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Infection Prevention and Control, and Antimicrobial Stewardship

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KEY CONCEPTS

- Infection prevention and control is a discipline in which epidemiologic and statistical principles are used to prevent both healthcare-associated infections and transmission of infections to patients and healthcare workers.
- Healthcare infection surveillance should be a systematic, ongoing risk-stratified process to monitor identifiable events (such as surgical site infections) in a defined population.
- The process and outcome data generated by hospital epidemiology and other practitioners is relevant to patient safety and quality of care at the level of the institution, across institutions and extending to credentialing and governmental regulatory boards such as the Joint Commission.
- One of the most critical functions of the Infection Prevention Program is to provide education and training for healthcare providers, including instruction on isolation precautions, aseptic techniques and sterile practices, prevention of blood and body fluid exposures, and appropriate usage of personal protective equipment and safety devices.
- The goals of an effective antimicrobial stewardship program (ASP) include optimizing clinical outcomes while minimizing toxicity associated with antimicrobial use and the emergence of resistance, resulting in a reduction of healthcare costs while maintaining or improving quality of care.

Introduction

The concept of infection prevention and control has its roots in the pre-germ theory era, when in 1846 Semmelweis introduced hand hygiene with chlorinated lye to physicians, and noted a reduction in puerperal sepsis.[1] In the USA the hospital discipline of infection control was established in the 1950s in response to a nationwide epidemic of nosocomial *Staphylococcus aureus* and the recognition of the need for nosocomial infection surveillance.[2] Since that time, the discipline has expanded dramatically, becoming an integral and critical part of promoting a safe environment in the healthcare setting.

Trends and Complexity of Current Healthcare in Higher-Income Countries

Healthcare-associated infections (HAIs) are a significant cause of morbidity and mortality in higher-income countries. It is estimated that between 4% and 10% of patients admitted to acute care hospitals acquire one or more infections.[3,4] Based on a 2011 point prevalence survey of acute care facilities in the USA, the most common HAIs were hospital-acquired pneumonia (HAP) at 21.8%, surgical site infections (SSI) at 21.8%, and *Clostridium difficile* infections (CDI) at 12.1%. Device-associated infections, i.e. central line-associated bloodstream infections (CLABSI), catheter-associated urinary tract infections (CAUTI) and ventilator-associated pneumonia (VAP) accounted for 25.6% of HAIs.[5]

HAIs also result in excess mortality, length of stay (LOS) and increased costs.[5,6] In 2007, it was estimated that the overall annual direct medical costs to US hospitals of all HAIs among hospital patients was between 28.4 and 45 billion dollars.

In addition to the challenges posed by the numbers of HAIs, the complexity and the measures required to prevent and track HAIs have also increased. Such challenges include:

- controlling antimicrobial resistance and spread of multidrug-resistant pathogens;
- addressing emerging infections such as severe acute respiratory syndrome (SARS), Ebola, novel influenza viruses;
- providing constantly updated data for an increasingly sophisticated public, including public reporting;
- attempting to modernize surveillance and reporting systems, often with limited resources available;
- addressing the infectious consequences of ever-more complicated medical procedures, with special populations such as highly immunosuppressed transplant patients, gene therapy, xenotransplantation;
- maintaining a safe workplace in an ever-more complex medical system.

Organization of Infection Prevention and Control

Infection prevention and control is a discipline in which epidemiologic and statistical principles are used in order to prevent or control the incidence and prevalence of infections. The primary role of an infection prevention and control program (IPCP) is to reduce the risk of acquisition of HAI. To ensure the success of an infection control program, the appropriate infrastructure and institutional support, both material and administrative, need to be made available to healthcare epidemiology staff.

The critical functions that often fall under the umbrella of a healthcare epidemiology program are listed in Box 6-1.[2,7]

MANAGE CRITICAL DATA AND INFORMATION

Develop, Implement and Monitor Surveillance Based upon an Institution-Specific Risk Assessment

The importance of surveillance and feedback to the clinical users as a part of hospital infection control programs was established by the 1976 Study on the Efficacy of Nosocomial Infection Control (SENIC). SENIC found that hospitals reduced their nosocomial infection rates by about 32% if their surveillance and control plan included the following components: appropriate emphasis on surveillance activities and control efforts; appropriate staffing of the infection control program; and, for surgical site infections, feedback of wound infection rates to practicing surgeons.[8]

Healthcare infection surveillance should be a systematic, ongoing process to monitor identifiable events (such as surgical site infections) in a defined population. This will initially require a risk stratification to determine what the critical targets of surveillance should be. In the USA and other higher-income countries, many surveillance activities will be mandated by local or federal authorities and other licensing and regulatory bodies. Other surveillance activities will vary, based on an understanding of the epidemiology and risk at a particular institution. For instance, surveillance for invasive aspergillosis in an institution

