 cm (3 ft) in common waiting areas. **(c)** Health care workers with respiratory infections should avoid direct patient contact or wear a surgical mask when in proximity to patients.

Treatment of Ebola virus–infected patients has received significant attention because of the recent outbreak in West Africa. Ebola virus is transmitted by droplets and/or contact with infectious body fluid, such as saliva, urine, feces, and vomitus. Although the virus is not transmitted through the aerosol route, airborne precautions should be used with the utmost care because of the very high mortality rate among infected patients (50%–90%) (26). Radiology personnel should consult their institutional infection control specialists when involved in the care of patients potentially infected with Ebola virus.

Airborne Precautions

Airborne precautions are implemented to reduce the transmission of pathogens, such as *M tuberculosis,* that remain infectious over long distances and travel in normal air currents (Table 1). A negative-pressure room may not be available in the radiology department for aerosol-generating procedures performed for patients under airborne precautions or for patients receiving mechanical ventilation who are under airborne precautions (mechanical ventilators continuously generate aerosols). A local exhaust ventilation device should be used in these situations. Nonimmune health care workers should avoid the care of patients with measles and varicella-zoster virus infection (3).

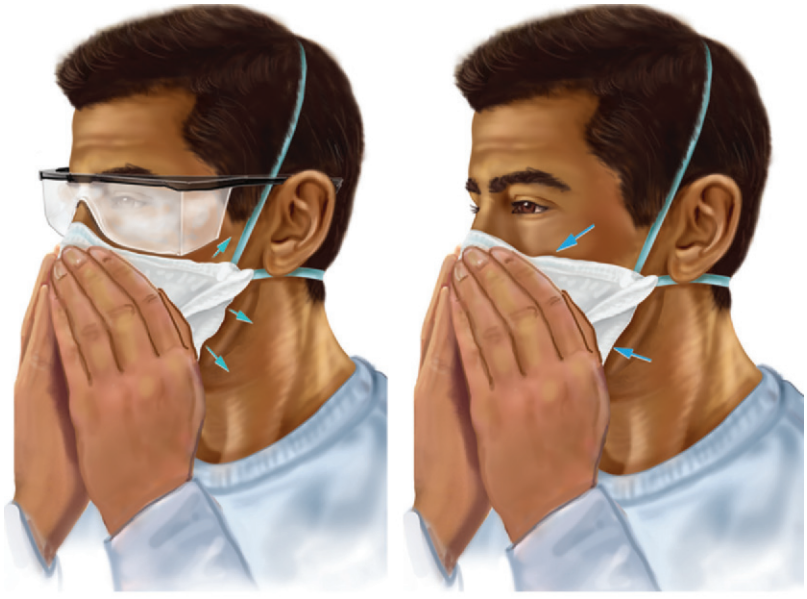
There may be confusion about the differences between a surgical mask and the particulate respirator required with airborne precautions. Whereas a surgical or isolation mask primarily protects the wearer from blood and body fluid splashes and reduces droplet transmission, the N95 particulate respirator filters out at least 95% of airborne particles but does not provide the same degree of fluid imperviousness as a surgical mask. Other particulate respirators (eg, P99) are more fluid resistant and are appropriate when anticipating contact with body fluids while airborne precautions are in effect (3,27). A surgical mask may not take the place of a respirator and vice versa (Fig 2).

The use of a particulate respirator requires medical personnel to undergo both an annual fit test and regular user seal checks (also called *fit checks*). The Occupational Safety and Health Administration–regulated fit test (Fig 6) is used to determine whether a user can wear a particulate respirator, such as an N95 respirator, or must use a powered air-purifying respirator. If the user is unable to achieve a tight air seal with a particulate respirator or if the user has facial hair or certain medical comorbidities, a powered air-purifying respirator must be worn when airborne precautions are in effect. Proper use of the powered air-purifying respirator requires additional training (12,29,30).

