Understand the implication of agricultural agents. Antimicrobial resistance is an adaptive response in which microbes tolerate the amount of medication that previously halted the growth of the organism [33]. The most resistance has emerged to antibiotics, chiefly because health care providers have written too many prescriptions for patients without a bacterial infection; organisms have shed sensitivity to the prescribed antibiotic class or dose; and patients have ingested antibiotics incorrectly. Many physicians and researchers have speculated that the widespread use of antibiotics has spurred an evolutionary adaptation that enables bacteria to survive these powerful drugs. The World Health Organization (WHO), Centers for Disease Control and Prevention (CDC), and Food and Drug Administration (FDA) have suggested that the bacterial infections that contribute the most to the emerging antimicrobial resistance are diarrheal diseases, respiratory tract infections, meningitis, sexually transmitted disease and hospital-acquired infections [41].

Antimicrobial resistance is a challenging, frustrating problem for health care providers, patients and the community. Unfortunately, a patient who has developed resistance to a certain antibiotic and/or a class of antibiotics may develop further complications or die. It is important that nurses understand their role to prevent patients from becoming resistant to antimicrobial agents, especially antibiotics that may potentially save their lives. Unless we collaborate to potentially eradicate and reduce the risk of resistance, we may encounter a society faced with previously treatable diseases that are untreatable again, as in the days before antibiotics were developed.

**Antibacterial definitions**

The term antimicrobial is a broad, general term that encompasses agents produced synthetically or from natural sources that are able to fight against bacteria, viruses, fungus and parasites. There is not one drug that will eradicate all four of the microbes. Since each microbe is unique in its own genetic makeup, development and replication, practitioners need to ensure that they prescribe the appropriate agent to eradicate or inhibit the specific microbe. The CDC, Mosby’s and Stedman’s medical dictionaries are congruent in the definitions for the following terminology [22, 25, 32]:

- **Bacteria** are small, unicellular microbes that are encased in a rigid cell wall, an envelope. The morphology of bacteria includes spheric (cocci), rod shaped (bacilli), spiral (spirochetes) or comma-shaped (vibrios). Therefore, if the offending microbe is speculated or confirmed to be bacterial in nature, the practitioner will prescribe the appropriate class of antibiotic to eradicate the specific bacteria and to break down the rigid cell wall. There are several classifications of drugs that will be explored, such as penicillins and cephalosporins that are capable of weakening the cell wall and promoting lysis of the bacteria (See classification of antimicrobial drugs).
- **Viruses** are minute parasitic microbes that are smaller than bacteria. The unique component of viruses is that they do not have independent metabolic activity and they can only replicate within a cell of a living plant or animal host. A virus consists of a core of nucleic acid deoxyribonucleic acid (DNA) or ribonucleic acid (RNA) surrounded by a coat of antigenic protein that may be surrounded by an envelope of lipoprotein. Depending upon the type of virus, the practitioner will allow it to run the course and/or prescribe an antiviral agent. Antibiotics should never be prescribed for a viral illness.
- **Fungi** are eukaryotic, thallus-forming organisms that feed by absorbing organic molecules from their surroundings. Fungi lack chlorophyll and therefore are not capable of photosynthesis. They are treated by antifungal agents.
- **Parasites** are organisms that live in or on a different organism. Parasites are treated by antiparasitic agents.

Throughout this course, the term antimicrobials will be used to describe mechanisms to fight microbes. In some literature, the term anti-infective is used interchangeably with antimicrobials. Microbes are small microorganisms that are not visible to the naked eye and require a microscope to be detected. The terms microbes and microorganisms are used interchangeably, and microbes will be used here.

Many times, the term “antibiotic chemotherapy” is used in the literature. As nurses, when we hear the word chemotherapy, we automatically think of drugs that suppress cancer cells. Although that is accurate, antibiotic chemotherapy is defined as the use of chemicals against invading microbes, making the term applicable to the treatment of both cancer and infectious diseases.

**Types of drug resistance**

Microbes are living organisms that evolve over time by their ability to divide and proliferate efficiently and quickly. The unique component of microbes is that even if an antimicrobial ceases the microbe’s ability to spread, genetic changes can evolve that will enable it to survive. The microbe’s genetic versatility and adaptability make it difficult for practitioners to try to circumvent or inactivate the aggravating microbe. And when drug resistance occurs, it will render a previous treatment useless, creating a potential clinical crisis and an imminent need for a new medication [27, 33]:

- **Intrinsic resistance occurs with an alteration in the structure and function of the microbe based upon the genome.**
- **Mutation.** Microbes reproduce by dividing every few hours, allowing them to evolve rapidly and adapt to new environmental conditions that may potentially arise. In spontaneous DNA mutation, bacterial DNA may mutate spontaneously; drug-resistant tuberculosis arises this way. Microbes are very adaptable organisms. A key factor in the development of antibiotic resistance is the ability of infectious organisms...
to adapt quickly to new environmental conditions. Of all of the microbes, bacteria are more efficient in enhancing the effects of resistance secondary to their ability to multiply rapidly and transfer their resistance genes [41].