BOX 6-1 CRITICAL FUNCTIONS OFTEN MANAGED BY HOSPITAL EPIDEMIOLOGY

- Managing critical data and information
  - Monitoring and reporting of surveillance results/infection rates to clinical services, administration and regulatory bodies
  - Developing, implementing and monitoring surveillance based upon an institution-specific risk assessment
- Developing and implementing policies and procedures to prevent or minimize infection risk (e.g. isolation precaution policies, etc.)
- Intervening to prevent disease transmission
  - Outbreak investigation and control
  - Education and training
- Collaborating with other programs to achieve common goals
  - Occupational and employee health
    - Post-exposure prophylaxis in the healthcare setting
    - Management of the infected healthcare worker
  - Environmental health and safety
    - Construction infection control
    - Infectious waste management
    - Environmental cleaning service
    - Air and water handling
    - Respiratory protection
    - Disinfection and sterilization
  - Microbiology laboratory
    - Monitoring for isolation of sentinel organisms
    - Monitoring antibiotic resistance profiles
  - Pharmacy and therapeutics
    - Antimicrobial utilization
  - Safety, quality and public reporting
  - Disaster preparedness committee
    - Bioterrorism preparedness

undergoing new construction and with a large compromised host population might be rated a higher priority than the long-term monitoring of *Legionella* in an institution where *Legionella* has not been identified for years. Each hospital must tailor its surveillance activities based on risk assessment of the population as well as the available resources within the infection control team and healthcare entity. Such 'targeted' surveillance should be defined for each healthcare environment.[9]

A number of components are critical for an effective surveillance system.

1. Clear and uniform definitions of the outcome variables should be developed. In the USA, standardized definitions and methodologies developed by Centers for Disease Control (CDC)/National Health and Safety Network (NHSN) have been widely adopted so that comparisons can be made both within the health system and across institutions.[10,11]
2. Surveillance should be an active process that includes review of microbiologic data, clinical and nursing records, pharmacologic and pathologic data, readmission and reoperation data following surgery for selected procedures, etc. Automated surveillance systems utilizing computer-based patient records or other electronic data may provide a sensitive, specific, time-efficient and cost-effective mechanism in many institutions.[12,13] The surveillance methodology should rely on metrics that are objective, standardized and incorporate meaningful risk adjustment.
3. Case adjudication by the practitioners of the procedural area under evaluation should be avoided; in this setting the process may be prone to bias and lose objectivity, especially if financial incentives are involved. On the other hand, periodic review of the case definitions and feedback on the surveillance by members of the practice team may provide insights that can result in corrective quality improvement actions adapted to that specific practice.
4. Whatever the system of surveillance is, both numerator and denominator data must be available for review. For instance, central line-associated bloodstream infections (CLABSI) are expressed as number of CLABSI/number of central line days × 1000. Thus, trends can be tracked and compared within and between institutions.
5. Appropriate benchmarking should be sought. Increasingly, healthcare systems are being compared and inferences on quality of care are being made, sometimes with suboptimal risk adjustment.
6. Appropriate risk stratification is essential to identify and prioritize which areas should be targeted for performance improvement within a given institution. However, differences in hospital size, patient mix and risk adjustment introduce complexity when comparing rates between smaller community hospitals and tertiary care/specialty hospitals. In 2009, NHSN transitioned from reporting rates of HAIs to the standardized infection ratio (SIR).[14] The SIR is the ratio of expected over observed events for a particular HAI. Expected events are based on NHSN national data collected in the previous years and risk adjusted using multivariate regression analysis. Both SIR and rates are currently being used to compare similar healthcare facilities at the state and national level.[15]
7. Reports describing the surveillance activities and findings should be prepared (using appropriate statistical analysis) and distributed to the appropriate groups.
8. After feedback to the particular service is provided, that service (generally in conjunction with the IPCP) should develop an action plan for process improvement with measurable outcome metrics.

DEVELOP AND IMPLEMENT POLICIES AND PROCEDURES TO PREVENT OR MINIMIZE INFECTION RISK

Another critical role for the infection control unit within a healthcare facility is to develop and implement evidence-based policies and procedures, such as isolation precaution policies, that are aimed at preventing HAIs. In general, these policies will be adapted to institutional needs using resources available from the following:

- relevant published literature
- professional society guidelines
- professional practice guidelines
- state and federal regulatory bodies
- governmental and regulatory agencies.

Institutional policies and procedures should be regularly reviewed and updated, and easily accessible to users.

INTERVENE TO PREVENT DISEASE TRANSMISSION

Outbreak Investigation and Control

An outbreak can be defined as an increase in the incidence of a disease/infection above the background rate in a given population. In a healthcare setting, the 'background' rate may be provided by ongoing surveillance activities as described above. In the healthcare setting, prompt identification of an outbreak and intervention on the part of the IPCP is critical in preventing adverse outcomes and accruing costs. The basic components of outbreak investigation are followed, as outlined in Box 6-2.[16] An example would be as follows:

Hospital X performs a large number of hip joint replacements, and this is a procedure monitored by the IPCP (Figure 6-1). Standardized NHSN criteria are used to define surgical SSIs for hip prosthesis. Hospital X's surveillance for hip prosthesis involves review of all microbiology data for all hip replacements done at the institution plus readmission data after hip replacement, as well as antibiotic utilization data for patients with hip replacement. Charts are then reviewed to evaluate if a hip infection occurred and at what level (superficial, deep or organ/space, by NHSN criteria).

