

Reference Manual for
Health Care Facilities with Limited Resources

Infection Prevention and Control.

Module 1. Introduction to Infection Prevention and Control

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Chapter 1. Introduction to Health Care-Associated Infections

Key Topics

- Health care-associated infections (HAIs) of public health concern
- Burden and impact of HAIs in low- and middle-income countries (LMIC)
- Microorganisms responsible for HAIs
- Factors that contribute to HAIs in LMIC
- Prevention of HAIs

Key Terms

- **Disease transmission cycle** describes the six components required for the spread of an infectious organism to a susceptible host. The essential components in the cycle are: agent (disease-producing microorganism), reservoir (place where agent lives—humans, animals, plants, soil, air, water), mode of escape—how the agent exits the reservoir, mode of transmission, place of entry, and susceptible host. Each of these components must be present for the infection to be transmitted.
- **Health care-associated infection (HAI)** is an infection that occurs in a patient as a result of care at a health care facility and was not present at the time of arrival at the facility. To be considered an HAI, the infection must begin on or after the third day of admission to the health care facility (the day of admission is Day 1) or on the day of or the day after discharge from the facility. The term “health care-associated infection” replaces the formerly used “nosocomial” or “hospital” infection because evidence has shown that these infections can affect patients in any setting where they receive health care.
- **Resident flora** are microorganisms that live in the deeper layers of the skin and within hair follicles and cannot be completely removed, even by vigorous washing and rinsing with plain soap and clean water. In most cases, resident flora are not likely to be associated with infections; however, the hands or fingernails of some health care workers (HCWs) can become colonized by microorganisms that do cause infection (e.g., *Staphylococcus aureus*, gram-negative bacilli, or yeast), which can be transmitted to patients.
- **Standard Precautions** are a set of infection prevention and control practices (IPC) used for every patient encounter to reduce the risk of transmission of bloodborne and other pathogens from both recognized and unrecognized sources. They are the basic level of IPC practices to be used, at a minimum, in preventing the spread of infectious agents to all individuals in the health care facility.
- **Transient flora** are microorganisms acquired through contact with individuals or contaminated surfaces during the course of normal, daily activities. They live in the upper layers of the skin and are more amenable to removal by hand hygiene. They are the microorganisms most likely to cause HAIs.
- **Transmission-Based Precautions** are additional precautions, used along with Standard Precautions, used to reduce the risk of airborne, droplet, and contact transmission of infection among hospitalized patients and HCWs when the disease transmission cycle is not completely interrupted using Standard Precautions.

Background

A health care-associated infection is an infection that occurs in a patient as a result of care at a health care facility and was not present at the time of arrival at the facility. The term “health care-associated infection” (HAI) has replaced “nosocomial” or “hospital-acquired” infection as evidence has shown that these infections can affect patients in any setting where they receive health care. To identify HAIs, a timeframe for onset of an infection must be defined to differentiate an HAI from an infection acquired in the community. The US Centers for Disease Control and Prevention (CDC) , defines HAIs as infections that begin on or after Day 3 of hospitalization (the day of hospital admission is Day 1), on the day of discharge, or on the day after discharge. (CDC 2018; WHO 2011)

Health care-associated infections are the most frequent adverse events in health care delivery systems worldwide. They are a major cause of preventable diseases, deaths, and higher health care costs. Many HAIs are caused by microorganisms that are present on the patient’s body (resident flora) or from transient sources such as HCWs’ hands, contaminated equipment, or the environment. The spread of these organisms usually results from breaches in compliance with Standard Precautions, such as inadequate hand hygiene and environmental cleaning, lapses in disinfection and sterilization, and incorrect use of personal protective equipment, as well as inappropriately applied Transmission-Based Precautions, namely Contact, Droplet, and Airborne Precautions. Such breaches result in transmission of infections to and from patients. (WHO 2011)

Health Care-Associated Infections of Public Health Concern

Health care-associated infections can affect the cardiovascular, respiratory, gastrointestinal, and genitourinary tracts, central nervous systems, and bones and joints. HAIs may also affect skin, soft tissues, and muscles. HAIs of public health concern in many settings include:

- Urinary tract infection (UTI), including catheter-associated urinary tract infection (CAUTI)
- Blood stream infection, including central line-associated bloodstream infection (CLABSI)
- Surgical site infection (SSI)
- Pneumonia, including ventilator-associated pneumonia (VAP)
- Multidrug-resistant infections
- Infectious Diarrhea and *Clostridium difficile* infections

Burden of Health Care-Associated Infections

The true burden of HAIs in LMIC is unknown due to a scarcity of microbiological (microorganism) data, inaccurate patient records, and a lack of electronic medical records and inadequate surveillance systems to track HAIs. From the limited surveillance that has been conducted in LMIC, it has been estimated that for every 100 hospitalized patients, 10 to 15 acquire at least one HAI. This compares to five to seven HAI patients for every 100 hospitalized patients in high-income countries. A prevalence survey (i.e., a survey used to detect the number of individuals with a specified disease or infection present in a defined population at a given point in time) was conducted by the World Health Organization (WHO) in 2002 in 55 hospitals in 14 countries representing four WHO regions (Europe, Eastern Mediterranean, South-East Asia, and Western Pacific). The results of the survey showed that an average of 8.7% of hospitalized patients had HAIs, resulting in over 1.4 million HAIs. (Allegranzi et al. 2011; WHO 2002; WHO 2011; Yokoe et al. 2014)

CLABSI, CAUTI, VAP, SSI, and infectious diarrhea are common HAIs in both high-income countries and LMIC. CAUTI are the most frequent HAIs in high-income countries, while, according to available information, SSIs and other postoperative infections are the most prevalent HAIs in settings with limited resources. (WHO 2011)

Impact of Health Care-Associated Infections in Low- and Middle-Income Counties

In resource-limited settings, SSIs occur in over one-third of all surgical patients, more than nine times higher than in higher-income countries. In most instances, it is the patient who pays for the additional cost of medicines and incidental expenses. Women and their newborns are more at risk of HAIs in LMIC, with infections rates three to 20 times higher than high-income countries. HAIs in intensive care unit (ICU) patients in LMIC are two to three times higher than in high-income countries, and device-associated infection (e.g., catheter and central line) densities¹ are up to 13 times higher than in the United States. (WHO 2011)

The impact of HAIs is of special concern in LMIC because managing and treating HAIs increases length of stay and requires additional resources that could be used for other patients. A review of several studies showed that increased length of stay associated with HAIs varied between 5 and 29.5 days. HAIs increase the use of antibiotics and the need for patient care supplies and laboratory and diagnostic testing, which drive up the costs of care. They also cause emotional and financial distress to patients and families and lead to disabling conditions that affect the quality of life. Furthermore, HAIs impact the reputation of the facility where the HAI occurred. Knowledge about patients acquiring an infection from a health care facility can spread in the community, making patients fearful and affecting their health-seeking behaviors. (WHO 2011)

Microbiology of Health Care-Associated Infections

Table 1-1 below provides the list of microbes that cause the four major HAIs of global public health interest.

Table 1-1. Microorganisms That Cause the Four HAIs of Global Public Health Interest

HAIs	Microorganisms that cause the HAIs
Central line-associated bloodstream infection	Coagulase-negative staphylococci, <i>Staphylococcus aureus</i> , <i>Enterococcus</i> spp., <i>Candida</i> spp., methicillin-resistant <i>S. aureus</i> (MRSA), <i>Klebsiella pneumoniae</i> , <i>Escherichia coli</i> , <i>Pseudomonas aeruginosa</i>
Surgical site infection	<i>S. aureus</i> , coagulase-negative staphylococci, <i>Enterococcus</i> spp., <i>E. coli</i> , <i>P. aeruginosa</i> , <i>Enterobacter</i> species, <i>K. pneumoniae</i> and <i>oxytoca</i> , <i>Candida</i> spp., <i>Acinetobacter baumannii</i>
Catheter-associated urinary tract infection	<i>E. coli</i> , <i>Enterococcus</i> spp., <i>P. aeruginosa</i> , <i>Candida</i> spp., <i>K. pneumoniae</i> , <i>Enterobacter</i> spp.
Pneumonia	<i>E. coli</i> , <i>Klebsiella</i> spp., <i>Proteus</i> spp., <i>Streptococcus pneumoniae</i> , <i>Haemophilus influenzae</i> , <i>S. auerus</i> , <i>Acinetobacter</i> spp., <i>P. aeruginosa</i>

Adapted from: American Thoracic Society 2005; Carr 1998; CDC 2011; Hidron et al. 2008.

¹ The number of infectious episodes per 1,000 patient-days or device-days (number of days the device is in a single patient).

Contributing Factors for Health Care-Associated Infections

Anyone can acquire an HAI while receiving care but certain patient groups are at higher risk (e.g., newborns, elderly patients, and patients with underlying diseases that compromise their immune systems and make them chronically ill, such as HIV). There are many factors associated with the occurrence of HAIs at a health care facility, including the infrastructure, available resources, staff compliance with IPC standards, and the type of patients treated.

Factors found to contribute to HAIs in LMIC include:

- High patient-to-nurse ratio
 - Bed space less than 1 meter (3 feet) apart
 - Low compliance with hand hygiene practices
 - Lack of resources including rooms for isolation or cohorting (grouping together patients with the same infection)
 - Lack of trained IPC practitioners and limited opportunities for staff training
 - Increasing use of complex medical and surgical procedures
 - Increasing use of invasive medical devices (e.g., mechanical ventilators, urinary catheters, central intravenous lines) without proper IPC training or laboratory support
 - Inadvertent contamination of prepared supplies/pharmaceuticals (e.g., IV fluid, infant formula, general medications)
 - Suboptimal cleaning, disinfection, and sterilization practices
 - Antibiotic resistance due to overuse of broad-spectrum antibiotics
- (Allegranzi et al. 2011)

Interventions to Prevent Health Care-Associated Infections

Understanding the disease transmission cycle is a cornerstone in the prevention and control of infections. Knowledge about ways to break the disease transmission cycle can assist health care facilities in putting together prevention strategies to stop the spread of infections.

Key interventions for prevention of HAIs include:

- Establishing systems to track targeted HAIs in a health care facility and sharing data with the staff and program managers
- Having dedicated staff for IPC and tracking of HAIs
- Fully adhering to recommended general IPC practices, including Standard Precautions, Transmission-Based Precautions, and hand hygiene (which protect staff and prevent all types of HAIs)
- Implementing interventions targeting specific HAIs (See Table 1-2.)

Table 1-2. Key Interventions for Prevention of Specific HAIs

HAIs	Prevention Measures
Catheter-associated urinary tract infection	<ul style="list-style-type: none"> • Consider alternatives to indwelling urinary catheterization. • Insert catheter only for appropriate indications. • Remove catheter as soon as possible. • Ensure that only properly trained persons insert and maintain catheters. • Insert catheters using aseptic technique and sterile equipment. • Maintain a closed drainage system. • Maintain unobstructed urine flow. • Comply with Standard Precautions, including hand hygiene recommendations. <p>For detailed information, see Module 10, Chapter 2, Preventing Catheter-Associated Urinary Tract Infections.</p>
Surgical site infection	<p>Before surgery:</p> <ul style="list-style-type: none"> • Use antimicrobial prophylaxis in accordance with evidence-based standards and guidelines. • Treat remote infections whenever possible before elective operations. • Avoid removing hair at the operative site unless it will interfere with the operation; do not use razors. • Use appropriate antiseptic agent and technique for skin preparation. • Consider also: <ul style="list-style-type: none"> – Screening and decolonization of the nose for <i>S. aureus</i> carriers for selected procedures (i.e., cardiac, orthopedic, neurosurgery procedures with implants) – Screening of pre-operative blood glucose levels and maintaining tight glucose control <p>During surgery:</p> <ul style="list-style-type: none"> • Keep operating-theater doors closed during surgery, except as needed for passage of equipment, personnel, and the patient. • Follow strict procedures to maintain sterility. • Maintain normothermia. • Consider also: <ul style="list-style-type: none"> – Adjusting the antimicrobial prophylaxis dose for obese patients (body mass index > 30) – Using at least a 50% fraction of inspired oxygen intraoperatively and immediately postoperatively in selected procedures <p>After surgery:</p> <ul style="list-style-type: none"> • Protect primary closure of incision with a sterile dressing. • Control blood glucose levels during the immediate postoperative period (for cardiac surgery). • Discontinue antibiotics after surgery according to evidence-based standards and guidelines. • Maintain staff and patient hand hygiene. <p>For detailed information, see Module 10, Chapter 1, Preventing Surgical Site Infections.</p>

Health Care-Associated Infections

HAIs	Prevention Measures
Central line-associated bloodstream infection	<ul style="list-style-type: none"> • Comply with Standard Precautions, including with recommended hand hygiene practices. • Choose proper central line insertion sites. • Provide staff education on central line maintenance and insertion. • Follow and monitor proper insertion practices. • Use appropriate agents for skin antiseptics. • Follow and monitor proper central line maintenance practices. • Perform adequate hub/access port disinfection. • Remove unnecessary central lines. • Also consider: <ul style="list-style-type: none"> – Daily chlorhexidine bathing <p>For detailed information, see Module 10, Chapter 3, Preventing Intravascular Catheter-Associated Bloodstream Infections.</p>
Pneumonia	<p>When caring for all patients:</p> <ul style="list-style-type: none"> • Comply with Standard Precautions, including recommended hand hygiene practices. • Teach patients and staff to follow respiratory etiquette. • Apply recommended Transmission-Based Precautions for patients with signs and symptoms of respiratory illness. • Exclude staff with respiratory illness from contact with patients. • Avoid crowding patients in wards and waiting areas. • Provide or recommend appropriate vaccinations for staff and patients. • Teach caregivers to recognize danger signs of pneumonia and treat appropriately. • Clean, disinfect/sterilize, and maintain respiratory care equipment properly. • Teach patients to: <ul style="list-style-type: none"> • Use deep-breathing techniques. • Move frequently, even while in bed. • Cough frequently. • Optimize pain medication to keep the patient comfortable but able to cough. <p>When caring for ventilated patients:</p> <ul style="list-style-type: none"> • Avoid intubation if possible and use oro-tracheal rather than naso-tracheal tubes in patients who receive mechanically assisted ventilation. • Use aseptic technique for intubation, suctioning, and other procedures that involve entering the endotracheal tube • Minimize sedation. • Minimize pooling of secretions above the endotracheal tube cuff • Use single-use suction catheters and other respiratory care items appropriately. • Prevent condensed fluids in ventilator tubing from flowing back toward the patient. • Elevate the head of the bed. • Provide oral-hygiene care.