A demonstration of the fit test can be viewed at *https://www.osha.gov/video/respiratory_protection/fittesting.html* (31). Only the specific make, model, and size of particulate respirator for which an individual is being fit tested should be used. If

a. b.

Figure 6. The fit test. The user must first undergo medical screening to assess for comorbidities such as asthma, chronic obstructive pulmonary disease, and cardiovascular disease, because particulate respirators have been shown to increase respiratory and cardiac workloads and may precipitate an adverse cardiopulmonary event (28). If no medical contraindication is identified, a particulate respirator (eg, N95 model) is placed on the user and the adequacy of the air seal is assessed by one of several Occupational Safety and Health Administration–approved methods. **(a)** According to a commonly used method, the user dons a particulate respirator and a testing hood, into which a saccharin solution is introduced. **(b)** The user then performs various activities; if the user experiences a sweet taste, the air seal is inadequate and the mask size or deformable nosepiece must be adjusted. If the user can taste the saccharin solution despite manipulations of the respirator, the user should try a different respirator model. Of note, there are many different sizes, models, and manufacturers of particulate respirators, and a user may need to test more than one respirator to find one that provides an adequate air seal.



a. b.

Figure 7. The fit check is performed before every use of the respirator. After donning the respirator, the user assesses the adequacy of the air seal by either the positive or the negative pressure method. **(a)** With the positive pressure method, the user covers the surface of the respirator with his or her hands and exhales gently. Slight pressure normally builds in the facepiece. The seal is inadequate if pressure does not build in the respirator, air is felt leaking out of the mask at the edges, or the user's glasses fog. **(b)** The negative pressure method is used with respirators that have an exhalation valve. The user blocks air entry into the mask and inhales sharply; with a tight seal, the mask should collapse with inspiration. If the respirator fails the fit check, the user should adjust the edges of the respirator and the deformable nosepiece and then repeat the fit check until an adequate seal is achieved (30).

the wearer is approved for use of an N95 or other particulate respirator, a user seal check (fit check) should be performed before each use (Fig 7).

Transportation Precautions

To reduce the spread of infection associated with patients under the aforementioned transmission-based precautions, limit the transportation of these patients to essential diagnostic and therapeutic procedures that cannot be performed at the bedside. Both health care workers and patients should use appropriate personal protective equipment during patient transportation. For example, a coughing patient or a patient under airborne precautions must wear a surgical mask for transportation. Infectious or draining skin lesions should be wrapped. Finally, notify health care personnel in the receiving department of the patient's arrival and necessary transmission-based precautions. Consider the route of transportation and limit the amount of patient exposure to public hallways and nonessential personnel (3).

Table 2: Allegheny Health Network Guidelines for the Transportation of Specimens to the Laboratory for Culture and pH Testing

Specimen Type	Minimum Volume	Container Type	Time to Laboratory Transportation
Abscess fluid	Bacterial: 1 mL; fungal: 1 mL	Anaerobic transport system (for bacterial culture)	Up to 2 h
Biopsy tissue	As much as possible	Anaerobic system or screw-cap container	Up to 1 h
Body fluid (pericardial, peritoneal, pleural, or synovial)	Bacterial: 1 mL; fungal: 10 mL; pH: 2 mL	Anaerobic system, blood culture bottle (for bacterial culture), or screw-top tube	Immediate
CSF	Bacterial: 1 mL; fungal: 2 mL	Screw-top tube	Up to 1 h
Urine	Bacterial: 1 mL; fungal: 1 mL; pH: 5 mL	Screw-top tube or urine cup	Up to 2 h; 24 h with a preservative or if stored at 4°C

Source.—Reference 33.

Safe Handling of Specimens

The World Health Organization (WHO) recommends leakproof plastic containers over glass specimen containers. The outside of the container should not be visibly contaminated after the specimen is placed in it. Containers should be carefully labeled to ensure that the correct test is performed for the correct specimen. The laboratory requisition should be placed in a separate waterproof compartment (32).