It is noted that in the third quarter, compared with the previous quarter, there was an increase in the number of hip infections with a standardized infection ratio (SIR) of 4.0. Charts are reviewed to confirm, and an epidemic curve is generated, suggesting that the increase in infection started in mid July. This information is reported back to Orthopedics as well as the Administrative hospital

BOX 6-2 STEPS IN THE INVESTIGATION AND CONTROL OF A POTENTIAL OUTBREAK

1. Establish case definition(s).
2. Confirm that the cases are 'real' (case confirmation).
3. Establish the background rate of disease (in order to confirm the outbreak and determine the scope of the outbreak geographically and temporally).
4. Case finding.
5. Examine the descriptive epidemiology of the cases (e.g. define the age, sex, home/overseas travel, occupation, attendance at events) and plot an 'epidemic curve' of time of onset of disease.
6. Generate a hypothesis regarding the source and route of exposure.
7. Test the hypothesis by case control, cohort or intervention studies and by epidemiologic typing of representative samples if indicated and if possible.
8. Collect and test potential sources of infection such as environmental surfaces, patients, personnel, iv fluids, etc. as indicated; consider epidemiologic typing to establish an epidemiologic link to cases.
9. Devise and implement control measures.
10. Review results of investigation or report on ongoing investigations to administration and staff; consider consultation with local public health officials.
11. Follow-up surveillance to evaluate efficacy of control measures; generate reports for administration and staff.

leadership. Patient data review indicates that the infections are with multiple different organisms, with procedures performed with multiple different surgeries in different operating rooms (ORs).

It is noted by one of the healthcare workers interviewed that a new surgical scrub was put into place in late June in the orthopedic ORs, and the concern is raised that this may be associated with the increase in infections. A review reveals that the new scrub is not being used per recommendations. A plan to develop and implement an educational module regarding surgical scrub is enacted, and by September the SIR for hip infections has decreased to 1.8.

The Role of the Microbiology Laboratory

The microbiology laboratory plays a critical role in both surveillance and outbreak investigations. Rapid detection and reporting of key organisms with high potential to cause outbreaks such as *C. difficile* or *Mycobacterium tuberculosis* are critical components of infection prevention, leading to appropriate implementation of control measures and reducing the risk of secondary spread.[17]

The development of an institutional antibiogram is a critical function that often results from collaboration between different groups, as will be discussed below.

Understanding pathogen distribution and relatedness in the hospital is an important component of both surveillance and outbreak investigation. Typing of microbial isolates can help determine whether epidemiologically linked pathogens are genetically related and may help identify the source of an outbreak (environmental, personnel, etc.). The incorporation of molecular typing methodologies along with

