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Special Problems

IV

A Nosocomial Infections

300 Infection Prevention in the Health Care Setting

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HISTORICAL BACKGROUND

Infection control as a formal discipline in the United States developed during the late 1950s, primarily to address the problem of nosocomial staphylococcal infections. Over the next 50 years, the field of infection control developed slowly, initially focused on surveillance for health care–associated infections (HAIs), then incorporating the science of epidemiology to elucidate risk factors for HAIs. However, three pivotal events signaled the beginning of a new era in health care epidemiology—the Institute of Medicine's 1999 report on errors in health care, which included HAIs[1]; the 2002 Chicago Tribune exposé on HAIs,[2] which was the beginning of the mainstream media's interest in this topic; and the publication in 2004 and 2006 of dramatic reductions in bloodstream infection rates by simply standardizing the process of central venous catheter insertion.[3,4] This new era in health care epidemiology is characterized by consumer demands for more transparency and accountability, increasing scrutiny and regulation, and expectations for rapid reductions in HAI rates.[5] The paradigm shifted from viewing most HAIs as an unpreventable "cost of business" to the vast majority being preventable. Accordingly, the focus for hospital programs shifted from infection control to infection prevention, which required rapid identification of infections and timely actions to analyze them, as well as playing an active role in the implementation of interventions for infection reduction.

ROLE OF INFECTION CONTROL

The primary role of an infection prevention program is to reduce the risk for hospital-acquired infection, thereby protecting patients, employees, health sciences students, volunteers, and visitors. HAIs develop in 1.7 million patients yearly in the United States, accounting for approximately 100,000 deaths,[6] at a direct cost of $37 to $45 billion.[7] However, these estimates are now 10 years old, and given the intense efforts under way since then, it is highly likely that significant reductions have occurred.

The functions of an infection prevention program vary from institution to institution but can generally be divided into the following areas: (1) surveillance, (2) isolation of patients with transmissible pathogens, (3) outbreak investigation and management, (4) education, (5) employee health, (6) the monitoring and management of institutional antimicrobial use and antibiotic resistance, (7) the development of infection prevention policies and interventions, (8) environmental hygiene, and (9) new product evaluation. In some hospitals, quality improvement and patient safety are also undertaken through the hospital epidemiology program. In the academic setting, additional functions of the program may include research and the provision of consultative services to other acute-care and long-term care facilities, public health agencies, and the university campus. The major functions of the effective hospital epidemiology program are listed in Table 300-1, and some of them are discussed in further detail here.

Surveillance

The first aim of surveillance is to determine endemic rates of infection. Once these rates have been established, an outbreak can be identified when its rate of occurrence is significantly higher than the endemic rate. The importance of surveillance was demonstrated nearly 3 decades ago by the Study on the Efficacy of Nosocomial Infection Control, which found a 32% reduction in HAIs in hospitals with active surveillance programs compared with hospitals without such programs.[8] Data from hospitals in the National Nosocomial Infection Surveillance System demonstrated that from 1990 to 1999, nosocomial bloodstream infections decreased by 44% in medical intensive care units (ICUs), 32% in pediatric ICUs, and 31% in surgical ICUs.[9] As hospitals gained experience in standardization of patient care processes (e.g., central venous catheter insertion, head of bed elevation), further reductions in HAIs have been observed. The Centers for Disease Control and Prevention (CDC) recently reported that in the time period 2008 through 2011 there was a 41% reduction in central line–associated bloodstream infections and a 17% reduction in surgical-site infections, with only a 7% reduction in catheter-associated urinary tract infections in the time period 2009 through 2011.[10] Over the past several years, many hospitals have begun to monitor compliance with process measures, because feedback to health care workers on compliance with best practices more forcefully drives compliance than simply providing feedback on infection rates.[11,12]

Surveillance for HAIs has generally targeted areas of the hospital where the highest rates of infection, highest impact of infection, and antibiotic resistance are likely to be found. These areas include ICUs, cardiothoracic surgery units, and hematology/oncology units. However, with the current scrutiny on HAIs, hospital-wide surveillance (i.e., concurrent surveillance throughout the hospital) is becoming more prevalent and has been mandated in some states. As more hospitals implement electronic medical records, hospital-wide surveillance has become less daunting from a resource perspective. For

KEYWORDS

airborne precautions; antibiotic stewardship; contact precautions; droplet precautions; hand hygiene; health care–associated infections; health care epidemiologist; health care epidemiology; infection control; infection prevention; infection preventionist; isolation precautions; nosocomial infections

TABLE 300-1 Functions That May Be Served By Infection Prevention Programs

Surveillance for health care–associated infections
Outbreak detection and management
Management of isolation precautions
Education of patients, patients' families, and health care workers
Occupational health program for health care workers:
Postexposure prophylaxis for health care workers with occupational exposures
Management of the infected health care worker
Respiratory protection program
Antimicrobial stewardship
Development and implementation of interventions and policy to decrease the risk for health care–associated infection
Environmental infection control:
Monitoring of environmental hygiene and infectious hazards
Construction infection control (via design process and monitoring of infectious hazards associated with demolition, renovation, and construction)
Infectious waste management
Sterilization and disinfection of medical instruments and devices
New product evaluation
Bioterrorism and disaster preparedness
Patient safety program
Quality assessment
Regulatory compliance

example, collection of device days (denominator data), which previously required a daily review of patients, often by an infection preventionist, can now be accomplished via extraction of data entered into the electronic record by the bedside nurse as part of the daily patient nursing assessment. It is important for hospitals to consider implementing surveillance outside of the ICU setting because the proportion of patients with invasive devices is increasing, and in many hospitals interventions to reduce infection have primarily been targeted to ICU patients. Although the rates of infection may be lower in the non-ICU setting, given that ICU beds typically make up a minority of beds in most hospitals, the burden of infections in the non-ICU setting may actually be higher.