HAIs	Prevention Measures
<p><i>Diarrhea</i> (including <i>C. difficile</i> diarrhea)</p>	<ul style="list-style-type: none"> • Apply Standard Precautions including gloves use for patient care. • Comply with recommended hand hygiene practices. • Use Contact Precautions for the duration of diarrhea, include isolating symptomatic patients presumptively. • Clean and disinfect patient care equipment. • Carry out environmental cleaning using a disinfectant as per the health care facility protocol. • Educate HCWs, housekeeping, administration, patients, and families about prevention of health care-associated diarrhea, including diarrhea caused by <i>C. difficile</i> infection (if relevant in the setting). <p>For settings with <i>C. difficile</i> consider also:</p> <ul style="list-style-type: none"> • Extending use of Contact Precautions beyond the duration of diarrhea • Conducting laboratory tests to isolate <i>C. difficile</i>, if the capacity to perform laboratory testing is available • Isolating symptomatic patients presumptively, pending confirmation of <i>C. difficile</i> infection • Cleaning and disinfecting patient-care equipment with disinfectants effective against spores. • Carrying out environmental cleaning using a disinfectant effective against spores as per the health care facility protocol • Implementing an antimicrobial stewardship program • Carrying out active surveillance for health care-associated diarrhea particularly caused by <i>C. difficile</i> • Making soap and water available for HCWs' hand hygiene after contact with a patient with <i>C. difficile</i> infection in case of an outbreak of <i>C. difficile</i> diarrhea <p>For detailed information, see Module 10, Chapter 6, Preventing Health Care-Associated Infectious Diarrhea.</p>
<p>Multidrug-resistant organisms (MDROs)</p>	<ul style="list-style-type: none"> • Adhere to Standard Precautions, most importantly hand hygiene and Transmission-Based Precautions (e.g., Contact Precautions) and cohorting patients with MDRO. • Clean environment thoroughly. • Develop/adapt guidelines for reporting and managing MDRO infections. • Train HCWs in IPC including prevention of MDRO infections. • Improve compliance with hand hygiene in health care facilities. • Strengthen implementation of an antibiotic stewardship program. • Monitor antibiotic susceptibility patterns for key targeted MDROs (e.g., carbapenem-resistant Enterobacteriaceae (CRE), methicillin-resistant <i>S. aureus</i>, vancomycin-resistant Enterococcus (VRE), multidrug-resistant extended-spectrum beta-lactamase-producing organisms). • Conduct active surveillance to identify MDRO infections in the facility. • Consider chlorhexidine bathing for patients in ICUs.
<p><i>Mycobacterium tuberculosis</i> (TB)</p>	<ul style="list-style-type: none"> • Adhere to Standard Precautions, most importantly hand hygiene and cough etiquette. • Apply Transmission-Based Precautions (e.g., Airborne Precautions) for patients suspected of having TB.

Health Care-Associated Infections

HAIs	Prevention Measures
	<ul style="list-style-type: none">• Ensure IPC measures for TB, including respiratory hygiene, cough etiquette, and appropriately ventilated rooms.• Screen patients for TB.• Adhere to the wearing of appropriate respiratory protection for staff, N-95 mask, when interacting for patients with suspected or confirmed TB.• Conduct routine screening for staff (refer to Module 4, Chapter 2 Infection Prevention and Control Aspects of Occupational Health in Health Care Settings)

Adapted from: CDC. n.d. Top CDC Recommendations to Prevent Healthcare-Associated Infections.

Summary

The burden of HAIs in LMIC is very high. HAIs negatively affect the health system and the patient by causing longer stays in health care facilities and increase the cost of care. Efforts to prevent HAIs will help to reduce health care costs, save staff time, reduce morbidity and mortality among patients, and improve the quality of care and health outcomes. Specific best practices for prevention of postoperative infections, UTIs due to catheterization, bloodstream infections following central line insertion, pneumonia, diarrhea, and maternal and newborn infections are discussed in more detail later in this manual.

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Chapter 2. Standard and Transmission-Based Precautions

Key Topics

- The disease transmission cycle
- Key components and use of Standard Precautions
- Key components and use of Transmission-Based Precautions, including Contact, Droplet, and Airborne Precautions

Key Terms

- **Airborne transmission** is the spread of an infectious agent carried through the air by particles smaller than 5 μm in size. This transmission can occur either through airborne droplet nuclei or dust particles containing the infectious microorganisms, which can be produced by coughing, sneezing, talking, or by procedures (e.g., bronchoscopy or suctioning). Due to their tiny size, airborne particles can remain in the air for up to several hours and can be spread widely within a room or over longer distances on air currents. Special air handling and ventilation are needed to ensure prevention of airborne transmission of infectious agents. Airborne particles do not land on and contaminate surfaces.
- **Cohorting** is the practice of placing patients with the same infectious disease (e.g., measles, influenza) or colonization (e.g., multidrug-resistant organisms) but no other infection, in proximity (e.g., the same room, the same ward, or the same area of a ward). In settings where definitive diagnosis is not readily available, patients may be cohorted based on presumptive diagnosis—epidemiological and clinical information suggestive of a similar diagnosis. When patients are placed in one room, beds should be spaced more than 1 meter (3 feet) apart.
- **Colonization** is the establishment of a site of pathogen reproduction in or on a host individual that does not necessarily result in clinical symptoms or findings (e.g., cellular change or damage). A colonized individual may transmit the colonizing pathogens to their immediate surroundings and other individuals.
- **Contact transmission** occurs when infectious agents/pathogens (e.g., bacteria, viruses, fungi, parasites) are transmitted directly or indirectly from one infected or colonized individual to a susceptible host. This can occur through physical contact (e.g., touching) with the infected individual or with contaminated equipment/environmental surfaces. Infectious agents/pathogens can often survive on physical surfaces from several hours up to several months.
- **Droplet nuclei** are small particles involved in the airborne transmission of pathogen-containing respiratory secretions expelled into the air by coughing. They are small, dry particles that can remain airborne for long periods of time and distance.
- **Droplet transmission** occurs when infectious droplets larger than 5 μm in size are spread and land directly on or come in contact with a susceptible host's mucous membranes of the nose or mouth or conjunctivae of the eye. Droplets can be produced by coughing, sneezing, talking, or during procedures (e.g., bronchoscopy or suctioning). Due to their size, particles remain airborne briefly and can travel about 1 meter (3 feet) or less. Droplet transmission requires close proximity or contact between the source and the susceptible host. Droplets may also land on surfaces and then be transferred by contact transmission.

Standard and Transmission-Based Precautions

- **Empiric** in the context of health services refers to an action, intervention, or practice being implemented on the basis of a clinical educated guess, based on experience and in the absence of laboratory test results for specific diagnosis. The empiric action, intervention, or practice is continued until the definitive diagnosis is made.
- **Engineering controls** are methods that are built into the design of the environment, equipment, or a process to minimize the hazards associated with use. An example is a medical device or piece of equipment that limits exposure to bloodborne pathogens in the workplace, such as sharps disposal containers, self-sheathing needles (a barrel or cover that automatically slides over the needle and locks in place once the needle has been removed from the patient), sharps with injury protection, and needleless systems.
- **Health care-associated infection (HAI)** is an infection that occurs in a patient as a result of care at a health care facility and was not present at the time of arrival at the facility. To be considered an HAI, the infection must begin on or after the third day of admission to the health care facility (the day of admission is Day 1) or on the day of or the day after discharge from the facility. The term “health care-associated infection” replaces the formerly used “nosocomial” or “hospital” infection because evidence has shown that these infections can affect patients in any setting where they receive health care.
- **Injection safety** is a set of techniques used to perform injections in an optimally safe manner for patients and health care workers (HCWs) during patient care.
- **Personal protective equipment (PPE)** items are the protective barriers and respirators used alone or in combination by an HCW to protect mucous membranes, airways, skin, and clothing from contact with harmful or infectious agents. PPE may also be used on an infectious patient to prevent the spread of infectious agents (e.g., surgical mask worn by a patient during transport to control the spread of illness).
- **Respiratory hygiene/cough etiquette** are measures taken to prevent transmission of respiratory infections including influenza in health care facilities. They involve maintaining at least a 1-meter (3-foot) distance from other individuals in common waiting areas, covering mouth/nose when sneezing/coughing, performing hand hygiene after soiling hands with respiratory secretions, and placing visual alerts to remind HCWs, patients, and visitors to practice respiratory hygiene and cough etiquette.
- **Sharps safety and needle safety** are procedures used to handle needles and other sharp devices in a manner that will prevent injury and exposure from infectious agents during routine patient care.
- **Standard Precautions** are a set of infection prevention and control practices (IPC) used for every patient encounter to reduce the risk of transmission of bloodborne and other pathogens from both recognized and unrecognized sources. They are the basic level of IPC practices to be used, at a minimum, in preventing the spread of infectious agents to all individuals in the health care facility.
- **Syndromic approach** is an approach that bases preventive actions on a set of signs and symptoms that are suggestive of a clinical condition rather than a specific diagnosis. The symptoms could be related to multiple systems or organs.

Background

The US Centers for Disease Control and Prevention’s (CDC’s) guidelines for Isolation Precautions, last updated in 2017, are a combination of Standard Precautions and Transmission-Based Precautions to prevent transmission of infectious disease in health care settings with the aim to protect providers, patients, and visitors.

The concept of Standard Precautions was first introduced as Universal Precautions in 1985 with the emergence of HIV/AIDS. The CDC introduced the term Standard Precautions in 1996 with the view that all patients are infectious regardless of suspected or confirmed infections (Siegel et al. 2017). In 2017, additional elements were added to the Standard Precautions to protect patients during health care delivery.

The aim of Standard Precautions is to reduce the risk of transmitting microorganisms from known or unknown sources of infection (e.g., respiratory droplets, contaminated objects, used needles and syringes, and multi-dose vials) within health care settings. Applying Standard Precautions while providing patient care is based on the anticipated interactions HCWs will have with blood, body fluid, or potential pathogen exposure from patients. (Siegel et al. 2017)

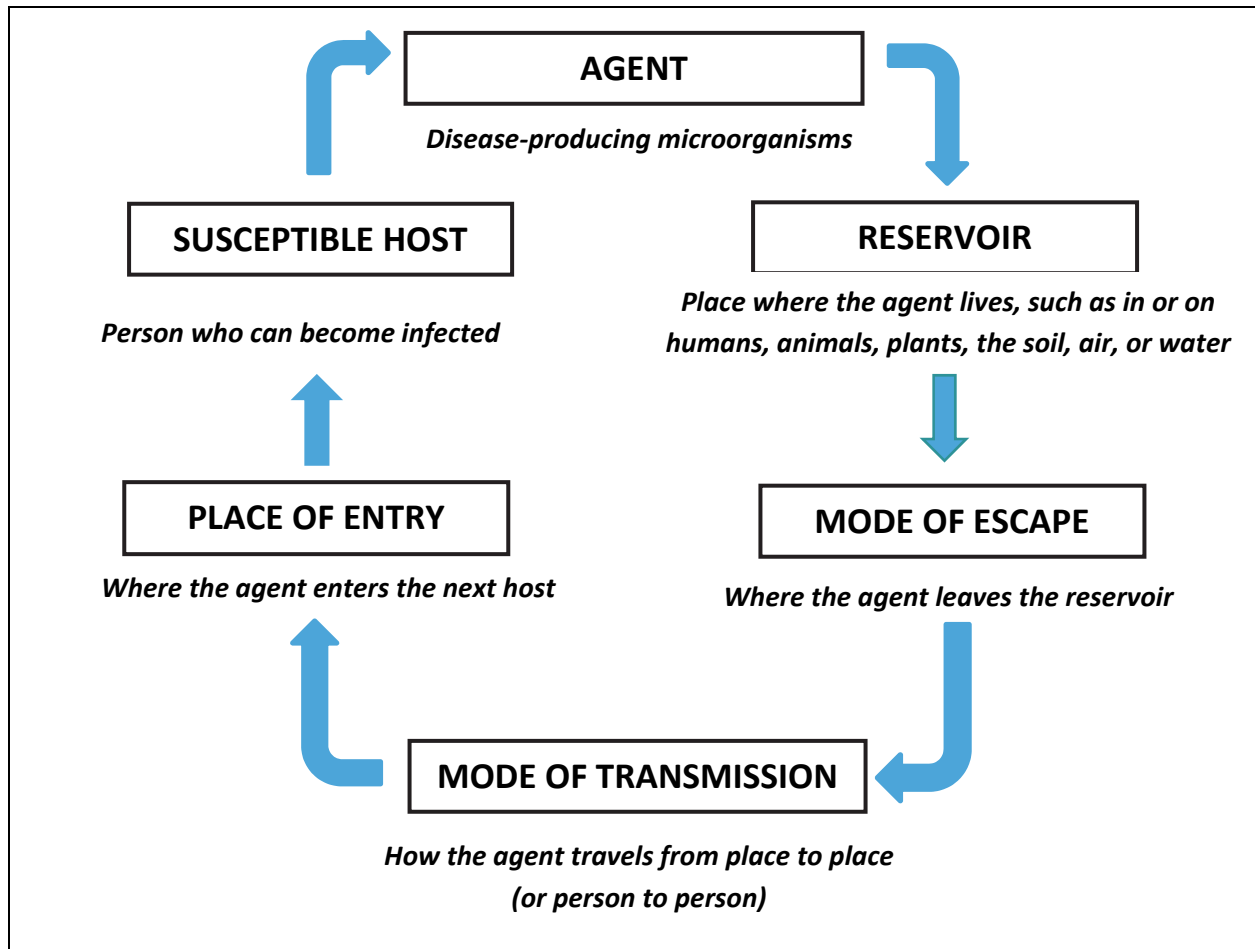
Transmission-Based Precautions are for patients who are known or suspected to be infected or colonized with those infectious agents that require additional control measures to effectively prevent transmission of infection in health care facilities.

Since the infecting agent is often not known at the time of admission to a health care facility, in addition to Standard Precautions for all patients at each encounter, Transmission-Based Precautions are used empirically for selected patients presenting with a relevant clinical syndrome indicating a likely infectious agent (e.g., acute onset respiratory symptoms, diarrhea). Transmission-Based Precautions are then modified as needed if/when the pathogen is identified or a transmissible infection is ruled out. (Siegel et al. 2017)

Disease Transmission Cycle

For transmission to occur, all components in the disease transmission cycle must be present (see Figure 2-1). Use of IPC principles to break the cycle is the primary means of preventing transmission.

Figure 2-1. The Disease Transmission Cycle



- The infectious agent is the disease-producing microorganism
- The reservoir of pathogenic microorganisms may be a human source (i.e., patients, HCWs, or visitors), animals, plants, the soil, air or water.
- The mode of escape, how the pathogenic microorganism leaves the reservoir could be via coughing, sneezing, contamination of hands and surfaces with blood and body fluids.
- Mode of transmission is how the agent travels from person to person, this usually occurs via HCWs' hands, contaminated equipment, instruments, devices, and the environment (including air and water).
- Place of entry, is where pathogenic microorganism can enter to infect susceptible host. Common places of entry include the mucus membrane, blood, surgical site, and urinary tract.
- Susceptible hosts are patients, HCWs, and visitors who may become infected by the infecting microorganisms. Resistance to infection will depend on the individual's immune system, with some individuals becoming infected but remaining asymptomatic carriers while others become infected and develop a clinical disease. Factors such as age, underlying diseases, and use of certain treatments (e.g., antimicrobials, corticosteroids, chemotherapy, and other agents that decrease immunity) play a role in the infection process.

The three main modes of infection transmission are contact, droplet, and airborne; however, an infectious microorganism can be transmitted by more than one route. For example, the varicella virus (chicken pox) can be transmitted both by the airborne and contact routes while the influenza virus can be transmitted by both the droplet and contact routes. This chapter describes the key strategies used to prevent HAIs by blocking the different modes of transmission.

Standard Precautions

The basic concept in the implementation of Standard Precautions is the maintenance of a physical, mechanical, or chemical barrier between microorganisms, the environment, and an individual, thus breaking the disease transmission cycle. The rationale is that, for transmission to occur within the health care setting, all elements in the disease transmission cycle must be present (see Figure 2-1). Whether it is a woman coming for antenatal care, a hospitalized patient, or an HCW caring for patients, Standard Precautions help prevent the spread of bloodborne pathogens, respiratory viruses (e.g., hepatitis B, hepatitis C, HIV, and influenza), and other infectious diseases in health care facilities.

The components of Standard Precautions create protective barriers for preventing infections in visitors, patients, and HCWs and are based upon the premise that every person (patient, visitor, or HCW) is potentially infectious and susceptible to infection.