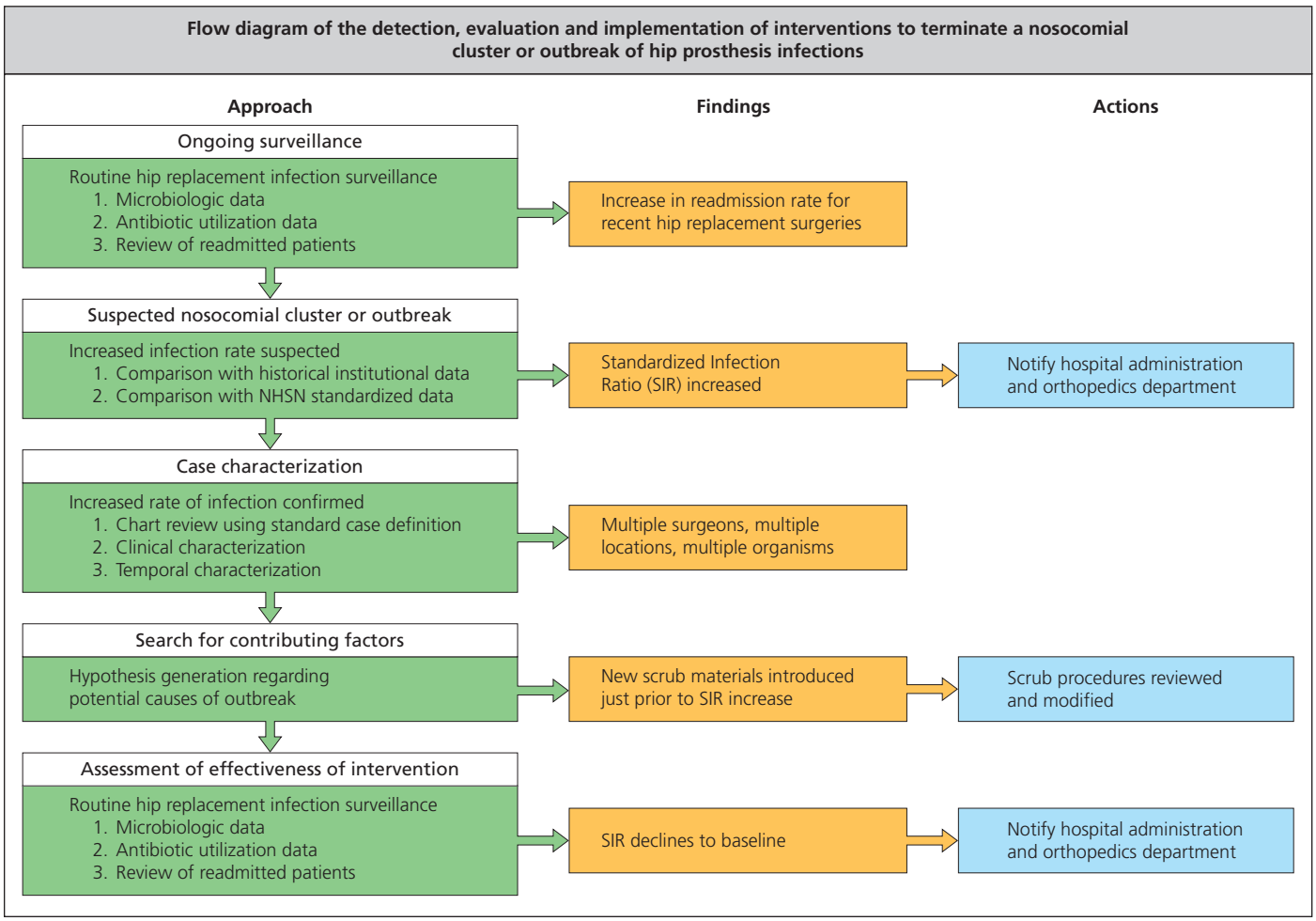

Figure 6-1 Flow diagram of the detection, evaluation and implementation of interventions to terminate a nosocomial cluster or outbreak of hip prosthesis infections.

traditional epidemiologic surveillance has been shown in a number of studies to reduce the number of HAIs and to be cost-effective.[18] Typing can be done using phenotypic methods (e.g. biotyping and serotyping) or genotypic/molecular methods (e.g. pulsed field gel electrophoresis, plasmid analysis, southern blotting or PCR). Sequence-based molecular epidemiologic analysis includes rapid whole genome sequencing, which has been used successfully in the evaluation and control of several important nosocomial outbreaks.[19]

Education and Training

One of the most critical functions of the IPCP is to provide education and training for healthcare providers including instruction on isolation precautions, aseptic practice, prevention of blood and body fluid exposures, and appropriate usage of personal protective equipment and safety devices.

COLLABORATE WITH OTHER PROGRAMS TO ACHIEVE COMMON GOALS

Occupational and Employee Health

An active employee health service and IPCP collaboration is critical in the protection of healthcare workers and the control of HAIs. Joint objectives generally include:

- education of personnel about the principles and importance of infection control
- prompt diagnosis and appropriate management of transmissible diseases in healthcare workers, such as respiratory syncytial virus or pertussis
- assessment and investigation of potential exposures and outbreaks among personnel
- identification and vaccination of workers susceptible to vaccine-preventable diseases
- identification of work-related infection risks and institution of preventive measures
- surveillance of healthcare workers for diseases such as tuberculosis.[20,21]

The CDC has published extensive guidelines and recommendations on immunization of healthcare workers, occupational health guidelines and protection of healthcare workers from blood-borne pathogens, including post-exposure prophylaxis guidelines.[22]

Environmental Health and Safety and Environmental Services

Environmental Health and Safety and IPCP work together to ensure environmental safety and prevent exposure of patients and staff to environmental and airborne pathogens. The combination of infection control and environmental engineering strategies can help prevent such occurrences. These control measures include:

- adherence to ventilation standards for specialized care environments (e.g. airborne infection isolation rooms, protective environments or operating rooms) and to water-quality standards, including for hemodialysis
- appropriate infectious waste management
- appropriate use of cleaners and disinfectants
- appropriate use of precautions during construction.

In this era of antibiotic-resistant pathogens, the importance of environmental cleaning cannot be overstated. Environmental contamination of floors, beds, tables, faucets, doorknobs, blood pressure cuffs, thermometers, gowns, stethoscopes and computer terminals has all been well documented.[23,24] Among other factors associated with transmission, acquisition of drug-resistant organisms such as vancomycin-resistant *Enterococcus* (VRE) and methicillin-resistant *Staph. aureus* (MRSA) may depend on room contamination, and the odds of acquiring antibiotic-resistant bacteria are increased by patient admission to a room previously occupied by a patient harboring the resistant organism.[24]

During a suspected or proven outbreak where an environmental reservoir is suspected, cleaning procedures should be assessed and adherence should be monitored and reinforced.

In general, use of a US Environmental Protection Agency (EPA)-registered detergent/disinfectant (used according to the manufacturer's recommendations for amount, dilution and contact time) is sufficient to remove pathogens from surfaces of rooms of colonized or infected individuals. Certain pathogens (e.g. rotavirus, norovirus, *C. difficile*) may be resistant to some routinely used hospital disinfectants. Many investigators have recommended the use of a 1:10 dilution of 5.25% sodium hypochlorite (household bleach) and water for routine environmental disinfection of rooms of patients with *C. difficile*, norovirus and rotavirus.

General and specific recommendations for disinfection and sterilization may be found in the CDC's *Guidelines for Environmental Infection Control in Healthcare Facilities*.[23]

Disinfection and Sterilization

Numerous reports detailing infection outbreaks secondary to faulty or inadequately disinfected medical instruments highlights the critical importance of sterilization and disinfection of such items.[28] IPCP collaborates with sterile processing to help prevent such problems.

Medical equipment and instruments/devices must be cleaned and maintained according to the manufacturers' instructions to prevent patient-to-patient transmission of infectious agents. Cleaning to remove organic material must always precede high-level disinfection (a process that eliminates many or all pathogenic organisms except bacterial spores) and sterilization (complete elimination or destruction of all microbial life).