Hospitals with sophisticated information systems may be able to streamline surveillance through the development of computer-based algorithms that identify patients at highest risk for an HAI. Surveillance for some infections (e.g., bloodstream infections or infections with antimicrobial-resistant organisms) is primarily microbiology based; therefore, hospital-wide surveillance for targeted infections can be implemented relatively easily.

The highest quality surveillance methodology for HAIs was developed by the CDC and is unit based, infection site specific, and risk adjusted (i.e., expressed in terms of device-specific denominators).[13] Because the National Healthcare Safety Network (NHSN) methodology is the most widely accepted, hospitals that use it are able to compare their institutional rates to those of a large group of hospitals across the country. The NHSN has rapidly expanded from a network of slightly more than 200 hospitals in 2006[14] to nearly 3500 in 2011,[10] primarily owing to mandatory reporting requirements by the Center for Medicare and Medicaid Services (CMS).

Unit-based surveillance trends should periodically be reported back to the health care workers in the unit. Although HAI rates (e.g., bloodstream infections per 1000 catheter-days) are useful for interhospital comparisons and the analysis of institutional long-term trends, feedback to frontline providers is more meaningful when expressed as a raw number of infections (e.g., four central line–associated bloodstream infections in the past 3 months).

Reporting

Infectious diseases of public health importance should be reported to public health agencies, whose requirements vary by state. Increasingly, states are mandating surveillance for HAIs with public reporting and the CMS now also mandates reporting of some HAIs.

ISOLATION

The purpose of isolation is to prevent the transmission of microorganisms from infected or colonized patients to other patients, hospital visitors, and health care workers, who may subsequently transmit them to other patients or become infected or colonized themselves. Although isolation guidelines are based on current understanding of the mechanisms of the transmission of organisms, few well-controlled studies have been performed to demonstrate their efficacy. Because HAIs are relatively uncommon events, any study designed to demonstrate efficacy requires sample sizes that are often prohibitively large. Thus, studies evaluating the efficacy of infection prevention interventions often lack the power to allow one to conclude confidently that there has been a lack of effect (i.e., such studies have a high probability of type II error).

Because patient isolation is expensive, time consuming, and uncomfortable for patients, impedes care, and generates large volumes of trash because of the use of disposable products, it should be implemented only when necessary. Conversely, failure to isolate a patient with a transmissible disease may lead to morbidity and mortality and may ultimately be expensive when one considers the direct costs of an investigation of an outbreak and excess length of stay and the indirect costs of lost productivity. The practice of isolating patients has moved from the requirement for separate infectious disease hospitals to separate wards for these patients and, ultimately, to providing precautions in the general hospital environment. In 2006, the American Institute of Architects, in its Guidelines for Design and Construction of Health Care Facilities, made single-patient rooms the standard.[14] Hospitals that have single-patient rooms exclusively are able to isolate patients with transmissible diseases without disrupting patient flow.[15] However, existing facilities often still have a significant proportion of double-patient rooms.

In 2007, the CDC and the Healthcare Infection Control Practices Advisory Committee issued a revision of the recommended guidelines for isolation.[16] These guidelines outlined a two-tiered approach: standard precautions, which apply to all patients, and transmission-based precautions, which apply to patients with documented or suspected infection or colonization with certain microorganisms. These guidelines are summarized in Table 300-2.

STANDARD PRECAUTIONS

Standard precautions are based on the assumption that any patient may potentially be colonized or infected with organisms that are transmissible. Therefore, standard precautions apply to all patients, in all settings, at all times. The essential elements of standard precautions are hand hygiene, personal protective equipment (gowns, gloves, masks, and eye protection), and safe needle practices.

Hand Hygiene

Because most HAIs are transmitted by contact, primarily via the hands of health care workers,[17] hand hygiene remains the single most important means to prevent transmission of nosocomial pathogens. Compliance by health care workers remains suboptimal although improving through numerous efforts, including The Joint Commission's mandate to measure hand hygiene via the National Patient Safety Goals program.

The microorganisms on hands can be divided into transient flora and resident flora.[18] The resident flora include organisms of low virulence (e.g., coagulase-negative staphylococci, *Micrococcus, Corynebacterium*) that are rarely transmitted to patients except when introduced by invasive procedures.[19] They are not easily removed through hand washing. The transient flora, however, are important causes of HAIs. These organisms are acquired primarily by contact, are loosely attached to the skin, and are easily washed off. Thus, the purpose of hand hygiene in the hospital is to remove the transient flora recently acquired by contact with patients or environmental surfaces.[18] In addition, HAIs have been attributed to bacterial contamination of artificial fingernails; therefore, health care workers should not wear them.