Key Components

- **Hand hygiene** involves HCWs cleaning their hands before, after, and at specific moments during patient care and when performing health care tasks. Hand hygiene is the single most important intervention for preventing transmission of infections (e.g., person to person or contaminated object to person). It must be performed consistently at the recommended moment during patient care using soap and water or alcohol-based handrub (ABHR) and with a technique that effectively removes microorganisms from hands. For detailed information see Module 2, Hand Hygiene.
- **Use of PPE** relies on an HCW's assessment of the likely risk of contact with potentially infectious materials during each task. The appropriate PPE should be chosen by the HCW according to the assessed risk. The risk is not based on the appearance, characteristics, or diagnosis of the patient, but rather the potential for the HCW coming into contact with blood, body fluids, non-intact skin, mucous membranes, or items that have been in contact with these. The risk may be re-assessed during the task (e.g., if the patient starts vomiting) and PPE added as needed. PPE may include the following depending on the assessed risk:
 - Use of gloves before touching anything wet, such as non-intact skin, mucous membranes, blood, or other body fluids or objects that may have been in contact with these
 - Use of eye protection such as goggles, surgical masks and/or face shields to protect an HCW's eyes, nose, and mouth (i.e., mucous membranes) from splashes of body fluids, exposure to respiratory droplets, or aerosolized, potentially infectious material
 - Use of fluid-resistant gowns and/or aprons to protect the HCW's skin and clothing from splashes, spills, and contacts with blood or body fluids (i.e., secretion and excretions) or objects that may have been in contact with these (i.e., linens, items in the health care environment, patients' skin and clothing)
 - Use of a surgical mask is appropriate in the following situations:

Standard and Transmission-Based Precautions

- > To protect an HCW's nose and mouth (i.e., mucous membranes) from splashes of blood or body fluids and exposure to respiratory droplets or aerosolized, potentially infectious material
- > To prevent the spread of microorganism from the respiratory tract and mouth of an HCW to a patient during procedures such as surgery, lumbar puncture, or central line insertion
- > To cover the mouth and nose of patients with infections transmitted by the droplet or airborne route, such as influenza or tuberculosis (source control)

For detailed information see Module 3, Chapter 1, Personal Protective Equipment Key Topics

- **Respiratory hygiene and cough etiquette** to prevent the spread of respiratory secretions via droplets expelled from the respiratory tract onto the hands and surfaces. This includes:
 - Cover the mouth and nose when coughing and sneezing and dispose of used tissues in the nearest waste container.
 - Perform hand hygiene after contact with respiratory secretions and contaminated objects.
 - Maintain an appropriate distance from and between symptomatic patients, at least 1 meter (3 feet).
 - Identify persons with symptoms suggestive of acute respiratory illness and teach them to use a surgical mask and practice cough etiquette.
 - During seasons of high transmission of respiratory diseases, screen patients for symptoms of respiratory infections and provide a separate space in the waiting area distant from other patients (at least 1 meter/3 feet).
 - Apply additional disease- or syndrome-specific Transmission-Based Precautions as needed.
- **Safe injection practices** are those that do not harm the patient, do not expose the HCW to any risks, and do not result in waste that is dangerous for the community. These practices include:
 - Use aseptic technique when preparing and delivering injections including using a new, sterile, single-use needle and a new, sterile, single-use syringe for each and every withdrawal of medication from a multi-dose vial (see Module 4, Chapter 1, Injection Safety).
 - Use single-dose vials for parenteral medications whenever possible. Do not administer medications from single-dose vials or ampules to multiple patients or combine leftover contents for later use. If multi-dose vials must be used, both the needle or cannula and syringe used to access the multi-dose vial must be sterile. Do not keep multi-dose vials in the immediate patient treatment area and store them in accordance with the manufacturers' recommendations; discard if sterility is compromised or questionable (see Module 4, Chapter 1, Injection Safety).
 - Prevent sharps injuries and needle sticks by safely handling sharps and hypodermic needles and safely dispose of them in designated closed, puncture-resistant containers (see Module 4, Chapter 3, Sharps Injuries and Management of Exposure to Bloodborne Pathogens).
 - Wear a mask for performing spinal procedures (e.g., lumbar puncture) to avoid the risk of bacterial meningitis due to droplet transmission.
 - Follow appropriate IPC practices while performing phlebotomy (see Module 8, Chapter 1, Clinical Laboratory Biosafety).
 - Ensure safe medication storage and handling.

- **Cleaning and disinfection** of patient care equipment, instruments, devices, and environmental surfaces:
 - Clean patient care equipment between each use on patients to prevent cross-contamination between patients.
 - Pay attention to disinfection and sterilization of instruments and devices and proper use of single-use items to prevent cross-contamination between patients.
 - Clean environmental surfaces around the patient in the patient care area thoroughly to decrease contamination of HCWs' and patients' hands and items used in patient care.
 - Clean up blood and body fluid spills of any size promptly, following recommended procedures.

For detailed information, see Module 6, Processing of Surgical Instruments and Medical Devices.

- **Processing reusable textile items** in a manner that:
 - Removes pathogens from the textiles and protects cleaned textiles from reintroduction of pathogens
 - Reduces risk for transfer of pathogens to HCWs, other patients, and the environment

For detailed information, see Module 5, Chapter 4, Processing Reusable Health Care Textiles.

- **Waste disposal:**
 - Dispose of sharps into leak-proof, puncture-resistant sharps containers.
 - Segregate infectious waste at the place where waste is generated and maintain segregation as waste moves through the facility to final disposal.
 - Treat waste contaminated with blood, body fluids, secretions, and excretions as infectious waste, in accordance with local regulations.
 - Follow national guidelines and manufacturers' instructions for disposing of hazardous waste.
 - Follow national guidelines on final disposal of health care waste (e.g., incineration, burying, and autoclaving).

For detailed information, see Module 5, Chapter 5, Waste Management in Health Care Facilities.

Note: Use of Standard Precautions is a key component of HCWs' safety and should be implemented at every encounter with every patient to protect all HCWs and patients in all health care settings. The HCW must choose the appropriate PPE needed for each encounter. Immunization of HCWs against infectious diseases is another key component (see Module 4 Chapter 2 Infection Prevention and Control Aspects of Occupational Health in Health Care Settings).

Transmission-Based Precautions

Transmission-Based Precautions are designed to reduce the risk of airborne, droplet, and contact transmission among hospitalized patients and HCWs when the disease transmission cycle is not completely interrupted using Standard Precautions. For transmission to occur within the health care setting, all elements in the disease transmission cycle must be present (see Figure 2-1). Using additional barriers to break the cycle is the primary goal for Transmission-Based Precautions. There are three main types of Transmission-Based Precautions: Contact, Droplet, and Airborne. Transmission-Based Precautions should be applied to patients with confirmed and with suspected infections. Diseases that

Standard and Transmission-Based Precautions

have multiple routes of transmission (e.g., influenza, Middle East Respiratory Syndrome-coronavirus [MERS-CoV], varicella) may require the use of more than one category of Transmission-Based Precautions.

Empiric/Syndromic Use of Transmission-Based Precautions

Every effort should be made to diagnose the microorganism responsible for infection; however, laboratory diagnosis is not immediately available and not always available. In these circumstances, precautions must be based on empiric/syndromic findings. If there is any question about whether a patient without a known diagnosis has a specific infection, implement Transmission-Based Precautions based on the patient’s signs and symptoms until a definitive diagnosis (i.e., laboratory test results) can be made. To ensure that appropriate empiric precautions are always implemented, health care facilities must have systems in place to routinely evaluate patients according to these criteria, as part of their pre-admission and admission care. Table 2-1 lists clinical conditions warranting the empiric use of Transmission-Based Precautions.

Table 2-1. Empiric Use of Transmission-Based Precautions (Based on Signs and Symptoms) for Isolation of Patients in Hospital Settings*

Contact	Droplet	Airborne
<ul style="list-style-type: none"> • Acute diarrhea in an incontinent or diapered patient • Diarrhea in an adult with a history of recent antibiotic use or hospitalization (in settings with <i>C. difficile</i>) • Upper respiratory infections in infants and young children (wear mask as per Standard Precautions) • History of infection/colonization with multidrug-resistant organisms (use Airborne Precautions for tuberculosis [TB]) • Abscess or infected draining wound that cannot be covered with bandages • Skin or wound infection with excessive drainage in a patient with recent hospitalization (in settings where multidrug-resistant microorganisms are prevalent) 	<ul style="list-style-type: none"> • Symptoms of upper respiratory infection; cough, runny nose, sore throat, congestion. • Severe, persistent cough during periods when pertussis is present in the community • Suspected meningitis: fever, vomiting, and stiff neck • Hemorrhagic rash with fever • Generalized rash of unknown cause 	<ul style="list-style-type: none"> • Chronic cough/fever/weight loss/night sweats and upper lobe chest findings • Cough or fever, and chest findings in a person who is infected with HIV or at high risk for HIV • Rashes (vesicles or pustules) suggestive of varicella • Acute respiratory distress syndrome when new respiratory organisms are a risk in the community • Vesicular rash (suspected varicella) (wear gown, gloves and eye protection also)

*IPC professionals should modify or adapt this table according to local conditions.

Adapted from: Siegel et al. 2017; WHO 2008.

In all situations, Transmission-Based Precautions must be used in conjunction with Standard Precautions. (Siegel et al. 2017)

Patient Care Items and Environmental Cleaning

Whenever possible, a patient on Transmission-Based Precautions should have designated patient care equipment used only for that patient. Always thoroughly clean and disinfect shared patient care equipment after using it in an isolation room or area and before using it on a different patient. Routinely clean and disinfect all surfaces in the patient care area (at least once per day) according to facility environmental cleaning protocols. (See Module 5, Chapter 2, Environmental Cleaning.)

Patient Transport

Limit patient transport to essential reasons only, for example, diagnostic tests or therapeutic procedures that cannot be performed in the room. If the patient needs to leave the room for a test or procedure:

- Alert the department or facility where the patient is being transported so they can prepare to receive a patient on Transmission-Based Precautions.
- Cover wounds with appropriate dressings.
- Use PPE appropriately:
 - If applicable, remove and dispose of contaminated PPE and perform hand hygiene prior to transporting the patient.
 - Put on clean PPE to transport the patient.
 - Remove PPE and perform hand hygiene once the patient has been transported.
- Clean and disinfect the wheelchair or gurney after transportation.
- Ensure that patients on Droplet or Airborne Precautions wear a surgical mask while outside of the patient room; no mask is required for persons transporting patients on Droplet or Airborne Precautions.

Patient Isolation

If sufficient numbers of single rooms are not available for isolation of patients on Transmission-Based Precautions:

- Prioritize single rooms for patients likely to be the most infectious. These patients might be the ones who are coughing, have active diarrhea, or have high fevers.
- If additional single rooms are not available, place the additional patient needing isolation in a low-traffic area, and maximize the distance from other patients. Make sure to indicate clearly that the patient is in isolation. Use barriers, such as curtains, screens, chairs, rope, or other material, to show the isolation area. Limit access to the isolation area, and make sure that hand hygiene supplies and PPE are available right outside the isolation area.
- If there is more than one patient infected or colonized with the *same* infectious agent, cohort these patients in the same room or area. Clearly mark off the area as being for isolated patients only. Control access to the area if possible. Make sure that hand hygiene supplies are available near each patient care area and hand hygiene supplies and PPE are available right outside the isolation area.
- For individual or group isolation, staff can be dedicated (**cohorted**) so that only a limited number of staff are exposed to isolation patients and those staff do not provide care to non-isolation patients. This reduces the opportunity of carrying infectious material from isolation patients to other parts of the facility. Cohorting of staff can also be based on factors such as immunity to an infection (e.g., measles or chicken pox) so that susceptible staff are not exposed.

Standard and Transmission-Based Precautions

- Place vulnerable patients without the infectious agent in areas away from the isolation area. These patients include newborns, those with compromised immune systems, patients with medical devices in place, and individuals with chronic illnesses (e.g., diabetes).
- If non-critical patient care items must be shared, make sure that these items are cleaned and disinfected prior to use on the next patient.

Contact Precautions

Patients are placed on Contact Precautions when they have suspected or known infections that are spread directly or indirectly from an infected or colonized individual by touch or contact with the patient or the patient's environment (surfaces and equipment). Contact is a common way that germs spread in health care facilities.

Organisms that require Contact Precautions include varicella-zoster (shingles); neonatal or mucocutaneous herpes simplex virus; enterovirus meningitis; multidrug-resistant organisms such as and carbapenem-resistant Enterobacteriaceae (CRE); and *C. difficile*.

Contact Precautions include the following:

- Patient placement: Isolate patients who require Contact Precautions in a single room, if possible.
- Patient care equipment: Use disposable or dedicated patient care equipment (e.g., blood pressure cuffs) and clean and disinfect equipment before reuse on other patients.
- Use of PPE:
 - Put on a clean, non-sterile gown and gloves upon entering the patient care area; remove and properly discard before exiting the patient room. (See Module 3, Chapter 1, Personal Protective Equipment, for details about putting on PPE.) Perform hand hygiene immediately after removing PPE.
 - For semi-private or multi-patient rooms, do not use the same PPE between patients. Remove PPE, perform hand hygiene, and put on new PPE before coming in contact with another patient or patient environment (e.g., bed, patient locker, over-bed table, IV pole, monitors).
- Cleaning:
 - Ensure that rooms of patients on Contact Precautions are frequently cleaned and disinfected (at least daily and prior to use by another patient). Focus cleaning on toilets, frequently touched surfaces, and equipment in the immediate patient area.
 - Use gloves and gown when cleaning patient care equipment and the environment of a patient who has been on Contact Precautions.
 - Organisms that form spores (such as norovirus and *C. difficile*) require cleaning products, such as bleach, that inactivate spores, which are more difficult to destroy than vegetative microorganisms. (See Module 5, Chapter 2, Environmental Cleaning.)

Droplet Precautions

Patients are placed on Droplet Precautions when they have known or suspected infections transmitted by large respiratory droplets (larger than 5 µm in size). These remain in the air briefly and can travel about 1 meter (3 feet) or less. Droplet transmission requires close proximity or contact between the source and the susceptible host. Droplets may also land on surfaces and then be transferred by contact transmission.

Organisms that require Droplet Precautions include *Bordetella pertussis*, seasonal influenza virus, adenovirus, *Neisseria meningitidis*, and certain types of pneumonia.

Droplet Precautions include the following:

- Source control: Patients should wear a surgical mask in waiting rooms and when outside of the patient room.
- Patient placement:
 - Ideally, place the patient in a single room.
 - In multi-patient rooms, waiting rooms, or similar areas, separation between patients (chairs or beds at least 1 meter [3 feet]) and use of a physical barrier, such as a curtain or divider, are especially important to prevent transmission by droplets.
- Use of PPE:
 - Wear eye protection and a face mask or face shield, which cover eyes, nose, and mouth completely, before entry into the patient care area. (See Module 3, Chapter 1, Personal Protective Equipment, for details about how to put on and remove PPE items.)
 - Remove PPE after leaving the patient care area. If PPE is to be re-used, it must be cleaned and disinfected before each reuse.
 - Always perform hand hygiene before and immediately after patient care.
- Cleaning:
 - Ensure that rooms of patients on Droplet Precautions are frequently cleaned and disinfected (at least daily and prior to use by another patient). Focus cleaning on surfaces, frequently touched items, and equipment in the immediate patient area.
 - Use gloves, gown and face/eye protection when cleaning patient care equipment and the environment of a patient who has been on Contact Precautions.

Airborne Precautions

Patients are placed on Airborne Precautions when they have known or suspected infections transmitted by tiny droplet nuclei (smaller than 5 μm in size). Due to their tiny size, these particles can remain in the air for up to several hours and can be spread widely within a room or over longer distances on air currents (e.g., down a hallway). Rooms with specific ventilation requirements, airborne infection isolation rooms (AIIRs), are recommended, when possible.

Organisms that require Airborne Precautions include *Mycobacterium tuberculosis*, measles, and varicella viruses.