Noncritical equipment, such as commodes, intravenous pumps and ventilators, computers used in patient care, etc., must be thoroughly cleaned and low-level disinfected before use on another patient. Providing patients who are on transmission-based precautions with dedicated noncritical medical equipment (e.g. stethoscope, blood pressure cuff, electronic thermometer) may prevent pathogen transmission. If this is not possible, disinfection after use is recommended. Semi-critical items come in contact with mucous membranes and intact skin. This includes respiratory therapy and anesthesia equipment. High-level disinfection after cleaning is an appropriate standard of treatment for heat-sensitive, semi-critical medical instruments (e.g. flexible, fiberoptic endoscopes).[25] This process inactivates all vegetative bacteria, mycobacteria, viruses, fungi and some bacterial spores. Critical items (objects that enter sterile tissue or the vascular system) should either be purchased sterile or undergo heat-based sterilization prior to patient use. This includes surgical instruments, various catheters, implants, etc.

Pharmacy and Therapeutics, and Antimicrobial Stewardship

Infection with antibiotic-resistant bacteria has been associated with increased morbidity, mortality and costs of healthcare. The goals of an effective antimicrobial stewardship program (ASP) include optimizing clinical outcomes while minimizing toxicity associated with antimicrobial use and the emergence of resistance, resulting in a reduction of healthcare costs while maintaining or improving quality of care. It has been shown that the use of an ASP program decreases inappropriate antibiotic use and clinical failure, and significantly increases the rate of cure in patients hospitalized with infections.[26] The proven benefits have now led some jurisdictions to mandate hospitals to establish ASPs.

The Infectious Diseases Society of America recommends a multidisciplinary approach to an ASP, with an infectious disease physician and a clinical pharmacist with infectious diseases training as core members of the ASP team. In order to decrease the occurrence of inappropriate antimicrobial use, an ASP often utilizes either formulary restriction with preauthorization or prospective audit with intervention and feedback. The former requires the hospital to establish a list of restricted antimicrobials and a method by which authorization for use is obtained from an infectious disease physician or clinical pharmacists. The latter requires the ASP team to review antimicrobial utilization and provide appropriate feedback to prescribing physicians.

Other methods that may be utilized include antimicrobial order forms, guidelines or order sets for the treatment of specific infections, computer-based alerts, and educational programs for hospital staff. A further area of growing importance is the de-escalation of empiric antimicrobial coverage once culture data have been finalized, thereby avoiding unnecessary antimicrobial exposure.

The benefit of an ASP in decreasing the incidence of drug-resistant pathogens has been demonstrated in multiple studies. For example, the incidence of vancomycin-resistant *Enterococcus* (VRE), *Clostridium difficile* and drug-resistant gram-negative bacilli have been shown to decrease in institutions with ASPs.[27,28]

An ASP requires a multidisciplinary approach, with collaboration with a clinical microbiologist, an information systems specialist, an infection control professional and hospital epidemiologist. Because such ASPs are important patient-safety initiatives, they often function under the umbrella of quality assurance and patient safety, and should receive hospital administrative and fiscal support.[29,30] The ASP may also work with microbiology, pharmacy and the IPCP to create an institutional and unit-specific antibiogram, which can be accessible to all antibiotic prescribers in the healthcare system.

Safety, Quality and Public Reporting

Healthcare-associated infections are one of the most common preventable complications of hospitalized patients, and therefore are frequently used as indicators of the quality of patient care. Thus, the process and outcome data generated by infection control and other practitioners is relevant to patient safety and quality of care at the level of the institution, across institutions and extending to credentialing and governmental regulatory boards.[31]

As of 2014, 37 states (74%) in the USA had enacted legislation that requires healthcare facilities to publicly report HAIs through NHSN. Although there is a wide variation among US states on which outcome measures are reported, CLABSI, CAUTI, selected surgical site infections, hospital-onset MRSA bloodstream infections and CDI are most often reported. In 2013 the CDC Healthcare Infection Control Practices Advisory Committee (HICPAC) published consensus recommendations for public reporting[10] which emphasize choosing consistent, standardized CDC definitions along with external validation of surveillance processes and HAI reporting, discouraging clinician veto and adjudication, ensuring feedback to healthcare providers and providing adequate infrastructure support.

Associated with the widespread adoption of quality improvement processes, a decrease in HAIs from an estimated 1.7 million HAI in 2002 to 721 800 HAI in 2011 has been observed.[5]

Disaster and Bioterrorism Preparedness

The anthrax letters mailed within the USA in 2001, the SARS outbreak in 2002, the H1N1 (swine flu) pandemic in 2009 and the Ebola outbrack in 2014 have heightened the awareness of the importance of disaster (natural or bioterrorism-related) preparedness. Infection control plays an integral role in such an effort, in order to develop plans to minimize exposure of staff and the potential for nosocomial transmission (see isolation guidelines).

Isolation Precautions

STANDARD AND TRANSMISSION-BASED PRECAUTIONS

Standard Precautions

Standard precautions constitute a system of barrier precautions designed to be used by all healthcare personnel on all patients, regardless of diagnosis, to reduce the risk of transmission of micro-organisms from both recognized and unrecognized sources. These sources include blood, all body fluids, secretions, excretions, intact and non-intact skin, mucous membranes, equipment and environmental surfaces.