Alcohol-based hand rubs have become the recommended agents for hand hygiene in the health care setting.[19] In situations in which the hands are visibly soiled, washing with soap (antimicrobial or nonantimicrobial) and water is recommended. Soap and water is also preferred when caring for patients with *Clostridium difficile* infection (owing to the poor sporicidal activity of alcohols)[20] or norovirus infection.[21] Hand hygiene should be performed before and after contact with patients, before any aseptic task, after contact with inanimate objects in the patient's surrounding environment, and immediately after removing gloves.[22]

TABLE 300-2 Essential Elements of Isolation Precautions

ELEMENTS	STANDARD PRECAUTIONS	TRANSMISSION-BASED PRECAUTIONS		
		Contact	Droplet	Airborne
Room	Single-patient room preferred; door may remain open.	Single-patient room preferred; door may remain open; use disposable, noncritical, patient care equipment or dedicate to a single patient.	Single-patient room preferred; door may remain open.	Negative pressure, single-patient room required with air exhausted to outside or through HEPA filters; door must be closed.
Mask			Surgical mask for those entering room; place surgical mask on patient if transport out of room is required.	N95 or portable respirator for entering the room; place surgical mask on patient if transport out of room is required.
Eye, mouth, nose protection	For any activity likely to generate a splash, spray, or aerosol			
Gowns	For any activity likely to generate a splash, or spray	On room entry		
Gloves	For contact with any body fluid, mucous membrane, or nonintact skin	On room entry		
Hand hygiene	Before and after patient contact; before any aseptic task; after contact with any body fluid, mucous membrane, or nonintact skin; after contact with inanimate objects in the immediate vicinity of the patient; after glove removal			

HEPA, high-efficiency particulate air.

Wall-mounted dispensers with alcohol-based, waterless hand rubs should be installed in all hospital and outpatient rooms. In areas where this is not feasible, individual health care workers should carry small containers of waterless agents. Technologic interventions to improve hand hygiene compliance include electronic dispensing counters, radiofrequency identification, alcohol vapor detection sensors, and videosurveillance.[23]

Gloves

Gloves should be worn by health care workers to prevent contamination of the hands with microorganisms, to prevent exposure of the health care worker to bloodborne pathogens, and to reduce the risk for transmission of microorganisms from the hands of the health care worker to the patient. Standard precautions stipulate that gloves should be worn to touch any of the following: blood, all body fluids, secretions, and excretions, except sweat, regardless of whether they are visibly bloody, nonintact skin, and mucous membranes.[20] Gloves should be changed during the care of a patient when moving from a contaminated body site (e.g., wound or perineal care) to a clean body site. However, gloves do not replace the need for hand hygiene. Contamination of the hands can occur with organisms on the surface of the gloves when they are removed, and some gloves have small perforations that may allow organisms to contaminate the hands. Thus, gloves should be viewed as an adjunctive protective barrier but not as a substitute for hand hygiene, which should be performed immediately after gloves are removed.

Personal Protective Equipment

For procedures that are likely to generate splashes or sprays of body fluid, a mask with eye protection or a face shield to protect the mucosa of the eyes, nose, and mouth, as well as a gown, should be worn. Disposable gowns should be made of an impervious material to prevent penetration and subsequent contamination of the skin or clothing.

Standard precautions also stipulate that health care workers performing procedures involving lumbar puncture wear masks to prevent contamination of the spinal needle or the procedure site with the oral flora of the operator, which may occur when the operator is talking. Standard precautions also address respiratory hygiene, which includes instructing patients to cover their nose and mouth with a tissue when coughing or sneezing, performing hand hygiene after contact with respiratory secretions, placing a surgical mask on the coughing patient in common areas, and spatially separating patients with respiratory tract infections from other patients when feasible.[20]

Injection Safety

Needles and syringes should be used only once and, when possible, single-dose medication vials should be used.[24] Single-use vials of medication should not be used for more than one patient, and when possible multiuse vials should be assigned to a single patient. Intravenous solution bags should not be used as a common source of supply for more than one patient. Needles should not be recapped, bent, or broken but should be disposed of in puncture-resistant containers.

Because of the potential for transmission for bloodborne pathogens, fingerstick devices for glucose monitoring should never be used for more than one person.[25] If blood glucose meters must be shared, they should be cleaned and disinfected after every use. Insulin pens and other medication cartridges and syringes should never be used for more than one person.

Bare Below the Elbows

For the past several years, the National Health Service in the United Kingdom has mandated a "bare below the elbows" approach to patient care.[26] To ensure optimal hand hygiene, this mandate requires that all health care workers wear either short-sleeved garments or long sleeves that are rolled up. In addition, wrist watches, bracelets, and rings with stones are not allowed. Neckties, if worn, must be kept tucked in.

TRANSMISSION-BASED PRECAUTIONS

Transmission-based precautions apply to selected patients based on a suspected or confirmed clinical syndrome, a specific diagnosis, or colonization or infection with epidemiologically important organisms. Transmission-based precautions are always implemented in conjunction with standard precautions. Three types of transmission-based precautions have been developed for the major modes of transmission of infectious agents in the health care setting—airborne, droplet, and contact.[20] A few diseases (e.g., varicella, severe acute respiratory syndrome) require more than one isolation category. Essential elements of each category are outlined in Table 300-2, and indications for implementation are delineated in Table 300-3.