Airborne Precautions include the following:

- Source control: Patients should wear a surgical mask while waiting for their evaluation and when outside of their patient room.
- Patient placement:
 - Ideally, patients should be placed in an AIIR that includes:
 - > Negative pressure compared to the corridor (6–12 air exchanges per hour)

Standard and Transmission-Based Precautions

- > Closed doors
- > Air exhausted directly to the outside and not recirculated in the room
- Limit movements in and out of the room to HCWs caring for the patient.
- Restrict susceptible HCWs from entering the room of patients known or suspected to have measles, chicken pox, disseminated zoster, or smallpox if other, immune HCWs are available.
- Use of PPE:
 - Wear a particulate respirator, such as a fit-tested N95, and conduct a seal check before entering the patient's room. (See Module 3, Chapter 1, Personal Protective Equipment, for details about how to put on and remove PPE.) A seal check should be performed every time the N95 is used.
 - Gown, gloves, and eye protection are not needed for many organisms transmitted exclusively by the airborne route (such as *M. tuberculosis*, measles) but may be needed when an infectious microorganism is transmitted by multiple routes (e.g., varicella virus).
- Cleaning:
 - Use a respirator when cleaning patient care equipment and the environment of a patient who has been on Airborne Precautions.
 - Once terminal cleaning of the room and all equipment has been completed, wait for aerosols to clear the room before entering an Airborne Precautions room without a respirator.
 - Consult the World Health Organization's *Natural Ventilation for Infection Control in Health-Care Settings* (2009) for more detailed guidance on appropriate engineering recommendations (e.g., air exchanges for natural and mechanical ventilation) for airborne isolation.

Settings with Limited Resources

Transmission-Based Precautions should be implemented wherever and whenever possible. However, there are situations where existing infrastructure and resources make the implementation of these guidelines difficult. In limited-resource settings, at a minimum, the following should apply:

- Implement Standard Precautions at all health care facilities for all patients at all times.
- Use appropriate PPE based on the suspected route of transmission, clinical symptoms and signs, or laboratory results. Prioritize available PPE, at minimum, for all contacts while carrying out high-risk interventions on patients (e.g., suctioning a patient with acute respiratory illness, cleaning up stool from a patient with diarrhea).
- Limit visitors and non-essential staff contact with patients based on the clinical diagnosis, experience (empiric), or presence of a set of signs and symptoms (syndrome) until the final diagnosis, including laboratory investigations, is available.
- Limit patients' movements outside of designated areas, based on their empiric/syndromic symptoms, following appropriate guidelines.
- Clean and disinfect patient care environments and reusable equipment between each patient. (Siegel et al. 2017; WHO 2008)

Summary

To protect HCWs, patients, and visitors from acquiring infections during health care facility visits, ensure compliance with Standard Precautions for all patients at all times and apply Transmission-Based

Precautions to all patients with potential or confirmed infections that are transmitted via contact, droplet, and airborne routes.

Standard Precautions, including hand hygiene, are the cornerstone of IPC. They provide the first line of defense in the prevention of transmission of pathogens in health care facilities. Transmission-Based Precautions, including their empiric use, are designed to provide additional protection and reduce the risk of transmissions via airborne, droplet, and contact routes among hospitalized patients and HCWs.

These guidelines serve as the minimum requirements that should be enforced in all health care settings to protect patients, visitors, and HCWs. Even with challenges in low- and middle-income countries, appropriate resources should be allocated and health care staff properly trained to implement these guidelines for every patient seeking care in a health care facility. To assist HCWs in correctly implementing the appropriate precautions, Appendix 2-A summarizes the types of illnesses for which each type of precaution is recommended.

Appendix 2-A. Type and Duration of Precautions Recommended for Selected Infections and Conditions

Infection/Condition	Type of Precautions	Duration of Precautions	Precautions and Comments
Abscess—draining, major	Contact + Standard	Until wound stops draining	Until drainage stops or can be contained by dressing
Bronchiolitis	Contact + Standard		Use mask.
<i>Clostridium difficile</i>	Contact + Standard	Duration of hospitalization	Discontinue antibiotics if appropriate. Do not share electronic thermometers; ensure consistent environmental cleaning and disinfection. Hypochlorite solutions may be required for cleaning if transmission continues. Handwashing with soap and water preferred.
Chicken pox,	see Varicella-zoster		
Congenital rubella, German measles	Contact + Standard	Until 1 year of age	Standard Precautions if nasopharyngeal and urine cultures repeatedly negative after 3 months of age
Conjunctivitis—acute viral (acute hemorrhagic)	Contact + Standard	Duration of illness	Adenovirus most common; enterovirus 70, Coxsackie virus A24 also associated with community outbreaks. Highly contagious; outbreaks in eye clinics, pediatric and neonatal settings, institutional settings reported. Eye clinics should follow Standard Precautions when handling patients with conjunctivitis. Routine use of IPC measures in the handling of instruments and equipment will prevent the occurrence of outbreaks in this and other settings.
Diphtheria—cutaneous	Contact + Standard	Until antimicrobial is stopped and two cultures taken 24 hours apart are negative	
Diphtheria-pharyngeal	Droplet + Standard	Until antimicrobial is stopped and two culture taken 24 hours apart negative	
Epiglottitis—due to <i>Haemophilus influenzae</i> type B	Droplet + Standard	Until 24 hours after initiation of effective therapy	

Infection/Condition	Type of Precautions	Duration of Precautions	Precautions and Comments
Furunculosis, staphylococcal in infant and young children	Contact + Standard	Duration of illness (with wound lesions, until wounds stop draining)	
Gastroenteritis, Adenovirus, Campylobacter species, cholera (<i>Vibrio cholerae</i>), Cryptosporidium species, <i>E.coli</i> other species, <i>Giardia lamblia</i> , noroviruses, Salmonella species (including <i>S. typhi</i>), Shigella species (bacillary dysentery), <i>Vibrio parahaemolyticus</i> , viral (not covered elsewhere) and <i>Yersinia enterocolitica</i>	Standard*		*Use of Contact Precautions for diapered or incontinent persons for duration of illness or to control institutional outbreaks.
Gastroenteritis, rotavirus	Contact + Standard	Duration of illness	Ensure consistent environmental cleaning and disinfection and frequent removal of soiled diapers. Prolonged shedding may occur in both immunocompetent and immunocompromised children and the elderly.

Standard and Transmission-Based Precautions

Infection/Condition	Type of Precautions	Duration of Precautions	Precautions and Comments
Hepatitis, viral, type A—diapered or incontinent patients	Contact + Standard	Maintain Contact Precautions in infants and children < 3 years for duration of hospitalization; for children 3–14 years for 2 weeks after onset of symptoms; > 14 years for 1 week after onset of symptoms	
Herpes simplex (<i>Herpesvirus hominis</i>) – mucocutaneous, disseminated or primary, severe	Contact + Standard	Until lesions dry and crusted	Also, for asymptomatic, exposed infants delivered vaginally or by C-section and if mother has active infection and membranes have been ruptured for more than 4 to 6 hours until infant surface cultures obtained at 24–36 hours of age negative after 48 hours incubation.
Herpes zoster (varicella-zoster) (shingles)– disseminated disease in any patient, localized disease in immunocompromised patient until disseminated infection ruled out	Airborne + Contact + Standard	Duration of illness	Susceptible HCWs should not enter room if immune caregivers are available; no recommendation for protection of immune HCWs; no recommendation for type of protection, i.e., surgical mask or respirator for susceptible HCWs.
Human Metapneumovirus	Contact + Standard	Duration of illness (with wound lesions, until wounds stop draining)	
Impetigo	Contact + Standard	Until 24 hours after initiation of effective therapy	
Influenza– pandemic Influenza (also a	Droplet		

Infection/Condition	Type of Precautions	Duration of Precautions	Precautions and Comments
human influenza virus)			
Lice, head (pediculosis)	Contact + Standard	Until 24 hours after initiation of effective therapy	
Measles (rubeola)	Airborne + Standard	4 days after onset of rash; duration of illness (with wound lesions, until wounds stop draining) in immunocompromised	Susceptible HCWs should not enter room if immune care providers are available. For exposed susceptible, post-exposure vaccine within 72 hours or immune globulin within 6 days when available. Place exposed susceptible patients on Airborne Precautions and exclude susceptible HCWs.
Meningitis, <i>Haemophilus influenzae</i> , type b known or suspected	Droplet + Standard	Until 24 hours after initiation of effective therapy	
Meningitis, <i>Neisseria meningitidis</i> (meningococcal) known or suspected	Droplet + Standard	Until 24 hours after initiation of effective therapy	
Meningococcal disease—sepsis, pneumonia, meningitis	Droplet + Standard	Until 24 hours after initiation of effective therapy	Post-exposure chemoprophylaxis for household contacts, HCWs exposed to respiratory secretions; post-exposure vaccine only to control outbreaks
Monkeypox	Airborne + Contact + Standard	Airborne: Until monkeypox confirmed and smallpox excluded; Contact: Until lesions crusted	

Standard and Transmission-Based Precautions

Infection/Condition	Type of Precautions	Duration of Precautions	Precautions and Comments
Multidrug-resistant organisms (MDROs), infection or colonization (e.g., methicillin-resistant <i>S. aureus</i> [MRSA]; vancomycin-resistant enterococci [VRE], vancomycin intermediate and vancomycin-resistant <i>S. aureus</i> [VISA/VERSA]; extended-spectrum betalactamases [ESBLs]; carbapenem-resistant Enterobacteriaceae [CRE]; resistant <i>S. pneumoniae</i>)	Contact + Standard		MDROs judged by the IPC program, based on local, state, regional, or national recommendations, to be of clinical and epidemiologic significance. Contact Precautions recommended in settings with evidence of ongoing transmission, acute-care settings with increased risk for transmission, diarrhea in incontinent/diapered patients or wounds that cannot be contained by dressings.
Mumps (infectious parotitis)	Droplet + Standard	Until 5 days	After onset of swelling; susceptible HCWs should not provide care if immune caregivers are available.
<i>Mycoplasma pneumoniae</i>	Droplet + Standard	Duration of illness	
Parainfluenza virus infection—respiratory in infants and young children	Contact + Standard	Duration of illness	Viral shedding may be prolonged in immunosuppressed patients.
Parvovirus B19 (Erythema infectiosum)	Droplet + Standard		Maintain precautions for duration of hospitalization when chronic disease occurs in an immunocompromised patient. For patients with transient aplastic crisis or red-cell crisis, maintain precautions for 7 days
Pertussis (whooping cough)	Droplet + Standard	Until 5 days	Single patient room preferred. Cohorting an option. Post-exposure chemoprophylaxis for household contacts and HCWs with prolonged exposure to respiratory secretions

Infection/Condition	Type of Precautions	Duration of Precautions	Precautions and Comments
Plague (<i>Yersinia pestis</i>), pneumonic	Droplet + Standard	Until 48 hours	Antimicrobial prophylaxis for exposed HCWs
Pneumonia—adenovirus	Droplet + Contact + Standard	Duration of illness	In immunocompromised hosts, extend duration of Droplet and Contact Precautions due to prolonged shedding of virus.
Pneumonia, <i>B. cepacia</i> in patients with cystic fibrosis (CF), including respiratory tract colonization	Contact + standard	Unknown	Avoid exposure to other persons with CF; private room preferred. Criteria for Droplet/Contact Precautions not established. ²
Pneumonia, <i>Haemophilus influenzae</i> , type b, infants and children	Droplet + Standard	Until 24 hours after initiation of effective therapy	
Pneumonia, meningococcal	Droplet + Standard	Until 24 hours after initiation of effective therapy	
Pneumonia, <i>Mycoplasma</i> (primary atypical Pneumonia)	Droplet	Duration of illness	
Pneumonia, streptococcus, group A, adults	Droplet + Standard	Until 24 hours after initiation of effective therapy	
Pneumonia, streptococcus, group A, infants and young children	Droplet + Standard	Until 24 hours after initiation of effective therapy	Contact Precautions if skin lesion present
Poliomyelitis	Contact + Standard	Duration of illness	
Pressure ulcer (decubitus ulcer, pressure sore) infected—major	Contact + Standard	Duration of illness (with wound lesions, until wounds stop draining).	If no dressing or containment of drainage; until drainage stops or can be contained by dressing

² See Infection Prevention and Control Guideline for Cystic Fibrosis: 2013 Update. <http://www.jstor.org/stable/pdf/10.1086/676882.pdf?cid=labsrecdlpdf>

Standard and Transmission-Based Precautions

Infection/Condition	Type of Precautions	Duration of Precautions	Precautions and Comments
Respiratory infectious disease, acute (if not covered elsewhere); infants and young children	Contact + Standard	Duration of illness	
Respiratory syncytial virus infection, in infants, young children, and immunocompromised adults	Contact + Standard	Duration of illness	Wear mask according to Standard Precautions.
Rhinovirus	Droplet + Standard	Duration of illness	Add Contact Precautions if copious moist secretions and close contact likely to occur.
Ritter's disease (staphylococcal scalded skin syndrome)	Contact + Standard	Duration of illness (with wound lesions, until wounds stop draining)	
Rubella (German measles, congenital measles)	Droplet+ Standard	Until 7 days after onset of rash	Susceptible HCWs should not enter room if immune caregivers are available. Pregnant women who are not immune should not care for these patients. Administer vaccine within three days of exposure to non-pregnant susceptible individuals. Place exposed susceptible patients on Droplet Precautions; exclude susceptible healthcare personnel from duty from day 5 after first exposure to day 21 after last exposure, regardless of post-exposure vaccine.
Scabies	Contact + Standard	Until 24 hours	
Scalded skin syndrome, staphylococcal	Contact + Standard	Duration of illness (with wound lesions, until wounds stop draining)	
Severe acute respiratory syndrome (SARS)	Airborne + Droplet + Contact + Standard	Duration of illness, plus 10 days after resolution of fever, provided respiratory symptoms are absent or improving	Airborne isolation preferred; droplet if AIIR unavailable. N95 or higher respiratory protection; surgical mask if N95 unavailable; eye protection (goggles, face shield); aerosol-generating procedures and "supershedders" highest risk for transmission via small droplet nuclei and large droplets. Vigilant environment disinfection.