The Allegheny Health Network guidelines recommend that health care workers wear gloves when handling the specimen container and specimen. Specimen containers should be transported in a Ziploc-type bag (S. C. Johnson & Son, Racine, Wis) marked with a biohazard symbol. It is important to place into two bags urine specimens in urine cups and specimens on ice. Body tissue specimens (ie, biopsy specimens), body fluid specimens greater than 90 mL, and CSF specimens cannot be transported through a pneumatic tube transportation system (33). In addition, there are specific specimen handling requirements for culture and pH testing (Table 2).

Decontamination of Reusable Items and Commonly Exposed Surfaces

Most instruments used during radiologic procedures are disposable. Reusable items may transmit infection from patient to patient if they are not properly decontaminated. Decontamination is the process by which the microorganism burden of a surface is reduced to a level that is considered to involve no risk for transmission of disease to an individual (4). Various levels of decontamination, including disinfection and sterilization, have been established by the CDC (Table 3).

According to the Spaulding classification adopted by institutions such as the CDC and U.S. Food and Drug Administration, reusable devices can be classified as critical, semicritical, or noncritical (4,34,35) (Table 4). In brief, critical items are those that contact normally sterile body cavities, semicritical devices are those that contact mucous membranes or broken skin, and noncritical items are those that contact intact skin. Noncritical items include certain patient care devices and environmental surfaces commonly encountered in the radiology department, such as the MR imaging or CT gantry, noninvasive ultrasound probes, blood pressure cuffs, and the viewing station keyboard and mouse. Decontamination of noncritical items should occur after every use and includes either washing with soap and water or disinfecting with an intermediate- or low-level product.

Specific sterilants and disinfectants have been recommended by the CDC (Table 5). Under federal law, all decontamination materials that are registered with the Environmental Protection Agency must be handled according to the manufacturer's guidelines for storage, safe use, dilution, material compatibility, contact time, and disposal. In addition, medical equipment manufacturers should be able to provide product-specific decontamination instructions (4).

Prion Diseases: Special Considerations

Prion diseases are rapidly progressive neurodegenerative disorders caused by misfolded prion proteins (Table 6). The exact infectious mechanism of prion particles is not yet understood. Unlike bacteria and viruses, prions are unusually

Table 3: Levels of Decontamination

Decontamination Type	Definition	Method and Use
Cleaning	The removal of foreign material from a device surface	Manually or mechanically with water, enzymes, or detergents
Disinfection	Reduction of the microorganism burden without the elimination of all microorganisms; disinfection does not eliminate bacterial spores	
Low-level disinfectants	Eliminate most bacteria (not including *M tuberculosis*), some viruses, and some fungi; comprise EPA-approved hospital disinfectants that are labeled "non-tuberculocidal"	Generally safe for use on environmental surfaces; short contact times (<10 min)
Intermediate-level disinfectants	Eliminate most bacteria (including *M tuberculosis*), most viruses, and all fungi; comprise EPA-approved hospital disinfectants that are labeled "tuberculocidal"	Widely used and generally safe for use on environmental surfaces
High-level disinfectants	Eliminate all bacteria, viruses, and fungi but not bacterial endospores	For use on medical devices, not environmental surfaces
Sterilization	The elimination of all microorganisms from a surface, including bacterial endospores; the chance that a microorganism survives sterilization is less than 1 in 1 million	Medical devices should be sterilized according to the device manufacturer's instructions to avoid instrument damage

Source.—References 4 and 34.
Note.—Some of the same agents that are considered by the U.S. Food and Drug Administration to be high-level disinfectants at short contact times (10–30 min) act as sterilants at long contact times (3–12 h). Low-level disinfection is also known as "sanitization"(4,34). EPA = Environmental Protection Agency.