Airborne Precautions

Airborne precautions are designed to prevent the transmission of diseases by droplet nuclei (particles <5 μm) or dust particles containing the infectious agent.[20] These particles can remain suspended in the air and travel long distances. If the particles are inhaled, a susceptible host

TABLE 300-3 Indications for Transmission-Based Precautions

CONTACT PRECAUTIONS	DROPLET PRECAUTIONS	AIRBORNE PRECAUTIONS
Syndromes (Before Pathogen Identification)		
Acute diarrhea with likely infectious cause	Meningitis	Vesicular rash*
Vesicular rash*	Petechial or ecchymotic rash with fever	Maculopapular rash with cough, coryza, and fever
Respiratory tract infection in infants and young children*	Paroxysmal or severe persistent cough during periods of pertussis activity	Cough, fever, upper lobe pulmonary infiltrate
History of infection or colonization with MDRO†	Respiratory tract infection in infants and young children*	Cough, fever, any pulmonary infiltrate in an HIV-infected patient (or at high risk for HIV infection)
SSTI or UTI with recent stay in a facility where MDROs† are prevalent		Cough, fever, any pulmonary infiltrate, recent travel to regions with outbreaks of SARS or avian influenza*
Abscess or draining wound that cannot be covered		
Cough, fever, any pulmonary infiltrate, and recent travel to regions with outbreaks of SARS or avian influenza*		
Known or Suspected Pathogens or Infections		
Adenovirus pneumonia*; conjunctivitis*	Adenovirus pneumonia*; conjunctivitis*	Measles
Burkholderia cepacia pneumonia in cystic fibrosis	Diphtheria, pharyngeal	MERS*†
Clostridium difficile infection	*Haemophilus influenzae* meningitis, epiglottitis; pneumonia (infants, children)	Monkeypox*
Conjunctivitis, acute viral	Influenza	Tuberculosis, pulmonary, laryngeal; draining lesion (e.g., from osteomyelitis)*
Decubitus ulcer, infected, drainage not contained	Meningococcal infections	SARS*
Diarrhea, infectious, in diapered or incontinent patient	Mumps	Smallpox*
Diphtheria, cutaneous	*Mycoplasma pneumoniae* pneumonia	Varicella*
Ectoparasites (lice, scabies)	Parvovirus B19	Zoster (disseminated; immunocompromised patient until dissemination ruled out)*
Enteroviral infections (infants, young children)	Pertussis	
Furunculosis (infants, young children)	Plague, pneumonic	
Hepatitis A, E (diapered or incontinent patient)	Rhinovirus*	
HSV (neonatal, disseminated, severe primary mucocutaneous)	Rubella	
Human metapneumovirus	SARS*	
Impetigo	Streptococcal (group A) pneumonia; serious invasive disease; major SSTI*; pharyngitis, scarlet fever (infants or young children)	
MDRO† infection or colonization	Viral hemorrhagic fevers*	
MERS*†		
Monkeypox*		
Norovirus		
Parainfluenza infection (infants, children)		
Rhinovirus*		
Rotavirus		
RSV infection (infants, children, immunocompromised)		
Rubella, congenital		
SARS*		
Smallpox*		
Staphylococcus aureus major SSTI		
Streptococcal (group A) major SSTI*		
Tuberculous draining lesion		
Vaccinia: fetal, generalized, progressive, eczema vaccinatum		
Varicella*		
Viral hemorrhagic fevers*		
Zoster (disseminated; immunocompromised until dissemination ruled out)*		

*Condition requires two types of precautions.

†MDRO, multidrug-resistant organism (e.g., carbapenem-resistant Enterobacteriaceae [CRE], extended-spectrum β-lactamase [ESBL], MDR-*Acinetobacter,* methicillin-resistant *Staphylococcus aureus* [MRSA], resistant *Streptococcus pneumoniae,* vancomycin-resistant enterococci [VRE], vancomycin-intermediate *S. aureus* [VISA], vancomycin-resistant *S. aureus* [VRSA]).

HIV, human immunodeficiency virus; HSV, herpes simplex virus; MDR, multidrug-resistant; MERS, Middle East respiratory syndrome; RSV, respiratory syncytial virus; SARS, severe acute respiratory syndrome; SSTI, skin and soft tissue infection; UTI, urinary tract infection.

may develop infection. Airborne precautions are indicated for patients with documented or suspected tuberculosis (pulmonary or laryngeal), measles, varicella, or disseminated zoster. Patients who are infected with, or at high risk for infection with, human immunodeficiency virus (HIV), with fever, cough, and a pulmonary infiltrate, should be empirically placed under airborne precautions until tuberculosis can be ruled out.[2] Although open tuberculous skin wounds are uncommon, they have been presumptively associated with nosocomial transmission after manipulation of the wound (surgical débridement, dressing changes, irrigation).[27-29] Therefore, such patients should be placed under airborne precautions. Patients with nontuberculous (atypical) mycobacterial pulmonary disease need not be isolated because person-to-person transmission does not occur.