Standard and Transmission-Based Precautions

Infection/Condition	Type of Precautions	Duration of Precautions	Precautions and Comments
Staphylococcal disease (<i>S. aureus</i>)—skin, wound, or burn—major	Contact + Standard	Duration of illness (with wound lesions, until wounds stop draining)	If there is no dressing or dressing does not contain drainage adequately
Streptococcal disease (group A streptococcus), skin, wound, or burn—major	Contact + Droplet + Standard	Until 24 hours after initiation of effective therapy	If there is no dressing or dressing does not contain drainage adequately
Streptococcal disease (group A streptococcus)—pharyngitis in infants and young children; pneumonia; scarlet fever in young children—serious invasive diseases	Droplet	Until 24 hours after initiation of effective therapy	
Tuberculosis (<i>M. tuberculosis</i>)—extrapulmonary, draining lesion	Airborne + Contact + Standard		Discontinue precautions only when patient is improving clinically and drainage has ceased, or there are three consecutive negative cultures of continued drainage. Examine for evidence of active pulmonary tuberculosis.
Tuberculosis (<i>M. tuberculosis</i>)—pulmonary or laryngeal disease, confirmed	Airborne	Discontinue precautions only when patient on effective therapy for 14 days is improving clinically and has three consecutive sputum smears negative for acid-fast bacilli collected on separate days.	Discontinue precautions only when patient has been on effective therapy for 14 days and is improving clinically and has three consecutive sputum smears negative for acid-fast bacilli collected on separate days.
Tuberculosis (<i>M. tuberculosis</i>)—pulmonary or laryngeal disease, suspected	Airborne	Discontinue precautions only when the likelihood of infectious TB disease is	

Standard and Transmission-Based Precautions

Infection/ Condition	Type of Precautions	Duration of Precautions	Precautions and Comments
		<p>deemed negligible, and either there is another diagnosis that explains the clinical syndrome or the results of three sputum smears for acid-fast bacilli (AFB) are negative. Each of the three sputum specimens should be collected 8–24 hours apart, and at least one should be an early morning specimen.</p>	
<p>Varicella-zoster (Chicken pox)</p>	<p>Airborne + Contact + Standard</p>	<p>Until lesions dry and crusted</p>	<p>Susceptible HCWs should not enter room if immune caregivers are available. In immunocompromised host with varicella pneumonia, prolong duration of precautions for duration of illness.</p> <p>Post-exposure prophylaxis: provide post-exposure vaccine as soon as possible but within 120 hours; for susceptible exposed persons for whom vaccine is contraindicated (immunocompromised persons, pregnant women, newborns whose mother’s varicella onset is < 5 days before delivery or within 48 hours after delivery) provide VZIG, when available, within 96 hours; if unavailable, use IVIG.</p> <p>Use Airborne Precautions for exposed susceptible persons and exclude exposed susceptible HCWs beginning 8 days after first exposure until 21 days after last exposure or 28 if received VZIG, regardless of post-exposure vaccination.</p>
<p>Viral hemorrhagic fever due to Lassa, Ebola, Marburg, Crimean Congo fever viruses</p>	<p>Droplet + Contact + Standard</p>	<p>Duration of illness</p>	<p>Single-patient room preferred. Emphasize:</p> <ol style="list-style-type: none"> 1. Use of sharps safety devices and safe work practices 2. Hand hygiene 3. Barrier protection against blood and body fluids upon entry into room (single gloves and fluid-resistant or impermeable gown, face/eye protection with masks, goggles or face shields)

Standard and Transmission-Based Precautions

Infection/ Condition	Type of Precautions	Duration of Precautions	Precautions and Comments
			<p>4. Appropriate waste handling. Use N95 or higher respirators when performing aerosol-generating procedures. Largest viral load in final stages of illness when hemorrhage may occur; additional PPE, including double gloves, leg and shoe coverings may be used, especially in resource-limited settings where options for cleaning and laundry are limited. Notify public health officials immediately if Ebola is suspected.</p>
Wound infection, major	Contact + standard	Duration of illness (with wound lesions, until wounds stop draining)	

Source: (Siegel et al. 2017)

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Chapter 3. Basic Microbiology for Infection Prevention and Control

Key Topics

- Basic features of microorganisms
- Classifications and identification of microorganisms
- How microorganisms cause disease
- Specimen collection and transport
- Common techniques for identifying microorganisms
- Characteristics of microorganisms of interest for infection prevention and control (IPC)
- Potential microbial agents of bioterrorism
- Role of clinical laboratories in IPC

Key Terms

- **Antibody** is a microscopic structure, called an immunoglobulin, produced by the immune system, which is the system that defends the body from infection. Antibodies can be found in the blood and other body fluids.
- **Antigens** are foreign molecules such as toxins, viruses, or bacteria that stimulate the body's immune system to produce antibodies.
- **Antimicrobial resistance** is the ability of a microorganism to resist the effects of an antimicrobial agent using various resistance mechanisms. Antimicrobial resistance occurs when microorganisms such as bacteria, viruses, fungi, and parasites develop ways to avoid the effects of medications used to treat infections (such as antibiotics, antivirals, and antifungals) and pass these changes on to their offspring, or in some cases to other bacteria via plasmids.
- **Antimicrobial susceptibility testing (AST)** measures the activity of one or more antimicrobial agents against a microorganism isolated from a sample. The purpose is to determine potential susceptibility or resistance to antimicrobials, which helps the prescriber to determine which antimicrobial will be most successful in treating a patient with a specific infection. The type and extent of the AST conducted depend on the organism isolated, the source of the culture (body site), available antimicrobial agents, and typical susceptibility patterns.
- **Colonization** is the establishment of a site of pathogen reproduction in or on a host individual that does not necessarily result in clinical symptoms or findings (e.g., cellular change or damage). A colonized individual may transmit the colonizing pathogens to their immediate surroundings and other individuals.
- **Colony** (bacterial colony) is a cluster of identical microorganisms growing on the surface of or within a solid medium, presumably cultured from a single cell.
- **DNA**, deoxyribonucleic acid, is the hereditary material for all living organisms; it contains the instructions that make each type of living creature unique. DNA is the substance in the genes that is organized into the chromosomes in the cells, determines particular characteristics, and allows these characteristics to be passed from parents to offspring.

Basic Microbiology

- **Endogenous infection** is caused by organisms normally present within an individual's body (normal flora or colonizing organisms).
- **Exogenous infection** is caused by organisms from a source outside of the individual's body.
- **Infection** is the condition resulting from an invasion and multiplication of microorganisms—such as bacteria, viruses, and fungi—that are not normally present within the body. An infection may cause no symptoms and be subclinical, or it may cause symptoms and be clinically apparent.
- **Normal flora/commensal bacteria** are microorganisms (usually bacteria and fungi) that are naturally present in and on healthy people (e.g., on the skin or in the gut, or reproductive or respiratory tract).
- **Opportunistic infection** is an infection caused by a microorganism that under normal circumstances does not cause disease but becomes pathogenic when the body's immune system is impaired and unable to fight off infection, or antibiotic therapy allows for overgrowth of some microorganisms (such as yeast in the gastrointestinal and reproductive tracts).
- **Plasmids** are genetic structures in a cell, typically a small, circular DNA strand in the cytoplasm of a bacterium or protozoan independent of the chromosomes. They are relevant for IPC as they enable antimicrobial resistance to pass from one genus of bacteria to another.
- **Polymerase chain reaction (PCR)** is a type of molecular test in which genetic material (DNA/RNA) is extracted from the sample and through complex techniques is duplicated or amplified until there is a large enough amount to test the DNA, RNA, or protein sequences and identify specific microorganisms.
- **Resistance mechanism** is a feature of a bacterial cell that enables it to be unaffected by an antibiotic or group of antibiotics. Mechanisms can include production of substances that inactivate the drug, an alteration in cell structure that prevents the drug from binding with the cell, or the ability to pump the drug out of the cell. Resistance develops by changes in existing genes or by acquisition of new genes (such as from plasmids).
- **RNA**, ribonucleic acid, is present in all living cells and many viruses. RNA molecules are involved in protein synthesis and sometimes in the transmission of genetic information.
- **Species** is the lowest taxonomic rank in the biological classification system; all species have a two-part name, called a binomial (e.g., *Staphylococcus aureus*). The first name is the generic name—genus—(e.g., *Staphylococcus*), the second name is the species (e.g., *aureus*), based on structural and biochemical characteristics. A species can have different strains and subgroups that can cause different diseases. Some organisms of medical interest are classified below the species level, based on their characteristics (e.g., *Escherichia coli* O157:H7, a strain that produces Shiga-like toxin).
- **Staining** is a technique that uses dyes to color the cell wall of bacteria to quickly identify it in a broad group of bacteria. It is one of the most commonly used techniques in the clinical laboratory and important for identifying bacteria types for treatment and IPC. Staining methods involve fixing bacteria cells to a glass slide and then staining and washing them with a dye and alcohol. The differing characteristics of a microorganism's cell wall cause the stain to be retained in the cell or not, resulting in color changes. For example, Gram stain is used to differentiate bacteria into two groups, gram positive and gram negative; acid-fast stain is used to identify *Mycobacterium tuberculosis*.

- **Strain** is a variation in members of the same bacterial species. For treatment and epidemiology, it may be helpful for clinical laboratories to distinguish between strains in the same species. For example, some strains of *E. coli* are harmless and play an important role in the human intestinal tract, but other strains can cause diarrhea. Tests such as PCR can identify strains.

Background

A basic knowledge of the microscopic organisms that commonly cause infections and the methods used by the clinical laboratory to identify and examine them is important in the day-to-day work of the IPC team. Team members who are knowledgeable about microorganisms can more effectively convince health care workers (HCWs) of the need for basic IPC strategies such as hand hygiene, Standard Precautions, Transmission-Based Precautions, cleaning, and disinfection. Also, knowing about the features and behavior of the microorganisms that are causing infections in a health care facility, in particular health care-associated infections (HAIs), can help the IPC team choose the most effective prevention strategy. Understanding the methods used in the clinical laboratory can also assist the IPC team in making sure that the best-quality samples are taken so that the microorganisms that are causing infection can be identified. (APIC 2014b; WHO 2009)

The Basics

The basic features that microorganisms of medical interest share can help hospital staff, patients, and families understand the importance of IPC. These features include:

- **Microscopic size:** Microorganisms can be seen only with a microscope.

Implications: Even a microscopic crack or space in equipment (such as an intravenous [IV] line or endoscope) can contain numerous microorganisms that can be passed to a patient.
- **Rapid rate of reproduction:** If conditions are favorable, microorganisms can multiply quickly.

Implications: If even just a few microorganisms enter a vulnerable patient under the right conditions, they have the potential to cause serious infection within a short period of time.
- **Tendency to spread from one place to another:** Microorganisms can spread through air currents, people's hands, or equipment.

Implications: Staff, patients, and families in health care facilities can spread microorganisms from one place to another and from one patient to another via their hands or equipment. Methods to remove microorganisms from hands, medical equipment, and surfaces in facilities (handwashing, cleaning, disinfection, and sterilization) must be performed carefully, consistently, and thoroughly.
- **Ability to resist eradication:** Some microorganisms can survive harsh conditions (heat, cold, dryness, and chemicals).

Implications: HCWs must carefully follow instructions for removing microorganisms from hands, medical equipment, and surfaces in facilities (handwashing, cleaning, disinfection, and sterilization).

(APIC 2014b)

Classification and Identification of Microorganisms

Microorganisms that HCWs and IPC staff may encounter in health care settings include bacteria, fungi, parasites, and viruses.

About the names of bacteria, viruses, fungi, and parasites

The names of bacteria, viruses, fungi, and parasites follow the naming convention of the biological classification system. Their names contain two terms and are written in italic letters. The first term is the genus name, the second term is the species name. For example, for *Staphylococcus aureus*, the genus name is *Staphylococcus*, the species is *aureus*.

After the first use of the full name in a text, the genus is abbreviated with the first letter; *Staphylococcus aureus* is written as *S. aureus*.

The genus name can be used alone (e.g., *Staphylococci*) but the species (e.g., *aureus*) cannot be used alone because a genus includes other species; *Staphylococcus* includes *Staphylococcus epidermidis* and *Staphylococcus haemolyticus*.

The singular form of “species” is abbreviated as “sp.” And the plural as “spp.” When used with a genus, spp. is a short way of saying that something applies to many species within a genus, but may not apply to all species within that genus.

Viruses are named by their family/subfamily, genera, and species. For example, influenza virus is from the family Orthomyxoviridae, in general *Influenza A, B, and C*. There are several subtypes of *Influenza A*, for example H1N1, H1N2, and H3N1.

It is common practice to name viruses based on the disease they cause. For example, the virus that causes acquired immunodeficiency syndrome was named human immunodeficiency virus (HIV).

Bacteria

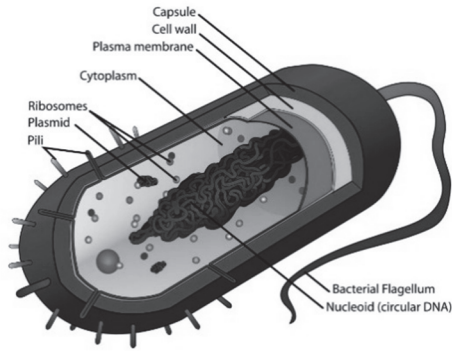
Characteristics

Bacteria are single-cell organisms (see Figure 3-1) with a well-defined cell wall that maintains the shape of the cell and protects an underlying structure called the plasma membrane, which surrounds and encloses the contents of the cell including:

- Cytoplasm, which contains the other cell contents
- Ribosomes, which produce proteins for cell function
- Genetic material, which is composed of a bacterial chromosome made of double-stranded DNA that is essential for cell function and replication. Some bacteria also have plasmids, which contain other DNA molecules that are not necessary for cell replication and that carry genes for antibiotic resistance and production of toxins and enzymes.

Some bacteria also have appendages on the outside of the cell that help the cell move (flagella) or help the cell attach to surfaces or other cells (fimbriae and pili). (APIC 2014b)

Figure 3-1. Structure of a Bacterial Cell



Source: By Mariana Ruiz Villarreal, LadyofHats, via Wikimedia Commons.
https://commons.wikimedia.org/wiki/File:Average_prokaryote_cell- en.svg.

Bacteria reproduce by cell division; a cell divides into two identical cells. When artificially grown on an appropriate culture medium, new cells form groups of the same species and strain of bacteria, called colonies, which may be seen with the naked eye.

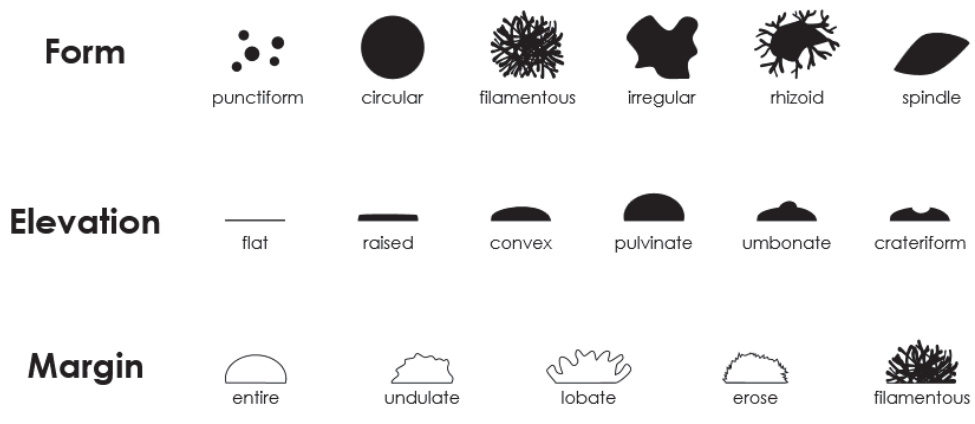
Significance

Bacteria are the most common causes of HAIs (WHO 2002) and thus it is helpful for HCWs as well as the IPC team to know the key characteristics of bacteria commonly seen in health care facilities. (Bacteria and other microorganisms that cause infections in patients in health care facilities are discussed in Chapter 1, Introduction to Health Care-Associated Infections, in this module.)

Laboratory methods of identification

Colonies of bacteria can be identified without a microscope by their appearance (known as clonal morphology) on the nutrient gel used to grow them. Colonies of bacteria differ in color, size, form, elevation, texture, and margin (see Figure 3-2).

Figure 3-2. Differing Characteristics of Colonies of Bacteria



Source: By Macedo [CC BY-SA 4.0], via Wikimedia Commons.
https://commons.wikimedia.org/wiki/File%3AColony_morphology.svg.