Elements of standard precautions include hand hygiene and the banning of artificial nails. In 2002, the CDC published guidelines for hand hygiene.[32] These guidelines were adopted by the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) in 2004 as part of the new National Patient Safety Goal 7A.[33]

Whenever possible and available, alcohol-based products are the primary method used for decontaminating hands. In addition, hands should be washed with soap and water for 15 seconds if they are visibly soiled, or after covering a sneeze, nose blowing or using the bathroom.

Lastly, in the presence of *Clostridium* spores, alcohol products are discouraged because spores are not killed by alcohol.

In healthcare settings hand hygiene must occur before any direct patient contact and between patients, between tasks/procedures on the same patient, before donning gloves and performing an invasive procedure, after contact with intact skin (e.g. taking a pulse/blood pressure), after removing gloves or other personal protective equipment (PPE), after contact with body substances or articles/surfaces contaminated with body substances, and before preparing or eating food. Hands should be washed with soap and water after 7–10 applications of an alcohol-based product.

Gloves, Masks, Eye Protection and Face Shields, Aprons, Gowns and Other Protective Body Equipment. Disposable gloves must be worn for anticipated contact with moist body substances, mucous membranes, tissue and non-intact skin of all patients, for contact with surfaces and articles visibly soiled or contaminated by body substances, during venous blood draws or other vascular access procedures (starting a venous line or blood draws) or any other situation where contamination of hands is anticipated.

When used, gloves should be donned immediately prior to the task. Gloves should be removed and disposed of after every task involving body substance contact and before leaving the bedside. Gloves should not be worn away from the bedside or laboratory bench, at the nursing station, to handle charts, when touching clean linen, clean equipment or patient care supplies, or in hallways or elevators. Hands have to be washed as soon as possible after glove removal or removal of other protective equipment.

Masks, in combination with eye protection devices (goggles or glasses with side shields) or chin-length face shields, should be worn during procedures or other close contacts that are likely to generate droplets, spray or splash of body substances to prevent exposure of mucous membranes of the mouth, nose and eyes. Nonexhaustive examples are surgery, trauma care, newborn delivery, intubation and extubation, suctioning, bronchoscopy and endoscopy, emptying bedpans and suction canisters into a hopper or toilet.

Plastic aprons or gowns and other protective body clothing are used during patient care procedures to prevent contamination of clothing and protect the skin of personnel from blood or body fluid exposure.

Additional protective equipment, including surgical caps, hoods and shoe covers or boots, may be used in surgical or autopsy areas. All protective body clothing should be removed immediately before leaving the work area.[23,32]

Transmission-Based Precautions

Transmission-based precautions are used in addition to standard precautions in patients with documented or suspected infections or who are colonized with an organism that is transmissible and/or that is of epidemiologic significance. There are three types of transmission-based precautions: contact, droplet and airborne. A sign with the type of transmission-based precautions should be placed outside the room of the patient. In the USA, to comply with the Health Insurance Portability and Accountability Act (HIPAA) the name of the infecting organisms may *not* be written on the sign.

Waste disposal, spill management, linen and food trays should be handled in the same way for all patients, regardless of precaution category. Isolation trays are not required. After patient use, both linen and food trays are sent directly for cleaning and disinfection.[34]

Contact Precautions. Contact precautions are initiated and maintained to interrupt the transmission of epidemiologically significant micro-organisms known to be spread by contact.

Contact precautions are instituted:

- when a patient is colonized or infected with multidrug-resistant organisms or organisms that are not treatable with the usual antibiotics, i.e. multidrug-resistant organisms
- when a particular organism is identified as being potentially hazardous because of its pathogenicity, virulence, epidemiologic characteristics and that persists in the environment or on hands and thus could be easily transmitted, e.g. rotavirus, *C. difficile*, *Salmonella* spp. and *Shigella* spp.
- on a case-by-case basis at the discretion of the IPCP staff, infectious diseases staff and/or medical or nursing staff.

After hand hygiene, the key element of contact precautions is personal protective equipment (PPE). Upon entering the room of a patient placed in contact precautions, disposable gown and gloves should be worn. All PPE must be removed before leaving the room and hand hygiene must be done. Gowns may be worn one time only, and then should be disposed of in the regular (nonbiohazardous) waste before leaving the room.

The patient should be placed in a private room whenever possible. When a private room is not available, cohorting of patients with the same confirmed micro-organism (but with no other infection) is acceptable after notification of IPCP. Because a negative air pressure room is not required, the door may remain open. When neither a private room is available nor cohorting is achievable, a space separation of at least 1 meter (3 feet) should be present between the infected patient and other patients or visitors.

To minimize contamination, equipment should not be shared (unless it is disinfected properly) between patients. For pediatric patients with fecal pathogens such as VRE or rotavirus and who require weighing, a dedicated scale should be placed in the room.

In critical care units or units where there is a high endemic rate of the organism wipe-down of high touch areas should be repeated as needed and at minimum each shift. Cleaning cloths used in the room should not be used to clean other patients' rooms and equipment.

Traffic into the patient's room should be limited only to essential staff/visitors. All visitors should be instructed in gowning and gloving and proper hand hygiene technique. Visitors may be referred to infection control or given written educational material.