Under airborne precautions, patients should be placed in a private room with monitored negative air pressure in relation to surrounding areas, and the room air must undergo at least 6, but preferably 12, exchanges per hour.[30] The door to the isolation room must remain closed. Air from the isolation room should be exhausted directly to the outside, away from air intakes, and not recirculated. If outdoor exhaust is not possible, air should be exhausted through high-efficiency particulate filters before it is returned to the general ventilation system.[30]

All persons entering the room of patients with suspected or confirmed tuberculosis must wear a personal respirator that filters 1-μm particles with an efficiency of at least 95% (N95 mask). These special masks must fit different facial sizes and characteristics, be fit-tested so that there is leakage of 10% or less, and be able to be checked for fit each time the health care worker puts on the mask. The Occupational Safety and Health Administration requires that health care workers who manage patients with tuberculosis undergo fit testing and training for self-fit checking,[30] and this must be performed annually.[31] Transport of the patient from the isolation room should be limited, and the patient should be fitted with a standard surgical mask before leaving the room.[20] Before transport, hospital personnel in the area receiving the patient should be notified so that proper precautions can be implemented. Gowns and gloves are used as dictated by standard precautions.

Any patient with confirmed or suspected tuberculosis should be instructed to cover his or her mouth and nose with a tissue when coughing or sneezing. Patients should remain in isolation until tuberculosis can be ruled out. Patients with confirmed tuberculosis who are receiving effective antituberculous therapy, are clinically improving with decreased cough frequency, and have three consecutive sputum smears each at least 8 hours apart, with no detectable acid-fast bacilli, can be released from isolation.[30] Patients with multidrug-resistant disease should remain in isolation for the duration of their hospital stay. Patients with active tuberculosis who require surgery present a special problem because operating rooms are typically at positive pressure. Thus, special precautions are necessary. Hospitalization is not warranted solely to provide isolation for clinically stable patients who are compliant with antituberculous therapy and agree to stay in their homes.

Patients with known or suspected measles, varicella, or disseminated zoster require airborne precautions and isolation. Nonimmune health care workers should avoid entering the rooms of these patients when possible and, if they are required to enter the room, should wear an N95 mask.[20]

Droplet Precautions

Droplet precautions are used to prevent transmission by large-particle (droplet) aerosols. Unlike droplet nuclei, droplets are larger, do not remain suspended in the air, and do not travel long distances. They are produced when the infected patient talks, coughs, or sneezes and during some procedures (e.g., suctioning, bronchoscopy). A susceptible host may become infected if the infectious droplets land on the mucosal surfaces of the nose, mouth, or eye.

Droplet precautions require patients to be placed in a private room, but no special air handling is necessary.[20] Alternatively, patients with the same disease can be placed in the same room with the privacy curtain between beds drawn if a private room is not available. Because droplets do not travel long distances (usually no more than 3 feet, although occasionally 6 to 10 feet), the door to the room may remain open. Health care workers should wear a standard surgical mask when entering the room. Gowns and gloves should be worn when dictated by standard precautions. When transported out of the isolation room, the patient should be fitted with a standard surgical mask.[20]

Some illnesses that require droplet precautions include invasive *Haemophilus influenzae* type b and meningococcal infections, *Mycoplasma pneumoniae* pneumonia, pertussis, mumps, rubella, and parvovirus B19 infections. Although influenza is generally transmitted via droplets, on rare occasions airborne transmission can occur.[32] Patients with seasonal influenza can generally be managed under droplet precautions, except when undergoing aerosol-generating procedures, such as bronchoscopy, sputum induction, elective intubation and extubation, and autopsies, during which management requires airborne precautions.[33]

Contact Precautions

Contact precautions are implemented to prevent the transmission of epidemiologically important organisms from an infected or colonized patient through direct contact (touching the patient) or indirect contact (touching contaminated objects or surfaces in the patient's environment). Patients with contact precautions should be placed in a private room, although patients infected with the same organism may be placed in the same room when private rooms are not available.[20] Multidrug-resistant organisms, such as vancomycin-resistant enterococci (VRE) and methicillin-resistant *Staphylococcus aureus* (MRSA), contaminate the environment (surfaces and items) in the vicinity of the infected or colonized patient. Therefore, barrier precautions to prevent contamination of exposed skin and clothing should be used.

Contact precautions are indicated for patients infected or colonized with multidrug-resistant bacteria (e.g., MRSA, VRE, multidrug-resistant gram-negative bacilli).[20] Other indications include *C. difficile* infection, infections transmitted by the fecal-oral route (e.g., *Shigella,* rotavirus, hepatitis A virus infections) in patients who are diapered or incontinent, and acute diarrheal diseases likely to be infectious in origin. Because of the propensity for norovirus to cause institutional outbreaks, patients with this infection should be placed under contact precautions.[21] Infants and young children with respiratory syncytial virus, parainfluenza, or enteroviral infection and patients with neonatal, disseminated, or severe primary mucocutaneous herpes simplex virus infection should also be placed under contact precautions. Ectoparasitic infestations (lice and scabies) are additional indications. Patients with varicella or disseminated zoster require both contact and airborne precautions.

Gowns and gloves should be worn when caregivers enter the patient's room and removed before leaving it. Gowns should be removed before leaving the isolation room, and care must be taken to prevent contamination of clothing while removing the gown.[20] After removing gloves, the hands must be decontaminated immediately with a medicated hand-washing agent or an alcohol-based hand rub, and care should be taken to prevent recontamination of the hands before leaving the room.

Numerous studies have documented contamination of noncritical patient care equipment (e.g., stethoscopes, blood pressure cuffs) with vancomycin-resistant enterococci and MRSA. These items should remain in the isolation room and not be used for other patients. If the items must be shared, they should be cleaned and disinfected before reuse. Transport of the patient from the isolation room should be kept to a minimum.