Basic Microbiology

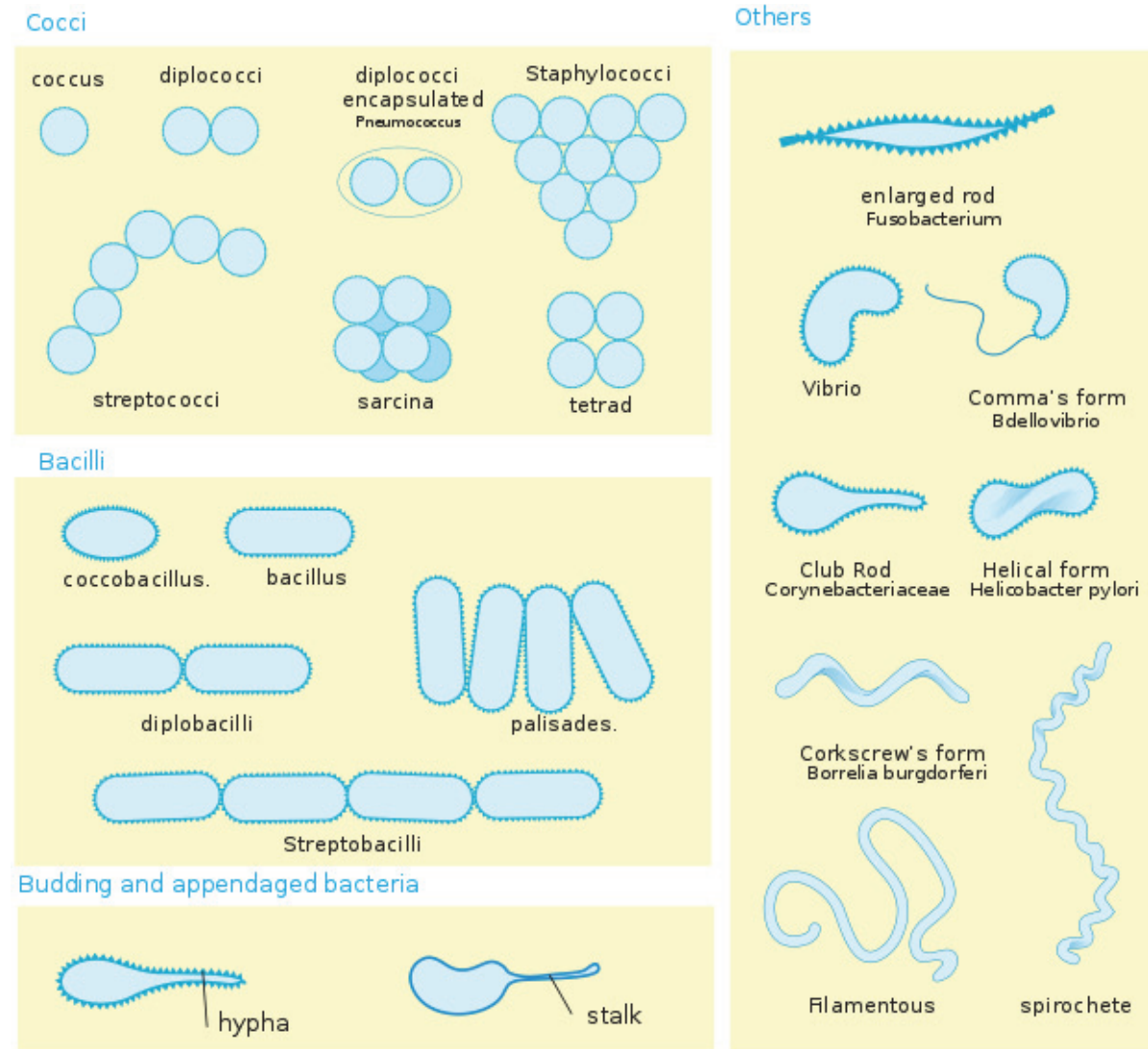
Morphology (forms and structure) of bacteria cells is used to identify and classify different groups of bacteria. Given the small size of these microorganisms, they can be viewed and recognized only under a microscope, based on their size, shape, and how they are grouped together. Figure 3-3 shows some of the different shapes and groupings of bacteria that can be seen under the microscope.

Coccus: *Staphylococcus aureus*

Rods (bacilli): *E. coli*, *K. pneumoniae*

Spiral: *Treponema pallidum pertenu*

Figure 3-3. Shapes and Groupings of Bacteria



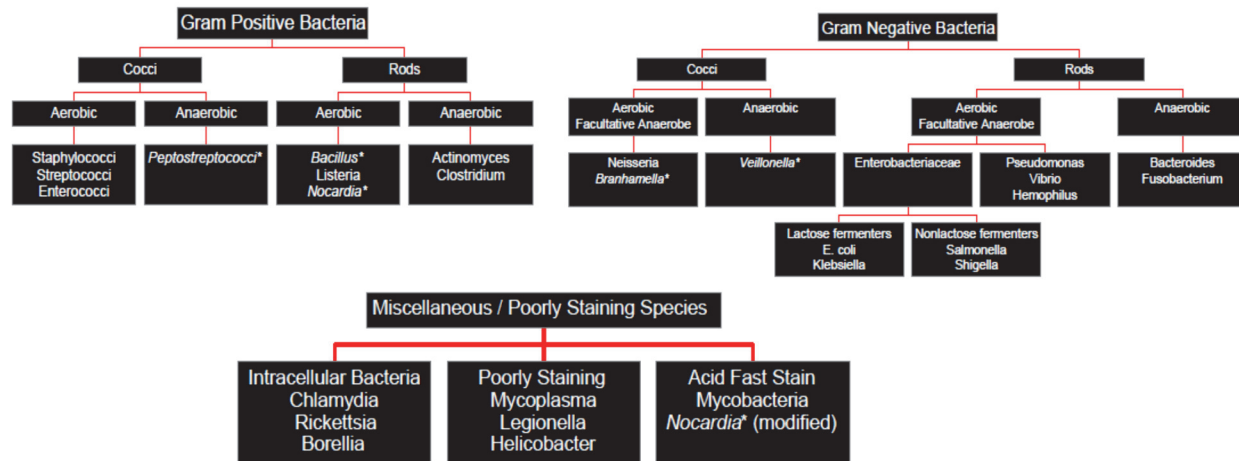
Source: Mariana Ruiz LadyofHats, via Wikimedia Commons.

https://commons.wikimedia.org/wiki/File%3ABacterial_morphology_diagram.svg.

Staining of the cell walls with different dyes is also used to identify and classify bacteria (see Figure 3-4). Gram stain is widely used in clinical laboratories to differentiate bacteria into two groups, gram positive and gram negative. Nearly all clinically relevant bacteria fall into one of these two groups based on whether or not their cell walls retain Gram stain. Another clinically relevant group of bacteria are acid-fast bacilli (AFB). These bacteria have a different type of cell wall that does not stain due to its large

lipid content. Alternative staining techniques such as acid-fast stain are therefore used that take advantage of the resistance to de-staining after lengthier initial staining. Gram stain quickly determines a broad group of bacteria, which can be important for choosing the appropriate antibiotic to treat the infection and for determining the need for isolation of the patient. For example, gram-negative diplococci in cerebrospinal fluid suggest meningococcal meningitis, and gram-positive cocci suggest staphylococci as the cause of infection. AFB-positive rods suggest *Mycobacterium* spp., which may be tuberculosis (TB). (APIC 2014b)

Figure 3-4. Bacterial Classification by Staining Properties



Source: Lowy F. Bacterial Classification, Structure and Function.

<http://www.columbia.edu/itc/hs/medical/pathophys/id/2009/introNotes.pdf>.

Gram stain can also help the IPC team focus and guide IPC activities. For example, gram-positive bacteria include *S. aureus*, which commonly colonizes the skin and nose of staff and patients. *S. aureus* is often resistant to antibiotics and can cause serious infections in the lungs, bones, and heart and can also result in sepsis.

Gram-negative bacteria include Enterobacteriaceae (e.g., *Escherichia coli*, *Klebsiella* spp., *Serratia* spp.) that commonly cause serious infections, particularly when medical devices are used (such as urinary catheters and IV lines), and are often resistant to antibiotics and colonize patients in hospitals. Other gram-negative organisms (*Pseudomonas* spp. and *Acinetobacter* spp.) live in damp and wet areas of facilities, are difficult to eradicate from the environment, and cause HAIs.

Growth characteristics, including growth rate, composition of the air, nutrients, and temperature in which bacterial colonies grow, are used to identify bacteria. Bacteria can be divided into groups according to:

- **Oxygen requirements:** “Aerobic” bacteria require oxygen to grow; “anaerobic” bacteria grow in the absence of oxygen. Aerobic bacteria are more likely to be found on the surface of the body. The presence of anaerobic bacteria (e.g., *Bacteroides fragilis* and *Clostridium perfringens*) can indicate a source from a deep wound, the gut, or vagina. Bacteria can be strict (obligate) anaerobes, which die in the presence of oxygen, or facultative anaerobes, which can survive with or without oxygen. (APIC 2014b)

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- **Fermentation of carbohydrates:** Lactose fermenting bacteria are typically gram negative. For example, *Enterobacter* spp. are lactose fermenting and *Pseudomonas* spp. and *Proteus* spp. are non-lactose fermenting.
- Presence of specific enzymes:
 - **Catalase test** differentiates streptococci (negative) from staphylococci (positive).
 - **Coagulase test** differentiates *S. aureus* (positive) from other staphylococci such as *S. epidermidis* (negative).

(APIC 2012; APIC 2014b)

Viruses

Characteristics

Viruses are microorganisms that are smaller than bacteria and consist of genetic material, which can be either DNA or RNA, surrounded by a protein coat and, in some viruses, by a membranous envelope. Viruses do not have many of the cell structures found in bacteria and fungi and are able to multiply only within the living cells of a host (see Figure 3-5.) They attach to receptors on the host cell (such as a respiratory tract cell), enter the cell, and use the cell to replicate. The offspring are then released from the host cell.

Viruses are classified based on:

- The type of substance that makes up their central core—DNA (e.g., herpesvirus, cytomegalovirus) or RNA (e.g., HIV, measles, Ebola, SARS, hepatitis C, and polio)
- The number of strands in the core—double-stranded (e.g., rotavirus) or single-stranded
- The presence or absence of a membrane-like envelope surrounding them—enveloped (herpesvirus, chicken pox virus, influenza viruses, and Ebola virus) and non-enveloped viruses (adenovirus, poliovirus)

(APIC 2014b)

Figure 3-5. Transmission Electron Micrograph of the Ebola Virus



Credit: CDC/Cynthia Goldsmith, #1832.

Significance

Many viruses can be transmitted in the health care environment and often cause HAIs and outbreaks. Bloodborne viruses, such as HIV and hepatitis B and C, can be spread from patient to patient during transfusions, dialysis, injections, and endoscopy. Viruses such as influenza and respiratory syncytial virus (RSV) can be spread from patient to patient by respiratory fluid droplets during crowding or sharing of respiratory equipment, or on contaminated hands. Others viruses such as measles and varicella quickly spread to patients on air currents. Rotaviruses and enteroviruses infect the gastrointestinal tract and are transmitted by hand-to-mouth contact due to poor hand hygiene and inadequate cleaning. (WHO 2002)

The presence or absence of a virus envelope has significance for cleaning and disinfection. Enveloped viruses (e.g., herpes, HIV, Ebola) are easier to kill with disinfectants than non-enveloped viruses (e.g., norovirus, rotavirus, adenovirus, and poliovirus). Cleaning products should be evaluated for their ability to kill both enveloped and non-enveloped viruses. (Rutala et al. 2008)

Laboratory methods of identification

Most virus identification methods are out of the scope of many clinical laboratories in limited-resource settings but may be available in reference laboratories. Examples of some tests commonly used to detect the presence of virus are:

- Enzyme-linked immunosorbent assay (ELISA) for detecting antibodies against HIV, RSV, rotavirus, and hepatitis B
- Polymerase chain reaction (PCR) for DNA and RNA detection of HIV, HPV, and many others viruses
- Papanicolaou (Pap) smears for the effect of human papillomavirus on squamous cells lining the cervix

(APIC 2014b)

Fungi

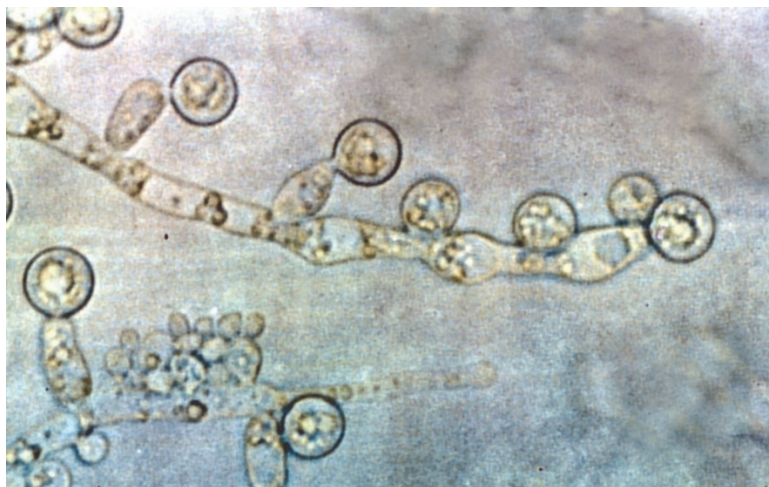
Characteristics

Fungi are typically slightly larger than bacteria and can be divided into yeasts and molds based on their appearance:

- Yeasts are single-celled, microscopic, and form smooth, creamy colonies in culture (see Figure 3-6).
- Molds consist of long, branching filaments of cells called hyphae. A tangled mass of hyphae visible to the naked eye is a mycelium and can be various colors (black, white, or green).

(APIC 2014b)

Figure 3-6. *Candida albicans*



Credit: By Graham Colm (Own work) [CC BY-SA 3.0 (<http://creativecommons.org/licenses/by-sa/3.0>) or GFDL (<http://www.gnu.org/copyleft/fdl.html>)], via Wikimedia Commons.

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Significance

While fungi can cause infection in humans (e.g., *Candida albicans*), most are opportunistic pathogens that cause infections (which can be severe) in those who are on extended antibiotic treatment or are immunosuppressed (*C. albicans*, *Aspergillus* spp., *Cryptococcus neoformans*, *Cryptosporidium*). A species of yeast, *Candida auris*, with a propensity to spread in hospitals and resistant to multiple antifungals, is emerging globally. Molds such as *Aspergillus* spp., which originate in dust and soil, can become airborne and infect vulnerable patients during hospital renovation or construction if precautions are not taken. (APIC 2014b; WHO 2002)

Laboratory methods of identification

Like bacteria, fungi can also form colonies. Fungi are mainly identified using direct examination under the microscope of physical characteristics of the mold, such as shape, color, staining, and the root-like structures; they are also identified through culture and non-culture tests. (APIC 2014b)

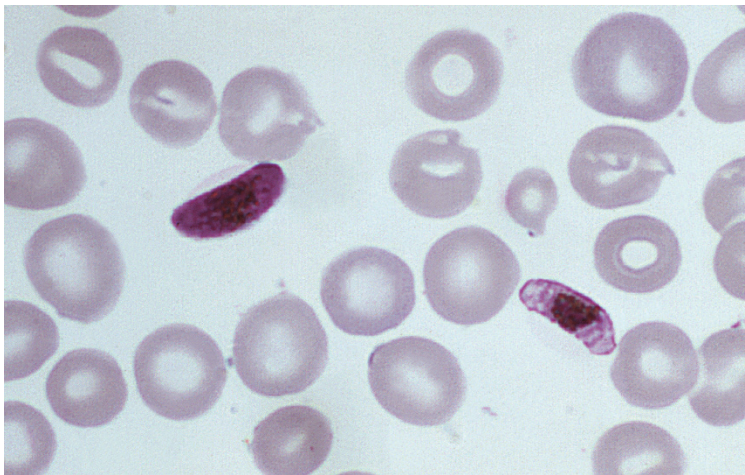
Parasites

Characteristics

Parasites range from single-cell protozoan parasites (*Giardia* spp. and *Plasmodium* spp.) to large worms (e.g., hookworm) and insects (*Sarcoptes scabiei*, the scabies parasite). Some parasites can live inside the cell (intracellular), such as the parasite that causes malaria (*Plasmodium* spp.) (see Figure 3-7). Others (such as scabies, mites, and lice) live on the outside of the body, on the skin. Most protozoan parasites exist in two different forms:

- The trophozoite stage—the feeding stage during which the parasite produces effects in the host
- The cyst stage—the dormant stage, when most protozoan parasites are transmitted

Figure 3-7. *Plasmodium falciparum*, Malaria Parasite



Credit: CDC/Dr. Mae Melvin.

Common parasitic infections

Health care-associated parasitic infestations include scabies, lice, and myiasis (maggots). Water- or foodborne parasite infestations—such as amoebiasis (caused by *Entamoeba histolytica*) or cryptosporidiosis (caused by *Cryptosporidium parvum*)—mainly occur in community settings but can also spread within hospitals.