Table 4: Spaulding Classification of Reusable Medical Items and Their Recommended Decontamination Methods According to the CDC Guidelines

Item Type	Definition	Examples	Decontamination
Critical	Items that contact normally sterile body cavities and/or have high risk for infection transmission if they are not sterilized	Endovascular or endovaginal ultrasound probes and reusable surgical instruments, such as forceps and needle drivers	Steam-sterilization of heat-resistant items after every use; heat-sensitive items can be sterilized with ethylene oxide gas, hydrogen peroxide gas plasma, ozone, or liquid chemical sterilants* after every use
Semicritical	Items that contact mucous membranes or broken skin	Endoscopes, cystoscopes, and respiratory and anesthesia equipment	High-level decontamination with chemical disinfectants* after every use
Noncritical	Items that contact intact skin	CT or MR imaging gantry, noninvasive ultrasound probes, blood pressure cuffs, and viewing station keyboard and mouse	Wash with soap and water after every use or decontaminate with an intermediate- or low-level disinfectant* after every use

Source.—References 4, 34, and 35.
*Shown in Table 5.

resistant to standard decontamination methods and are most reliably destroyed by incineration. Infection occurs when prions contact an individual's central nervous system tissue, including the brain, spinal cord, or eye. After this tissue is contaminated with prions, it is considered to have high infectivity (ie, it carries a high risk for conferring infection). Body tissue of non–central nervous system origin is considered to have low or no risk for infectivity. The WHO classification of tissue infectivity is listed in Table 7 (4,34,36,37).

Standard precautions are recommended for the routine care, including radiologic examinations, of patients with suspected prion disease (36). However, a specific concern for the radiologist is performing lumbar puncture in a patient

Table 5: Classification of Selected Sterilants and Disinfectants Recommended by the WHO, CDC, and U.S. Food and Drug Administration

Liquid chemical sterilants
Peracetic acid
Hydrogen peroxide
Peracetic acid and hydrogen peroxide solution
Glutaraldehyde for contact time of 3–12 h
High-level disinfectants
Liquid chemical sterilants for contact time of 10–30 min
Ortho-phthalaldehyde
Intermediate-level disinfectants
Ethyl alcohol
Isopropyl alcohol
Household bleach
Phenolic germicidal detergent solution
Iodophor germicidal detergent solution for contact time >10 min
Low-level disinfectants
Intermediate-level disinfectants for contact time <10 min
Quaternary ammonium germicidal detergent solution

Source.—References 4, 32, and 34.
Note.—Formaldehyde use is discouraged because of its carcinogenic potential.

Table 6: Human Prion Diseases, by Year First Reported

Human Transmissible Spongiform Encephalopathies	Year First Reported
Creutzfeldt-Jakob disease*	
Sporadic (85%–90%)	1921
Familial (5%–10%)	1924
Iatrogenic (<5%)	1974
Variant	1996
Gerstmann-Sträussler-Scheinker syndrome	1936
Kuru	1957
Fatal insomnia	
Familial	1986
Sporadic	1999

Note.—Reprinted, with permission, from reference 36.
*Percentages vary somewhat among countries.

with known or suspected prion disease. Most instruments associated with lumbar puncture are disposable. However, there may be confusion regarding the proper disposal of materials used during the procedure, environmental protection, and decontamination. The WHO recommends, in the 1999 "Infection Control Guidelines for Transmissible Spongiform Encephalopathies" (36), that disposable materials contaminated with high- or low-infectivity tissue (including CSF) be incinerated.

The WHO 1999 recommendations (36) for the decontamination of reusable instruments contaminated with CSF are the same as those for the decontamination of instruments contaminated with high-infectivity tissue, although CSF is considered to be a low-infectivity tissue. The rationale given is that there is a higher risk for disease transmission if the CSF-contaminated instruments are reused for lumbar puncture. Specific decontamination methods are described in the WHO document (36), which generally recommends the highest level of decontamination that will not damage the instrument. In contrast, the 2010 Society for Healthcare Epidemiology of America guidelines (37) give specific recommendations for the decontamination of reusable instruments exposed to only high-infectivity tissue and finds the decontamination of instruments exposed to low-infectivity tissue (including CSF) to be an unresolved issue without specific recommendation. This is especially relevant for patients who require anesthesia for an image-guided lumbar puncture: although the instruments used