The concept of contact precautions was developed at a time when hand hygiene compliance in health care settings was quite low. As hand hygiene compliance improves, it is likely that the incremental benefit of contact precautions is diminished, and it may be that when hand hygiene compliance is sustained at high rates, the incremental benefit of contact precautions will be very small. As with much of the domain of infection prevention, there is little evidence available to guide practice and further research is needed to address many important questions.

OUTBREAK INVESTIGATION AND MANAGEMENT

Data accumulated by ongoing surveillance allow detection of nosocomial outbreaks. When the monthly rate for a particular infection exceeds the 95% confidence interval based on the previous years' rates for that month, the possibility of an outbreak exists and an investigation is warranted. At other times, an astute observation of a potential cluster of infections by physicians, nurses, or the microbiology laboratory technologists should prompt at least an initial investigation.

When the cluster involves a common organism, hospitals with the capability of performing molecular typing more rapidly may do so first. Pulsed-field gel electrophoresis has been commonly used for outbreak investigation and is generally adequate for this purpose. More recently, whole-genome sequencing has been used. Although this method provides greater detail with regard to tracking an organism in the hospital,[34] in most cases pulsed-field gel electrophoresis is adequate. If the cluster appears to be polyclonal, it is most likely due to antimicrobial usage patterns, a technical problem, or an importation of strains; a formal case-control study may not be necessary. A clonal outbreak suggests a point source or nosocomial transmission, in which case a case-control study may be warranted.

The primary investigating team should include the hospital epidemiologist, the director of employee health, the infection preventionists, and the director of the microbiology laboratory. External consultants are necessary in some cases.

Most outbreaks in health care settings are due to pathogens that are transmitted via direct or indirect contact and often involve multidrug-resistant organisms. Control of such outbreaks involve cohorting the patients and staff (i.e., geographically separating colonized or infected patients from the noncolonized and uninfected and assigning nursing staff to care only for one group or the other to minimize the potential for cross-transmission), heightening environmental cleaning and possibly using environmental cultures or other technology to monitor the cleaning process, performing active surveillance cultures on patients to identify newly colonized patients, ensuring high levels of hand hygiene compliance and strictly enforcing contact precautions, and communicating frequently with hospital staff to maintain vigilance. Early on, the microbiology laboratory should be alerted and asked to archive all isolates potentially related to the outbreak for future molecular typing to assess genetic relatedness.

EDUCATION

A substantial role for the infection preventionist is to educate hospital personnel in the areas of communicable disease transmission, sterilization, disinfection, and institutional infection prevention policies. In many hospitals the epidemiology team is responsible for bloodborne pathogen training and in some hospitals for airborne isolation mask training and fit testing. Some hospitals have successfully established an infection prevention liaison program, whereby each hospital unit appoints a nurse who attends educational sessions periodically and helps disseminate infection prevention information to colleagues. Likewise, the hospital epidemiologist should be available to provide physicians with education targeting specialty-based infection prevention topics.

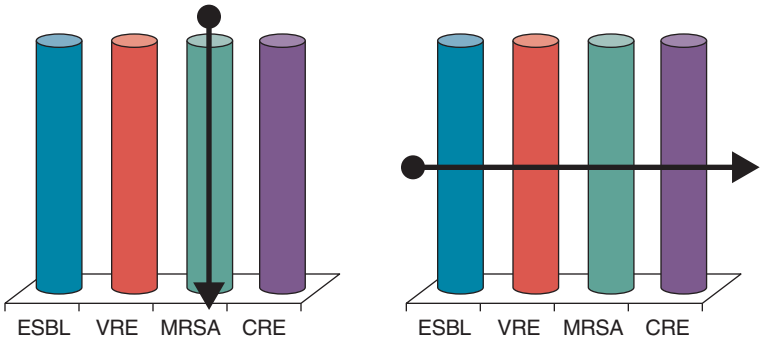

FIGURE 300-1 Comparison of vertical *(left)* and horizontal *(right)* infection prevention strategies. CRE, carbapenem-resistant Enterobacteriaceae; ESBL, extended spectrum β-lactamase gram-negative bacilli; MRSA, methicillin-resistant *Staphylococcus aureus;* VRE, vancomycin-resistant enterococci.

EMPLOYEE HEALTH

The infection prevention program must work closely with the employee health service. Issues such as the management of exposure to bloodborne pathogens and other communicable diseases (e.g., varicella, influenza, meningococcal disease, tuberculosis) require a concerted effort by the two groups. In addition, the employee health service is responsible for ensuring that health care workers are fit for duty and free of communicable diseases. At the time of employment, workers should be reviewed to ensure that they have adequate immunity against illnesses such as rubella, measles, mumps, pertussis, tetanus, hepatitis B, and varicella. In addition, baseline and periodic testing for latent tuberculosis should be performed, as well as postexposure testing. The employee health service should proactively and creatively devise delivery systems that encourage compliance with and remove barriers to annual influenza vaccination by all health care workers.