Significance

Some parasites can spread from person to person in health care facilities. *Giardia lamblia* is easily transmitted from person to person through poor hand hygiene and unclean surfaces. The mite that causes scabies can cause outbreaks in health care facilities. Others, such as malaria, are spread via mosquitoes (vectors) and so can spread within health care facilities if patients are not protected from mosquito and other insect bites. (WHO 2002)

Laboratory methods of identification

Several laboratory methods for identification of parasite infestation are available. They include microscopy, serology-based assays, and molecular-based essays. Direct examination of stool or urine for blood or ova from intracellular parasites is the primary method of diagnosis for parasites in some laboratories. (APIC 2014b)

Microbial Pathogenesis—How Microbes Cause Disease

Normal Flora/Commensal Microbiota

Normal flora/commensal microbiota vary by body site. For example, coagulase-negative staphylococci are common on the skin and *E. coli* in the gut. (APIC 2014b; WHO 2002)

Implications: Under normal conditions, commensal microbiota (i.e., entire population of microorganisms including bacteria, virus, fungi, and parasites that colonize human beings but do not cause disease) work with the human body to help prevent colonization and infection by pathogenic microorganisms by using up the available nutrients and by other mechanisms. For example, the commensal bacteria of the gut help stop pathogenic bacteria, such as *Clostridium difficile*, that cause diarrhea. However, commensal bacteria can cause opportunistic infections when the immune system is compromised (e.g., in infants, the elderly, or those with acute or chronic disease) or the other body defenses are interrupted (e.g., a surgical wound disrupting the protective barrier of the skin, a medical device like an IV or urinary catheter entering the body, or prolonged use of antimicrobial agents leading to an imbalance in the commensal gut microbiota). Examples include coagulase-negative staphylococci from the skin, which can cause an IV line infection, and *E. coli* from the gut, which can cause a urinary tract infection. (WHO 2002)

Colonization

Examples of colonization include *Neisseria meningitidis* in the throat, *Salmonella* species in the gut, methicillin-resistant *S. aureus* (MRSA) in the nose, or yeast in the genital tract.

Implications: Colonization may result in infection of the colonized person when the immune or other body defenses are interrupted (e.g., a person colonized with MRSA has surgery, which interrupts the natural barrier of the skin, and develops a MRSA surgical site infection [SSI]). Transmission to others (e.g., a person with *Salmonella* colonization is involved with food preparation at the health care facility and does not wash his/her hands and transmits *Salmonella* to patients).

Organisms that are resistant to antibiotics often colonize hospitalized patients, which can then lead to infections that are difficult to treat. Surveillance cultures (such as nose swabs for MRSA and rectal swabs for vancomycin-resistant enterococci [VRE] or carbapenem-resistant Enterobacteriaceae [CRE]) may be used in some settings to identify patients with colonization. If colonization with MRSA, which can cause

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serious SSIs, is identified before surgery from surveillance cultures of the nose (or other sites), medications to decolonize can be prescribed to decrease the risk of an SSI from MRSA.

Infection

An infection usually causes clinically apparent symptoms or sometimes may cause no symptoms and be subclinical. Symptoms vary according to the type of microorganism and the location of the infection. Symptoms are a result of the actions of the microorganisms on the body (e.g., diarrhea, necrotic tissue) and the immune response to them (e.g., fever, purulence). The characteristics and location of the microorganism as well as the immune status of the person determine if and how an infection progresses. (APIC 2014b)

Implications: People seeking care at health care facilities may be the more vulnerable and prone to infections, particularly infants, pregnant women, the elderly, people with acute or chronic diseases, and those with a condition that suppresses the immune system and/or disrupts body defenses (wounds, invasive medical devices). It is important to protect patients from exposure to pathogenic microorganisms in the facility and identify any patients with infections that may spread to others.

Sources of Microorganisms

HAIs can be categorized according to the source of the microorganisms that cause them. Bacteria can come from:

- **The patient (endogenous):** Organisms from the individual's own body (normal flora or colonization) can cause infection when the immune system is compromised, other body defenses are interrupted (via a wound or medical device), or antibiotic therapy causes overgrowth of some microorganisms (such as yeast in the gastrointestinal and reproductive tracts). (APIC 2014b; WHO 2002)

Implications: IPC includes surgical asepsis, pre-operative skin antisepsis, preventive care when inserting and maintaining invasive medical devices, removal of invasive medical devices as soon as possible, decolonization of colonized patients using an appropriate antimicrobial agent, patient education on hand hygiene and cleanliness, and rational use of antibiotics.

- **Another person (exogenous cross-infection):** Organisms that cause infection can come from a source outside of the individual, such as:
 - Other patients (direct contact with blood or other body fluids, respiratory droplets, unwashed hands)
 - Airborne (aerosols/air droplets carrying TB, varicella, or measles)
 - Staff (contaminated or colonized hands, clothing, skin)
 - Objects contaminated by an infected person (equipment, environmental surfaces) or contaminated sources (water, fluids, food)

(APIC 2014b; WHO 2002)

Implications: IPC includes Standard Precautions, including hand hygiene and use of personal protective equipment, and isolation using Transmission-Based Precautions. Administrative and environmental controls should also be considered.

- **The health care environment:** Organisms causing infection can come from the hospital environment where they live permanently or transiently, including places such as:

- Water, damp areas, fluids, and even disinfectants (e.g., *Pseudomonas spp.*, *Acinetobacter spp.*, *Mycobacterium spp.*, *Legionella spp.*)
- Surfaces, equipment, supplies, and patient care items if re-used and/or not well-cleaned
- Food prepared or stored by the hospital or the patients' families
- Dust/soil, such as during construction or renovation of the facility (e.g., *Aspergillus spp.*)

(APIC 2014b; WHO 2002)

Implications: IPC includes proper handling of fluids, correct handling and dilution of disinfectants, elimination of damp areas when possible, use of the cleanest water available, monitoring of the food service, regular and thorough environmental cleaning, hand hygiene, proper cleaning of multi-use items, and isolation/careful control in areas undergoing construction/renovation.

Specimen Collection and Transport

When an infection is suspected, specimens are usually obtained to help identify the location and cause in order to guide diagnosis and treatment. For the clinical microbiological laboratory to correctly identify microorganisms, specimens must be correctly collected, transported to the laboratory, and processed. Incorrect specimen collection and transport can result in:

- No growth when microorganisms were actually present, which can occur when antibiotics are started before the specimen was collected, the wrong container was used so microorganisms died before arriving at the laboratory, poor collection techniques were used so microorganisms were not collected, or transport was delayed and microorganisms died before they arrived at the laboratory.
- Growth of the wrong organisms, which can occur when poor collection techniques allow contamination of the sample, such as in a blood culture contaminated from skin, or when delayed transport or incorrect storage allows overgrowth of unimportant microorganisms, such as for a stool sample.

Incorrect results can lead to inappropriate patient management, erroneous surveillance results, and the wrong choice of IPC strategies. (APIC 2014b)

The IPC team should be aware of optimal specimen collection techniques and teach them to all HCWs who collect specimens (see Table 3-1). In addition, the microbiology laboratory should provide information on specific procedures for collection and transport of specimens. HCWs collecting the specimens should be competent in these procedures.

Table 3-1. General Guidelines for Optimal Specimen Collection

Guidelines	
5.	Put on personal protective equipment and perform hand hygiene before collecting and transporting specimens.
6.	Whenever possible, collect specimens in the acute stage of the illness and prior to administration of antimicrobial agents (and/or before switching antimicrobial drug regimen).
7.	Collect the specimens at optimal times (for example, for TB: early morning sputum for AFB microscopy and culture; or during febrile episode for blood cultures). Collect the specimens from the actual site of infection or where the microorganisms are most likely to be found.

Guidelines	
8.	Use Standard Precautions for collecting and handling all specimens to protect staff from blood and body fluids (e.g., through hand hygiene, personal protective equipment, injection safety, and proper waste disposal).
9.	Avoid contamination from surrounding tissues or secretions. Use sterile equipment and aseptic techniques to collect specimens to prevent introduction of microorganisms during invasive procedures.
10.	Use appropriate collection devices, transport media, and sterile, leak-proof specimen containers.
11.	Properly label each specimen with the patient's name and identification. Fill in the test request form. Provide the source of the specimen (e.g., wound, skin).
12.	If the specimen is collected through intact skin, prepare the skin using iodine solution (e.g., povidone-iodine) or a chlorhexidine-alcohol combination. Allow a drying time of 2 minutes without wiping or blowing to maximize antiseptic effect.
13.	Collect a sufficient quantity of material for the specimen.
14.	Provide clear instructions to patients if they are collecting their own specimens (e.g., clean catch urine or stool, collection of sputum).
15.	Minimize transport time, preferably within 2 hours of collection.
16.	Always transport specimens in a leak-proof container clearly labeled as a biohazard.
17.	Maintain an appropriate temperature between collection of specimens and delivery to the laboratory. Check if the specimens should or should not be transported on ice.
18.	Remove personal protective equipment and perform hand hygiene after collecting and transporting specimens.

Adapted from: APIC 2012; APIC 2014b; Johns Hopkins Medicine 2015.

Diagnostic Approaches in Clinical Microbiology

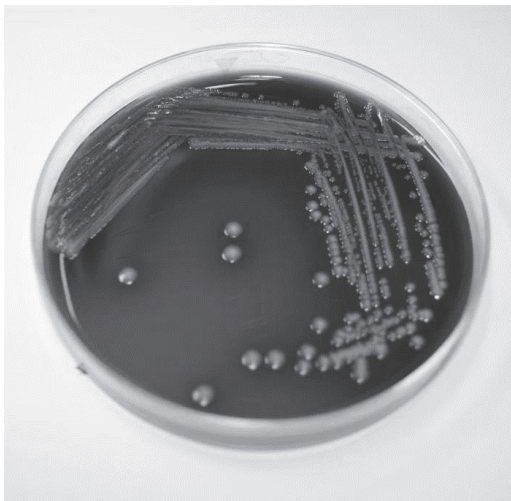
There are a variety of diagnostic tests available to microbiology laboratories. IPC staff are encouraged to become familiar with those commonly used at their facility. Brief descriptions of some microbiological methods are given below. For further details, consult your clinical laboratory staff and review relevant guidelines. Visiting the microbiological laboratory to observe these tests can be very informative for IPC staff who are not familiar with laboratory methods.

- **Direct examination of wet-mount** is used for specimens such as sputum, body fluid aspirates, stool, vaginal fluids, and urine sediments. The specimens are prepared for direct examination by being placed directly on the slide with sterile saline.
- **Smears** are prepared by spreading samples on a slide and fixing them with heat or chemicals. This process will kill the organisms so they are safe to handle. Once the sample is fixed on the slides, it is easy to stain.
- **Staining** methods are used to classify bacteria. Staining makes microorganisms stand out from the background so they can be identified under the microscope. Gram stains and acid-fast stains are most commonly used:
 - **Gram stain:** The sample is fixed on the slide and is washed with crystal violet/iodine dye to stain the bacteria. The slide is then washed with alcohol. If the microbes retain the purple color, the sample is gram positive. If the alcohol removes the stain from the cell wall, the bacteria are

gram negative. The gram-negative bacteria are further stained with red dye (safranin) so that they appear red under the microscope.

- **Acid-fast stain:** Acid-fast bacteria, for example *Mycobacterium tuberculosis*, *Nocardia* spp., and *Actinomyces* spp., have a particular cell wall structure that does not lose color from stain (crystal violet or any such dye) when rinsed in a solution of acid and alcohol. (APIC 2014b)
- **Plating and culture** are used to grow bacteria and yeast. The specimen is added to a culture medium that contains necessary nutrients and then incubated at a specific temperature to allow the bacteria to grow (see Figure 3-8). Because the specimen may contain more than one type of bacteria, the culture medium used is based on the suspected bacteria to be cultured. The medium may include components that will inhibit the growth of certain types of unwanted bacteria. Once colonies have formed, they are examined with or without a microscope. (APIC 2012; APIC 2014b)

Figure 3-8. Streak Plate Growing Pure Culture on Sheep Blood Agar



Source: Public Health Image Library (PHIL) <http://phil.cdc.gov/phil> ID: 11773. By CDC/Megan Mathias and J. Todd Parker.

- **Antimicrobial susceptibility testing (AST):** Some microorganisms can survive despite being exposed to specific antimicrobial drugs that should kill them (have developed resistance). AST was developed to determine which antimicrobial would be most successful in treating a specific infection. The type and extent of the AST conducted at a health care facility will depend on the capacity of the clinical laboratory, the organism isolated, the source of the culture (body site), available antimicrobial agents, and typical susceptibility patterns for the area or region. (APIC 2014b)
- An **antibiogram** is a collection of data from antimicrobial susceptibilities of local bacterial isolates over a specific period of time, summarizing the percentage of individual bacterial pathogens susceptible to different antimicrobial agents. It is usually combined in an antibiogram table. Antibiograms provide information on the antimicrobial resistance patterns at the facility that can serve as an aid in selecting empiric antibiotic therapy, monitoring resistance trends over time within a facility, and developing antimicrobial stewardship programs to promote rational use of antibiotics. (See Module 7, Chapter 1, Rational Use of Antibiotics.)
- **Immunology/serologic testing:** The human body recognizes microorganisms as foreign bodies or antigens and the immune system produces antibodies to neutralize them. These antibodies are specific for each microorganism. Detecting antibodies in the blood helps detect specific antigens and thus diagnose infectious organisms; this process is called serologic testing. Clinical laboratories use

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serologic tests to diagnose diseases such as HIV, hepatitis B, and hepatitis C. Serologic tests are also used to detect and measure levels of antibodies to confirm successful vaccination or the occurrence of a disease in the past. IPC staff can use this information during surveillance for certain diseases (such as hepatitis B and C) and to verify the immune status of an HCW (such as to hepatitis B). (APIC 2012)

- **Molecular diagnostic methods:** Molecular methods, generally available at large centers or reference laboratories, use sequences in DNA, RNA, or proteins to test for specific organisms. Molecular methods can identify microorganisms in a clinical sample with improved accuracy and speed. These methods are also widely used in determining if certain specimens are related to each other (e.g., to help identify strains in order to determine if transmission is occurring). The most common molecular method is PCR to identify the DNA of a microorganism. It is widely used in large clinical and reference laboratories around the world.

Overview of Microorganisms of Interest for Infection Prevention and Control

Characteristics of Organisms Commonly Associated with Health Care-Associated Infections

The IPC team should know that microorganisms have characteristics that enable them to survive and/or easily spread in health care environments. These characteristics include:

- **Are able to survive on the hands of HCWs**, environmental surfaces, and medical equipment when IPC practices such as hand hygiene, cleaning, disinfection, and sterilization are suboptimal. Examples include influenza virus, RSV, and *S. aureus*, which can live for hours or days on hands and surfaces if not cleaned.
- **Can survive dryness, heat, and disinfectants** and so can cause infections in patients and HCWs in health care facilities despite IPC methods such as hand hygiene, cleaning, disinfection, and sterilization. Examples include norovirus, *C. difficile*, some molds that survive by forming spores, *Pseudomonas* spp., and microorganisms that have been known to survive in disinfectants.
- **Live in blood and body fluids** even though they cannot survive for long in the health care environment. These microorganisms can be passed from person to person via items contaminated with blood or body fluids—even minute amounts. Examples include hepatitis B virus, hepatitis C virus, and HIV on or in dialysis machines, multi-dose vials, multi-use lancets, or insulin pens; and Ebola virus on hands, equipment, and surfaces that are not adequately cleaned.
- **Thrive in damp areas**, and thus the drains, sinks, and equipment that use water (such as humidifiers, patient warmers, and respiratory equipment) can harbor these organisms. Fluids used in health care, such as IV fluids and disinfectants, can also grow microorganisms. Examples include *Mycobacterium* spp. and gram-negative bacteria such as *Acinetobacter* spp., *Pseudomonas* spp., *Burkholderia* spp., and Enterobacteriaceae.
- **Colonize patients and staff**, allowing the microorganisms to survive in the health care environment and pass from person to person, causing an infection if the immune defenses become suboptimal, such as after surgery or when medical devices are in place. Examples include *S. aureus*, Enterobacteriaceae, and *Enterococcus* spp.
- Are small in size and able to remain suspended in the air and be transmitted short distances through the air in respiratory droplets, particularly when propelled by coughing or sneezing, and therefore can cause transmission if personal protective equipment to protect the nose, mouth, and eyes—as described for Standard and Transmission-Based Precautions—is inadequate. Examples include influenza and *N. meningitidis*.