Droplet Precautions. Droplet precautions are required when a patient is suspected or known to have an illness transmitted by large particle droplets or direct contact with respiratory secretions. Droplets are often 30–50 µm in size compared to aerosolized droplet nuclei, which are less than 5 µm in size. They are often generated by a patient coughing, sneezing or talking, or during suctioning while in close contact with the patient. Organisms and diseases that require droplet precautions are listed in Box 6-3. After hand hygiene, the key element of droplet precautions is the use of a surgical mask with eye protection for contact within 1 meter (3 feet) of a symptomatic patient. All PPE must be removed before leaving the room and hand hygiene must be done.

The patient should be placed in a private room whenever possible. Because a negative air pressure room is not required, the door may remain open. When neither a private room is available nor cohorting is achievable, a space separation of at least 1 meter (3 feet) should be present between the infected patient and other patients or visitors.

Patient movement should be limited to essential needs outside of the room. Patients must wear a surgical mask while outside of the room.

Visitors should be limited and they must wear a surgical mask with face shield. Nursing staff must instruct family and visitors to wash hands when entering and exiting the room.

Airborne Precautions. Airborne precautions are required when a patient is suspected or known to have a disease transmitted by airborne droplet nuclei. The evaporated droplets contain micro-organisms that remain suspended in the air and can be widely dispersed by air currents within a room or over a long distance. The diseases or infections requiring airborne precautions are listed in Box 6-4.

BOX 6-3 INFECTIONS REQUIRING DROPLET TRANSMISSION-BASED PRECAUTIONS

- Adenovirus infection
- Anthrax pneumonia
- Coronavirus infection, respiratory
- Croup (laryngotracheobronchitis)
- Diphtheria
- Ebola virus infection
- Herpes simplex
- Influenza
- Meningitis
- Meningococcal pneumonia
- Meningococcemia
- Mumps (infectious parotitis)
- *Mycoplasma* infections
- Parainfluenza
- Parvovirus B19
- Pertussis (whooping cough)
- Plague
- Rabies
- Respiratory infectious disease, acute (if not covered elsewhere)
- Respiratory syncytial virus (RSV) infection
- Rhinovirus infection, respiratory
- Rubella (German measles)
- Scarlet fever
- Streptococcus: Group A

BOX 6-4 CONDITIONS REQUIRING AIRBORNE TRANSMISSION-BASED PRECAUTIONS

- Hemorrhagic fevers
- Lassa fever
- Marburg virus disease
- Mycobacteria, tuberculous
- Pneumonia
- SARS (coronavirus)
- Tuberculosis (TB) including multidrug-resistant tuberculosis (MDR-TB)
- Vaccinia

Strict hand hygiene is required before entering the room, after contact with the patient or items contaminated with respiratory secretions, and upon exiting the room. An OSHA-approved mask for tuberculosis, such as the N95 respirator that has been fit-tested or a powered air purifying respirator (PAPR), must be worn by healthcare personnel.

In the USA, the patient will be placed in a designated private room with monitored negative air pressure in relation to surrounding areas, with a minimum of 12 air exchanges per hour for new construction and renovation and six air exchanges per hour for existing facilities. Air from the room must be discharged directly outdoors or re-circulated through high-efficiency particulate air (HEPA) filters before being circulated to other areas in the hospital. The windows and the door to the patient's room must remain closed except for entry/exit. The patient is confined to the room unless a procedure outside the room is necessary. The patient must wear a tight-fitting surgical mask outside of the room when transported to another department. Patients who are discharged from the hospital but are still considered contagious must be instructed about the need to wear a surgical mask. Visitors should be limited at all times to those strictly necessary and visitors must wear a surgical mask. Symptomatic household or other contacts of the patient should be instructed not to visit.

Vacating an Airborne-Precautions Patient Room. If the patient is being evaluated for TB or diagnosed with TB and was in a room without negative pressure, the room must not be used for 1 hour after the patient has been discharged. If the patient is being ruled out for TB or is diagnosed with TB and was in a negative-pressure room, the room must not be used for 30 minutes after the patient has been discharged.

BOX 6-5 ORGANISMS REQUIRING AIRBORNE NON-ACID-FAST BACILLUS TRANSMISSION-BASED PRECAUTIONS

- Chickenpox (varicella)
- Herpes zoster (disseminated)
- Herpes zoster (shingles in immunocompromised)
- Rubeola (measles)

Airborne precautions are also required for patients with diseases that are highly communicable by the airborne route. Examples of diseases that fall into this category of precaution are listed in Box 6-5. Nonimmune staff or visitors are not allowed to enter the patient's room even to provide care. Nonimmunity means either no history of the specific disease or no vaccination against that disease. Respiratory protection is not needed for immune healthcare workers.

Healthcare and Device-Associated Infections

Healthcare-associated infections (HAIs) are infections occurring as a result of treatment and after exposure to the healthcare environment. Infections can be acquired in all healthcare settings – ambulatory, inpatient or during emergency room visits. HAIs include those with hospital onset and those with community onset in patients with previous healthcare encounters. Hospital-onset HAIs manifest 48 hours or more after admission to a hospital, within 30 days of discharge from a healthcare facility or if a patient visited an outpatient medical facility within the past 6–12 months.[4] Community-associated infections are defined as infections manifesting and diagnosed within 48 hours of admission in patients without any previous encounter with healthcare.