ANTIMICROBIAL STEWARDSHIP

Approximately 60% of hospitalized patients receive antimicrobial agents, and antimicrobial usage varies widely across hospitals.[35,36] Recent analysis from a consortium of teaching hospitals demonstrated that over 80% of patient days are associated with administration of an antimicrobial agent.[36] Increasingly, hospitals are establishing antimicrobial stewardship programs, which are designed to prevent the emergence of antimicrobial resistance, improve patient outcomes, and control costs. These programs are usually staffed by infectious diseases physicians and clinical pharmacists.[37] Interventions implemented by stewardship programs can be classified as active or passive and can be targeted to the pre- or post-prescription periods.[38] Examples of active pre-prescription interventions include formulary restriction, preauthorization, and order sets, whereas passive interventions include treatment guidelines, education, feedback of antimicrobial utilization data, and selective reporting of antimicrobial susceptibility by the microbiology laboratory. In the post-prescription period, active interventions including the provision of real-time feedback to clinicians regarding antimicrobial usage and automatic conversion of intravenous to oral formulations for drugs that are highly bioavailable. Passive post-prescription interventions include de-escalation protocols and electronic alerts for prolonged antimicrobial therapy or bug-drug mismatches.

The program should monitor the antimicrobial susceptibility profiles produced by the microbiology laboratory on a regular basis to observe for trends in the development of antimicrobial resistance. The results should be correlated with the antimicrobial agents currently used in the institution. The best data are obtained if nosocomial isolates are distinguished from community-acquired isolates and if only one isolate per patient is counted in the numerator and denominator.

POLICY AND INTERVENTIONS

The primary administrative function of the infection prevention program is to develop, implement, and continually evaluate policies and interventions designed to minimize the risk for HAIs. Some policies are designed to be implemented throughout the institution, whereas others apply to specific areas of the hospital. Policies are generally developed by the infection control committee after a review of data generated in-house, as well as information available from the medical literature. Recommendations from the infection control committee may then need to be forwarded to other committees for review and approval before dissemination of the new policy.

Infection prevention interventions can be classified as vertical or horizontal (Figure 300-1).[39,40] Vertical interventions are aimed at reducing risk from a single pathogen and often involve a microbiologic testing component. Examples include active surveillance cultures and subsequent isolation of patients found to be colonized with multidrug-resistant organisms such as MRSA and VRE. Horizontal interventions are multipotent interventions aimed at reducing risk from all pathogens transmitted via the same mechanisms. Examples include hand hygiene, chlorhexidine bathing, the central line insertion bundle, and "bare below the elbows." With regard to influenza prevention in the health care setting, vaccination of health care workers is a vertical intervention; efforts to reduce presenteeism (working while ill) are horizontal because all causes of influenza-like illnesses, and even other types of infections (e.g., viral gastroenteritis), could be reduced by a reduction in presenteeism.

Vertical and horizontal interventions are not mutually exclusive. However, the economic and opportunity costs of vertical activities can be high. Some hospital infection prevention programs became consumed by obtaining MRSA surveillance cultures on patients at admission and weekly and then ensuring that colonized patients were appropriately isolated. But even if a vertical intervention for MRSA had 100% efficacy, it would have no impact on other multidrug-resistant organisms. Alternatively, investment in horizontal interventions such as improving compliance with hand hygiene has an impact on all pathogens transmitted via contact, even newly emergent organisms for which rapid screening tests have not yet been developed. Infection prevention programs that are primarily horizontal require long-term commitments to difficult targets (e.g., the behavior changes necessary to drive high compliance with hand hygiene).

ENVIRONMENTAL HYGIENE

As the hospitalized population has become more immunosuppressed, the importance of environmental hygiene has significantly increased. Technical issues regarding air handling, construction, demolition, water supply, pest control, and medical waste management may require collaboration with engineers, architects, and other nonmedical professionals, including external consultants. The CDC has produced a document on environmental infection control[41] that is an excellent resource for hospital epidemiologists on these issues.

NEW PRODUCT EVALUATION

A large number of new medical products are marketed each year. These products may be introduced into the hospital setting with few data to support their efficacy or their advantage over existing products. Often the new products are significantly more costly. The infection prevention program should play an active role in evaluating data on new

products designed to reduce infections or protect health care workers and then make recommendations regarding their introduction to the hospital.

REGULATORY COMPLIANCE

Increasingly, infection prevention programs are involved in the maintenance of compliance with governmental regulations, certification programs for various services provided, and accreditation. In order for hospitals to receive reimbursement from the CMS, it must demonstrate via an accreditation process that it is in compliance with the conditions of participation. Infection prevention is an integral part of this process. Accreditation can be accomplished via routine surveys by a state survey agency. However, most hospitals seek accreditation via an alternative agency, The Joint Commission. Two other alternative agencies are the Healthcare Facilities Accreditation Program (HFAP) and Det Norske Veritas (DNV) Healthcare.

ORGANIZATION OF THE INFECTION PREVENTION PROGRAM

The organizational structure for the infection prevention program should be tailored to meet the demands of the hospital and to use available resources optimally. Large hospitals with a high proportion of tertiary care patients require a more complex system to meet their needs.

Each hospital should develop an infection prevention plan that outlines the scope of the infection prevention program, the overarching and specific goals, and metrics used to assess progress toward those goals. Periodically throughout the year, the plan should be reviewed and updated as goals are met and new issues develop. At the end of each year, a more formal risk assessment should be conducted in light of yearly data trends and the findings reflected in the infection prevention plan for the upcoming year.