- **Are very small in size and so able to float long distances on air currents** if the ventilation of the facility is not protective of staff and patients. Examples include the viruses causing varicella, measles, and SARS.
- **Are resistant to antimicrobials**; examples include MRSA, VRE, and CRE.

Source: CDC 2014.

These characteristics help determine which microorganisms commonly cause HAIs. The causes of HAIs are generally similar, no matter the country or region (see Table 3-2). Although, gram-negative organisms are more likely to be the most common cause of bloodstream infection in middle- and low-resource settings than in high-income settings. A knowledge of the specific microbes and the microbial patterns of infection in your facility (from surveillance), country (from the health department or published articles), or region (from combined data such as those in Table 3-2) can be helpful in guiding IPC efforts at your facility. (Mahon et al. 2014; WHO 2011)

Table 3-2. Microorganisms That Cause the Four HAIs of Global Public Health Interest

HAI	Microorganisms That Cause the HAIs
Central line-associated bloodstream infection	Coagulase-negative staphylococci, <i>S. aureus</i> , <i>Enterococcus</i> spp., <i>Candida</i> species, MRSA, <i>Klebsiella pneumoniae</i> , <i>Escherichia coli</i> , <i>Pseudomonas aeruginosa</i>
Surgical site infection	<i>S. aureus</i> , coagulase-negative staphylococci, <i>Enterococcus</i> spp., <i>E. coli</i> , <i>P. aeruginosa</i> , <i>Enterobacter</i> species, <i>K. pneumoniae</i> and <i>oxytoca</i> , <i>Candida</i> spp., <i>Acinetobacter baumannii</i>
Catheter-associated urinary tract infection	<i>E. coli</i> , <i>Enterococcus</i> spp., <i>P. aeruginosa</i> , <i>Candida</i> spp., <i>K. pneumoniae</i> , <i>Enterobacter</i> spp.
Pneumonia	<i>E. coli</i> , <i>Klebsiella</i> spp., <i>Proteus</i> spp., <i>S. pneumoniae</i> , <i>H. influenzae</i> , <i>S. aureus</i> , <i>Acinetobacter</i> spp., <i>P. aeruginosa</i>

Adapted from: American Thoracic Society and Infectious Diseases Society of America 2005; Carr 1998; CDC 2011; Hidron et al. 2008.

Gram-Negative Bacteria

Health care-associated infections caused by gram-negative bacteria include pneumonia, bloodstream infections, wound or surgical site infections, and meningitis. Gram-negative bacteria are often resistant to antibiotics. This group, which includes *Klebsiella* spp., *Acinetobacter* spp., *Pseudomonas aeruginosa*, and *E. coli*, among many others, is found in damp areas and is transmitted via unwashed hands of HCWs, water sources, and inadequately cleaned medical equipment. Careful attention to IPC practices such as Standard Precautions, including hand hygiene and proper environmental cleaning, reduces the risk of patients acquiring infections. (See Appendix 2-A, Type and Duration of Precautions Recommended for Selected Infections and Conditions, in this module for more information) (CDC 2014; WHO 2002)

- **Enterobacteriaceae** are a group consisting of several families of gram-negative bacteria, many of which are normally present in the gut, including *E. coli*, and species of *Proteus*, *Enterobacter*, *Klebsiella*, *Citrobacter*, and *Serratia*. However, patients whose care requires medical devices (endotracheal tubes, urinary catheters, or IV catheters) and those who are on long courses of antibiotics are at risk of developing localized or bloodstream infections with these organisms. Members of this group can cause gastrointestinal illness (e.g., *Shigella*, *Salmonella*, and *Yersinia*).

Enterobacteriaceae in health care settings are of particular concern because they have become resistant to most or all available antibiotics and pass this resistance along to other bacteria. Similar

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to other gram-negative organisms, prevention includes cleaning, preventing damp areas, and paying careful attention to IPC measures such as Standard Precautions and hand hygiene. Rational use of antimicrobials is also a critical component. Contact Precautions may be warranted for known cases of multidrug-resistant colonization or infection. (CDC 2014; WHO 2002)

- ***Acinetobacter* species** are commonly found in water and soil but infections with this organism rarely occur in the community. Outbreaks of pneumonia and blood and wound infections in hospitals, including intensive care units, are usually caused by *Acinetobacter baumannii*. *Acinetobacter* spp. can also colonize patients (such as those on a ventilator, with wounds, or **with a long hospital stay**) and **spread to other patients**. Prevention includes cleaning, preventing damp areas, and paying careful attention to IPC practices such as Standard Precautions, including hand hygiene and environmental cleaning. (CDC 2014; WHO 2002)
- ***Pseudomonas*** infection is caused by strains of bacteria found in the health care environment, especially *Pseudomonas aeruginosa*. Although *P. aeruginosa* can cause infections in the community (such as ear and eye infections), serious infections usually occur in health care settings. Patients with weak immune systems, those with medical devices (endotracheal tubes, urinary catheters, or IV catheters) and those with wounds from surgery or from burns are at risk for life-threatening infections. Prevention includes cleaning, preventing damp areas, and paying careful attention to IPC practices such as Standard Precautions, including hand hygiene and environmental cleaning. (CDC 2014; WHO 2002)

Gram-Positive Bacteria

Gram-positive bacteria often cause infections in health care settings. These bacteria have sturdy cell walls and are therefore capable of surviving for longer periods on surfaces in the health care environment and on the skin. (WHO 2002)

- ***Staphylococcus aureus*** is found on the skin and in the nasal passages of about 30% of people. It causes skin infections in the community; however, in health care settings *S. aureus* can cause serious and life-threatening infections such as pneumonia, sepsis, endocarditis, osteomyelitis, and SSI. Patients with weak immune systems, those with medical devices (endotracheal tubes, urinary catheters, or IV catheters), and those with chronic conditions such as diabetes or cancer are at risk. *S. aureus* can become resistant to antibiotics, making the infections more difficult to treat (specifically the group of beta-lactam antibiotics that include methicillin, oxacillin, penicillin, and amoxicillin). These are known as methicillin-resistant *Staphylococcus aureus* (MRSA). Prevention includes careful attention to IPC practices such as Standard Precautions, including hand hygiene and environmental cleaning, and excellent asepsis of the skin before procedures. Contact Precautions may be warranted for known cases of MRSA. (CDC 2014; WHO 2002)

Organisms Specific to Particular Body Systems

It can be helpful for the IPC team to be aware of the microorganisms that typically cause infections to various body systems (see Table 3-3). Those infections occurring in the community may be caused by different organisms than those acquired in the health care facility (see Module 10, Chapter 4, Preventing Hospital-Acquired Pneumonia). An occurrence of one of these infections should alert the IPC team to investigate a possible HAI. In addition, infections with certain organisms warrant Transmission-Based Precautions to prevent their spread within the facility (see Chapter 2, Standard and Transmission-Based Precautions, in this module for more details on these organisms and recommended precautions).

Table 3-3. Overview of the Common Organisms That Cause Infection of Body Systems

Infection/Site	Common Organisms
Bone and joint infections	Osteomyelitis: <i>S. aureus</i> , <i>Salmonella</i> sp., <i>Pseudomonas</i> sp., <i>Streptococcus agalactiae</i> Septic arthritis: <i>S. aureus</i> , <i>Neisseria gonorrhoeae</i> , <i>S. pneumoniae</i> , <i>S. pyogenes</i>
Endocarditis/ heart valve	<i>St. viridans</i> , <i>S. aureus</i> , <i>Enterococcus</i> spp., <i>Haemophilus</i> spp., <i>S. epidermidis</i> , <i>Candida</i> spp.
Gastroenteritis/ intestines	<i>Salmonella</i> sp., <i>Shigella</i> spp., <i>Campylobacter</i> spp., <i>E. coli</i> O157:H7, viruses, <i>G. lamblia</i> , <i>Entamoeba histolytica</i> , <i>Yersinia</i> spp., <i>Vibrio</i> spp., <i>C. difficile</i>
Meningitis/brain membrane	Neonates: Gram-negative bacilli, <i>St. agalactiae</i> (group B), <i>Listeria monocytogenes</i> Infants: <i>St. agalactiae</i> (group B), <i>E. coli</i> , <i>H. influenzae</i> , <i>S. pneumoniae</i> , <i>N. meningitides</i> Children: <i>S. pneumoniae</i> , <i>N. meningitides</i> Older adults: <i>S. pneumoniae</i> , <i>N. meningitides</i> , <i>L. monocytogenes</i> , aerobic gram-negative bacilli Others: <i>C. neoformans</i> , <i>M. tuberculosis</i> , viruses
Peritonitis/ abdomen	<i>Bacteroides</i> spp., anaerobic cocci, <i>Enterococcus</i> spp., Enterobacteriaceae, <i>S. aureus</i> , <i>Candida</i> spp.
Respiratory tract infections, upper	Pharyngitis: <i>S. pyogenes</i> , respiratory viruses, <i>C. albicans</i> , <i>N. gonorrhoeae</i> , <i>Corynebacterium diphtheriae</i> Sinusitis: <i>S. pneumoniae</i> , <i>H. influenzae</i> , <i>S. pyogenes</i> , <i>S. aureus</i> , gram-negative bacilli
Respiratory tract infections, lower	Bronchitis: <i>S. pneumoniae</i> , <i>H. influenzae</i> , respiratory viruses, <i>Bordetella pertussis</i> , RSV Pneumonia: <i>S. pneumoniae</i> , <i>H. influenzae</i> , <i>Mycoplasma pneumoniae</i> , <i>Chlamydomphila pneumoniae</i> , <i>Mycobacterium tuberculosis</i> , <i>S. aureus</i> , gram-negative bacilli, anaerobes, <i>Legionella pneumophila</i> , <i>Pneumocystis jiroveci</i> (carinii) Empyema: <i>S. aureus</i> , <i>Streptococcus</i> spp., anaerobes, <i>S. pyogenes</i> , <i>H. influenzae</i>
Sexually transmitted diseases	<i>Chlamydia trachomatis</i> , <i>N. gonorrhoeae</i> , <i>Bacteroides</i> spp., Enterobacteriaceae, <i>Gardnerella vaginalis</i> , <i>Mobiluncus</i> sp., <i>Trichomonas vaginalis</i> , <i>Treponema pallidum</i> , HIV, cytomegalovirus, human papillomavirus, pubic lice, scabies
Skin infections	<i>S. aureus</i> , <i>S. pyogenes</i> , <i>Candida</i> spp., dermatophytes, gram-negative bacilli, <i>Clostridium</i> spp. Burns: <i>S. aureus</i> , <i>Candida</i> spp., <i>P. aeruginosa</i>
Urinary tract infections	<i>E. coli</i> and other Enterobacteriaceae, <i>Enterococcus</i> spp., <i>Candida</i> spp., <i>Klebsiella</i> spp., <i>Proteus</i> spp., <i>Pseudomonas</i> spp., <i>S. saprophyticus</i>

Sources: APIC 2014b; Brooks 2012; Mahon et al. 2014.

Potential Microbial Agents of Bioterrorism

Bacteria, viruses, and toxins could all be potentially used as agents of bioterrorism. Table 3-4 lists the microorganisms classified by the US Centers for Disease Control and Prevention (CDC) as most likely to be used for a bioterrorist attack. Likelihood of a bioterror event is highest in areas with large, dense populations (such as cities) and those in areas with ongoing or potential conflict.

Table 3-4. Agents That Can Be Used for Bioterrorism (Category A Agents)

Disease	Microorganism
Anthrax	<i>Bacillus anthracis</i>
Botulism	<i>Clostridium botulism</i> toxin
Plague	<i>Yersinia pestis</i>
Smallpox	Variola major
Tularemia	<i>Francisella tularensis</i>
Viral hemorrhagic fever (Ebola, Marburg, Lassa, Machupo)	Filoviruses and arenaviruses

Sources: APIC 2014a; Mahon et al. 2014.

The basis for including these microorganisms on the list includes the following:

- They can be easily spread or transmitted from person to person.
- They result in high death rates and have the potential for major public health impact.
- They might cause public panic and social disruption.
- They require special action for public health preparedness.

Laboratory tests for bioterrorism agents are often available only in specific research laboratories such as a public health laboratory at the national level or those operated and supported by the World Health Organization or CDC. However, it should be noted that when even a single case of an unusual disease is suspected or identified, it should be reported immediately to local public health officials. (See Module 11, Chapter 2, Principles of Public Health Emergency Preparedness and Outbreak Management for Health Care Facilities, for more information on the role of IPC in preparing for infectious disease disasters.)

Role of the Clinical Laboratory in Infection Prevention and Control

The clinical laboratory primarily functions to identify and analyze samples for clinical care. However, collaboration between the laboratory and IPC team members can greatly enhance the effectiveness of IPC programs by increasing the capacity to identify, investigate, and contain infectious diseases in a timely fashion and thus improve patient safety at the facility (APIC 2012; WHO 2009). The following are specific examples of how the IPC team can collaborate with the clinical microbiology laboratory:

- **Surveillance:** The clinical microbiology laboratory is an important partner for the IPC team for surveillance of HAIs. Good-quality samples and reliable results are critical to ensure that surveillance results are accurate. Positive cultures from the source of interest can identify HAIs, and knowing the organisms causing HAIs at the facility can assist with prevention strategies.
- **Outbreak identification and investigation:** The clinical microbiology laboratory can alert the IPC team about new or unusual organisms, clusters, or new antimicrobial resistance patterns that may indicate an outbreak may be taking place. The laboratory can also provide vital assistance when investigating an HAI outbreak. Depending on the capacity, the role of the clinical laboratory in outbreak investigation can include confirming the organism’s identity, confirming from the records normal or background rates of the organism in question, and determining the relatedness of isolates.

- **Environmental sampling:** Although environmental sampling is not routinely recommended, it may be used in limited circumstances with careful consideration when indicated by an epidemiological investigation (see Module 9, Chapter 3, Investigation of Outbreaks of Health Care-Associated Infections, for details). Most clinical laboratories do not have the capacity to process samples from the environment, but if the laboratory does, the staff can assist with developing consistent, specific, and systematic collection of samples and analysis of results.
- **Reporting:** The laboratory can assist with identifying and providing details for reporting of diseases (such as polio, Ebola Virus Disease, cholera) as required by department of health or other entities. (APIC 2012; APIC 2014b; WHO 2009)

Summary

Microorganisms that IPC staff may encounter in health care facilities include bacteria, fungi, parasites, and viruses. Each has different characteristics, methods of identification, and significance. Correct collection and transportation of specimens is important to ensure accurate results. After arrival at the laboratory, specimens undergo various processes to identify the microorganism of interest. The IPC team should have a basic understanding of these processes. Collaboration with the clinical laboratory can increase the IPC team's capacity to identify, investigate, and contain infectious diseases.

Knowledge of the microorganisms that cause HAIs and the methods used to identify them are important in the day-to-day work of an IPC team and will help improve patient safety at the facility. The IPC team needs to be aware of, and knowledgeable about, the basic characteristics of microorganisms that cause HAIs and should be familiar with the characteristics of those organisms that are significant in their setting and patient population.

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