Table 7: WHO Classification of the Infectivity of Tissues Contaminated with Prion Proteins

High infectivity
Brain, spinal cord, eye
Low infectivity
CSF, kidney, liver, lung, lymph nodes and spleen, placenta
No detectable infectivity
Adipose tissue, adrenal gland, gingival tissue, heart muscle, intestine, peripheral nerve, prostate, skeletal muscle, testis, thyroid gland, blood,* tears, nasal mucous, saliva, sweat, serous exudate, milk, semen, urine, feces

Note.—Reprinted, with permission, from reference 36. Assignment of different organs and tissues to categories of high and low infectivity is chiefly based on the frequency with which infectivity has been detectable, rather than on quantitative assays of the level of infectivity, for which data are incomplete. Experimental data are from primates inoculated with tissues from human cases of Creutzfeldt-Jakob disease but have been supplemented in some categories by data obtained from naturally occurring animal transmissible spongiform encephalopathies. Actual infectivity titers in the various human tissues other than the brain are extremely limited, but data from experimentally infected animals generally corroborate the grouping shown in the table.
*Blood has been found to have low levels of infectivity in experimental models but has not been linked clinically to prion disease transmission. Therefore, the WHO recommends no special handling of prion-contaminated blood specimens.

Table 8: Specific Reporting Information for Bloodborne Pathogen Exposures

Where and how the exposure occurred
Exposure sites on the health care worker's body
Type and brand of device involved, if any
Type and amount of exposure material (eg, 5 mL of blood)
Patient-identifying information to ensure appropriate follow-up testing

Source.—Reference 40.

for the lumbar puncture may be disposable and, therefore, subject to incineration, anesthesia equipment is often reused and may be exposed to CSF during lumbar puncture.

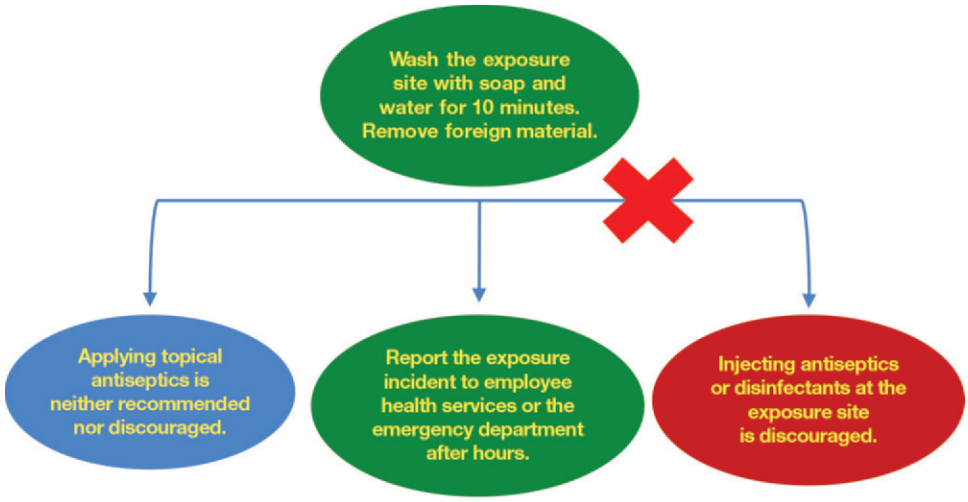
Noncritical (eg, environmental) surfaces should be protected with plastic during procedures that may generate high- or low-infectivity tissue, such as lumbar puncture. Standard disinfection is considered to be adequate for noncritical surfaces that are contaminated with low-risk tissue, including CSF. Standard sterilization or high-level disinfection is recommended for critical and semicritical devices contaminated with no-risk tissue. All single-use devices and plastic covers should be discarded (37). Although the 2010 Society for Healthcare Epidemiology of America guideline (37) does not specifically recommend the incineration of disposable materials, it can be inferred from the CDC and WHO recommendations that all disposable materials involved in lumbar puncture, including environmental covers, should be incinerated. This is reasonable even if there is no visible contamination. Sharp instruments, including the spinal needle, should be deposited into a sharps container that is also submitted for incineration.