HAIs can be divided into three broad, sometimes overlapping groups: device-related, non-device-related and procedure-related.

DEVICE-RELATED HAI

Central Line-Associated Bloodstream Infections

Of all device-related HAIs, central line-associated bloodstream infections (CLABSI) are among the best studied. Vascular access is an essential part of care of patients and often extends beyond the inpatient stay into ambulatory care. Colonization of the device around the insertion site by bacteria or fungi on the skin is thought to constitute the most frequent first step of a central line infection. However, for invasion into the bloodstream to occur, bacteria have to adhere and incorporate into the biofilm,[35,36] multiply and then invade.

Bacteremia and sepsis secondary to contamination of the infusate occur much less frequently but are a recognized source of clusters or outbreaks of bloodstream infections with gram-negative organisms.

Risk factors for CLABSI include host factors (severity of illness, lack of skin integrity, type of immunosuppression), factors related to the device (catheter insertion and maintenance processes, type and size of catheter, number of lumens, insertion site) and finally factors related to the function of catheter, and the duration of placement.

CLABSI prevention initiatives and surveillance have been standardized internationally, have well-established definitions and methodologies and therefore can be easily linked to measurable process and outcome measures. Unlike other quality and safety measures, surveillance of CLABSI has proven very helpful in the objective evaluation of the efficacy of performance improvement initiatives.[36]

In 2002, a working group published guidelines for the prevention of intravascular device-related bloodstream infections. Among the key evidence-based recommendations were education and standardization of insertion and maintenance processes, the use of maximal sterile barrier precautions upon insertion, chlorhexidine skin preparation, antiseptic/antibiotic-impregnated central venous catheters for short-term use only when rates of infection are high, avoiding routine replacement of the line for the purpose of line-infection prevention and using standardized process metrics to measure compliance with these guidelines. However, it was not until the Institute for Healthcare Improvement (IHI) launched the '100 Thousand Lives' CLABSI prevention initiative that these recommendations were widely adopted by healthcare facilities in the USA in the ICU setting.[37] Following implementation of the IHI campaign, CLABSI rates have seen substantial and sustained drops not only in the ICU setting but also on acute care wards.

Ventilator-Associated Pneumonia

Ventilator-associated pneumonia (VAP) develops in 9–27% of ICU patients who require mechanical ventilation.[38] To meet the criteria for VAP, the pneumonia has to manifest more than 48 hours after intubation.

VAP is the leading cause of death among HAIs and is associated with a doubling of mortality compared to ventilated patients with similar characteristics who do not develop VAP.[39,40]

Infection control/infectious diseases and critical care specialists have debated for many years on the definitions and methodology to be used for the diagnosis of VAP.[41] Diagnosis of VAP is challenging because patients requiring mechanical ventilation have underlying complex diseases and co-morbidities with similar and confounding symptoms and signs.

VAP prevention process measures are now better established and many are supported by randomized controlled trials. Preventive strategies are aimed at avoiding unnecessary intubation, decreasing the duration of ventilation, preventing aspiration, and minimizing inoculation and colonization of the lower respiratory tract with mouth, gastrointestinal and upper respiratory tract flora. When implemented fully, these measures have resulted in better patient outcomes and are cost-effective.

In January 2013, NHSN implemented new surveillance methodologies and a definition algorithm for ventilator associated events (VAE). The algorithm allows for the identification of several tiered infectious and noninfectious conditions and complications developing in mechanically ventilated adults: ventilator-associated condition, infection-related ventilator-associated complication and possible, probable VAP.[42,43]

Catheter-Associated Urinary Tract Infections

Catheter-associated urinary tract infections (CAUTI) are the second most common device-associated infections.[5] CAUTI are frequently used as a proxy measure for quality. Recommendations for implementation, performance measurements and surveillance of CAUTI have been recently published.[44]

PROCEDURE-RELATED HAI

SSIs are the most common procedure-related HAI and are associated with additional hospital days, increased morbidity and increased cost compared to uncomplicated surgeries.[45–48] Implementation of infection prevention bundles such as preoperative chlorhexidine bathing, glucose control, standardized wound care and antibiotic prophylaxis, have been associated with significant reductions in SSI rates.[49] Numerous guidelines and protocols have been developed in recent years.[44,50]

Multidrug-Resistant Organisms

As care has evolved and become more complex, new antimicrobials have increased antibiotic pressure and thus selection of drug-resistant mutants. As a result, organisms resistant to multiple classes of drugs have emerged worldwide.[51] Infections due to multidrug-resistant organisms (MDRO) represent a significant proportion of the both the HAI burden and the day-to-day work of the IPCP.

Guidelines for metrics to be used to monitor, and processes to prevent MDRO in healthcare settings are available.[51,52]

While resistance definitions for gram-positive organisms are well established, there is no standard definition for most gram-negative MDRO.[53] For the purpose of this chapter, gram-negative MDRO are defined as organisms resistant to one or more classes of antimicrobial agent.

New guidelines for the prevention of MDRO in the healthcare setting underscore the importance of well-described evidenced-based infection prevention measures and coordinated antimicrobial stewardship programs.[54,55]

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