Hospital Epidemiologist

The hospital epidemiologist occupies a unique position. He or she must interface with many hospital departments, hospital administrators, and extramural agencies; directly supervise the infection prevention program; and in some hospitals direct the quality improvement program. In areas where subspecialists are available, the position is generally held by a physician who is trained in infectious diseases. However, only approximately one fourth have additional training in health care epidemiology.[42]

Before assuming the position of hospital epidemiologist, the physician should meet with key hospital administrators to discuss the responsibilities and expectations of the position and to negotiate the human and material resources, including the salary support that will be made available to implement the infection prevention program. A survey performed in 2006 found that salary support for physician epidemiologists was on average 0.85 full-time equivalent for hospitals with fewer than 200 beds and increased to a mean of 1.79 full-time equivalent for hospitals with more than 600 beds.[42] An excellent review of resources necessary to operate an infection control program is found in the Society for Healthcare Epidemiology of America position paper on infrastructure for infection control.[43]

Infection Preventionists

Talented infection preventionists are essential for the operation of an excellent infection prevention program. These individuals are usually registered nurses with clinical experience or medical technologists with experience in microbiology. The effective infection preventionist must have a working knowledge of epidemiologic principles and basic microbiology and a sound understanding of the operations of the health care institution.

During the 1980s, the CDC recommended that hospitals have one infection preventionist for every 250 beds.[8] Since that time, the number of hospital beds has decreased, the severity of illness of hospitalized patients has markedly increased, with a corresponding increase in the number of critical care beds, infection control issues in the ambulatory setting have increased, and many new duties have been assumed by infection prevention programs. A 2002 study using the Delphi method determined that for acute-care hospitals the optimal ratio is one infection preventionist per 100 to 125 beds.[44] A more recent expert panel concluded that the optimal ratio is one infection preventionist per 67 to 100 beds depending on the patient mix.[42]

Infection Control Committee

A multidisciplinary infection control committee that meets at least quarterly is recommended. This committee should include representatives from the medical and nursing staffs, hospital administration, and the personnel directly responsible for management of the infection prevention program. The committee also typically includes the infection preventionists and representatives from the microbiology laboratory, pharmacy, operating room, and departments of employee health, housekeeping, central services, and engineering and maintenance.

Over the past few decades, preventing HAIs has become highly technical. Therefore, the bulk of the committee's work is best accomplished by a core of experts that includes the hospital epidemiologist, infection preventionists, a microbiologist, and the director of employee health. Policy formulations should be developed by this subgroup along with other experts on an ad hoc basis and brought to the entire committee for review, ratification, and support from political and administrative standpoints. Thus, the full infection control committee functions to educate key hospital administrators, provide the political support that allows the core members to implement policy, and disseminate new policy.

The meeting's agenda should be well planned and circulated to committee members before the meeting. In addition, the committee members should receive all policies to be reviewed before the meeting to allow adequate time for review by individual committee members and to improve the efficiency of the meeting.

The agenda should begin with an approval of the minutes of the previous meeting. This is followed by brief reports by representatives of the pharmacy, employee health department, clinical microbiology laboratory, and local public health department. In addition, all communicable disease exposure workups from the previous month are summarized, as are bloodborne pathogen exposures in health care workers. Ideally, old business is kept to a minimum. Recent infection rates and other trended metrics (e.g., hand hygiene compliance, influenza vaccine compliance) should be reviewed. The focus of the meeting then turns to more in-depth reports of a few current issues. Invited guests may discuss various aspects of these issues. It is also helpful to review, update, and reapprove a few existing policies at each meeting on an ongoing basis.

FUTURE CHALLENGES

Increasingly, third-party payers and health care consumers are demanding reductions in complications of medical care, including HAIs, as well as public reporting of infection rates. These expectations, along with continued media attention, have propelled infection prevention programs into a new era of much greater scrutiny and a demand for higher accountability. Despite the increasing severity of illness of hospitalized patients, the greater prevalence of invasive technologies, and a higher prevalence of immunocompromised patients, some are calling for hospital epidemiologists to achieve the goal of eliminating HAIs (getting to zero). It is important that the infection prevention community acknowledge that most HAIs are preventable and respond with a strong commitment to decrease HAIs to the irreducible minimum. However, unreasonable expectations can lead to adverse unintended consequences.[45]

The hospital epidemiologist as a steward of scarce resources and faced with unfunded mandates must decide how best to appropriate resources within his or her purview but must also be able to justify the cost of the marginal benefits gained by enhanced infection prevention activities in light of the impact on other programs with different goals in the health system. When considering new interventions, the hospital epidemiologist should focus on and integrate clinical outcomes, economic impact, and customer (health care provider and patient) satisfaction to balance quality and cost.[46]

Emerging infectious diseases and multidrug-resistant pathogens require infection control programs to be able to respond quickly to protect patients and health care workers, even in some cases with few data on the mechanism of disease transmission. Protecting the health

care worker with a chronic bloodborne infection and his or her patients remains a challenge, as does the protection of immunosuppressed patients and of health care workers from environmental pathogens.

Last, and perhaps most important, it remains the responsibility of the hospital epidemiologist to evaluate the medical literature and newly collected data critically when making decisions that affect the safety of patients and health care workers. Ensuring that all decisions are evidence based and free of ideology, politics, conflict of interest, or coercion of any form should be a deeply rooted ethic for all involved in this field.

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