The receiving laboratory should be informed directly that prion disease is suspected so that specimens are specially handled. The laboratory may perform manual analysis and/or may quarantine equipment if prion disease is suspected. It is imperative to become familiar with institutional policies regarding periprocedural precautions and specimen handling for patients with suspected or confirmed prion disease.

Bloodborne Pathogen Exposure

Common routes of bloodborne pathogen exposure in the radiology department include needlesticks and mucous membrane (ie, eye, nose, or mouth) splashes that may occur during vascular access, angiography, solid organ biopsy, lumbar puncture, drainage catheter placement, transjugular intrahepatic portosystemic shunt placement, biliary and urologic procedures, and joint injection or aspiration. Bloodborne pathogen exposure is of particular concern when performing procedures such as paracentesis or transjugular intrahepatic portosystemic shunt placement for patients with viral hepatitis. The seroconversion rates of human immunodeficiency virus, hepatitis B virus, and hepatitis C virus after a needlestick injury are 0.3%, 23%–62%, and 1.8%, respectively (38,39). The CDC recommends documenting certain details about the exposure incident as specified in Table 8. Algorithms for the immediate management of bloodborne pathogen exposures are shown in Figure 8.

All bloodborne pathogen exposures should be reported immediately to the appropriate health care provider as designated by your institution (typically, employee health services during business hours or the emergency department after



a.

b.

Figure 8. Management of bloodborne pathogen exposure. **(a)** The CDC does not discourage use of topical antiseptics; however, this practice has not been proven to reduce infection transmission. Similarly, expressing blood from the puncture site has not been found to reduce infection transmission, but the practice is not discouraged. Management of eye or mucous membrane exposures is the same as for needlestick injuries, except that the exposed area should be flushed with tap water, sterile water, or sterile saline (39,40). An eyewash station **(b)** may be available at your institution. The Allegheny Health Network guidelines recommend flushing the exposed mucous membranes for 10–15 minutes (41,42).

hours). According to Occupational Safety and Health Administration standard 1910.1030, the employer must provide timely and appropriate medical attention, including laboratory testing, follow-up, and postexposure prophylaxis at no cost to the employee (40). Prophylactic antiviral medications may be prescribed to the exposed individual in some instances, and if the source individual is infected with human immunodeficiency virus, hepatitis B virus, or hepatitis C virus, it may be prudent for the exposed individual to refrain from blood or tissue donation and high-risk activities until follow-up testing is performed (38–43).

Conclusion

An understanding of infection control methods, decontamination of reusable materials, and management of bloodborne pathogen exposure is crucial for the modern radiologist, because transmission of infectious organisms can occur during almost any portion of a radiologic examination. It is imperative that the radiology staff understands the various routes of infection transmission and implements transmission-based precautions when necessary to protect patients and other staff. This includes proper use of personal protective equipment.

In addition, specimens obtained during radiologic procedures must be handled according to institutional guidelines for both safety and accurate diagnosis. At the completion of each radiologic examination or procedure, the proper decontamination of reusable items and environmental surfaces must be undertaken for the protection of the next patient who will be exposed to the same equipment. Prion diseases are a special consideration for which additional attention is needed.

Finally, exposure to bloodborne pathogens may occur during radiologic procedures. Radiology personnel must be familiar with the proper management of needlestick injuries and mucous membrane exposure; the protocol should include immediate care of the exposed site, gathering of pertinent data on the details of the exposure, and pursuit of employer-provided medical assessment and indicated laboratory testing.

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