- **Microbes elaborate drug metabolizing enzymes.** At this time, many bacteria have become resistant to penicillin G because of an increased production of penicillinase, an enzyme that converts penicillin to an inactive product. Because practitioners so often prescribe penicillin products in general, resistance may develop. Every time a patient takes penicillin or another antibiotic for a bacterial infection, the drug may kill most of the bacteria present. However, a few tenacious germ may survive by mutating or acquiring resistance genes from other bacteria. The surviving genes can multiply quickly, creating drug-resistant strains. The presence of these bacterium strains affects the next infection because the patient may not respond to the prescribed antibiotics. In addition, the resistant bacteria may be transmitted to others in the patient’s community.

- **Gene transfer.** Microbes acquire genes from each other, including genes that make the microbe drug resistant. Chromosomal mutations or extra chromosomal DNA are transferred from a resistant species to a sensitive one.

- **Microbial drugs’ receptors change.** Sometimes bacteria become resistant to certain antibacterials, such as streptomycin. Unfortunately, streptomycin is losing its effectiveness because of structural changes in the ribosomes of bacteria. According to the Alliance for the Prudent Use of Antibiotics (APUA), intrinsic, genetic causes occur in about one in 10 million cells [1]. At any given point, there are numerous, distinct microbes present in any population, and a constant rate of mutations does occur. When resistance does occur, the end result will vary from a slight change in microbial sensitivity, which can be treated with larger doses of the medication, to complete loss of sensitivity.

- **Acquired resistance occurs through random events that are increased by the use of the drug.**

- **Conjunction.** Conjunction is the process by which an extra-chromosomal DNA is transferred from one gram-negative bacterium to another. In order for this process to occur, the donor organism must possess two unique DNA segments, one that codes for drug resistance and one that codes for “sexual” apparatus. Together, the two codes constitute the resistance (R) factor. A potentially dangerous scenario to contemplate is that a single plasmid can provide many different types of resistance. Research has demonstrated that plasmids encoded with drug resistance are naturally present in microbes before they have been exposed to the medication. The most common forms of bacteria that are affected by the (R) factor include gram-negative bacilli, such as pseudomonas and vibrio cholera; and gram-positive bacteria, such as bacillus and staphylococcus. In 1968, 12,500 people in Guatemala died in an epidemic of shigella diarrhea. The microbe harbored a plasmid that carried resistances to four antibiotics [40].

- **Selective pressure.** In the presence of antimicrobials, microbes will cease existing or they will survive if resistance genes are present. To prevent selective pressure, it is imperative that a patient who has a bacterial infection be prescribed an antibiotic that is sensitive to the bacterium. Unfortunately, any microbes that survive will replicate, and then their progeny will become dominant. Selective pressure becomes a potential problem when antibiotics are prescribed when there are no bacteria present and the drugs provide no benefit to the patient. Once the bacterium is present and antibiotics are introduced, it will create selective pressure, favoring the overgrowth of microbes to become resistant.

- **Spontaneous mutation.** Spontaneous mutation produces random changes in the DNA of the microbe causing an increase in resistance. Initially, it will begin with a low-resistance, then with additional mutations (use) it will become high-resistance. The most common cause of spontaneous mutation is related to overuse of the medication due to societal pressures. Society as a whole has a misconceived notion that an antibiotic will improve the symptoms and eradicate the organism that causes a person to become ill. Unfortunately, antibiotics are too often inappropriately prescribed, leading to antimicrobial resistance such as in the following scenarios:

  - **Incorrect diagnosis.** A provider assumes an illness is bacterial in origin when it is instead viral. A patient may develop resistance.

  - **Incorrect prescription.** If a practitioner speculates the source of infection is one source of bacteria and it is another, then the bacteria will continue to proliferate. In addition, certain sources of bacteria require heavier doses of antibiotics in order to eradicate the infection.

- **Misuse of antibiotics.** There are various ways patients may abuse the use of antibiotics.

  - Many times, patients will either not complete their prescribed antibiotics or they will take a leftover antibiotic for a subsequent illness. Patients who do not complete their prescribed antibiotics and/or they take a remnant dose may develop resistance.

- **Hospital use.** Critically ill patients are more susceptible to infections and thus require heavier use of antimicrobials. Often the complexity of the patient’s condition and numerous, heavy doses of antibiotics predispose the patient to potential drug resistance. It is estimated that approximately 70 percent of the bacteria that cause infections in the hospitals are resistant to at least one of the drugs most commonly used for the treatment and eradication of that bacteria [36]. Even more dangerous, some forms of bacteria are so resistant to antibiotics that previously eradicated them that only experimental toxic medications are being prescribed. In addition, the complexity of critically ill patients also predisposes other patients in hospitals and long-term care facilities to various bacteria and resistance. Hospitals also provide a fertile environment for antibiotic-resistant germs because of close contact among sick patients and extensive use of antibiotics.

- **Community-acquired bacteria are also becoming resistant to bacteria at alarming rates, especially staphylococci and pneumococci (streptococcus pneumonia) infections. In a recent study, 25 percent of bacterial pneumonia cases were shown to be resistant to penicillin, and an additional 25 percent of cases were resistant to more than one antibiotic [36].**

- **Agricultural use.** Another much-publicized concern is the use of antibiotics in livestock, where the drugs are used to prevent disease in well animals that are later slaughtered for food. For over 50 years, farmers have administered antibiotics to their livestock to ensure the health of animals, sometimes placing low levels in livestock’s food to increase the rate of weight gain and improve the efficiency of converting animal feed to units of animal production.
As noted, there is a plethora of reasons antimicrobial resistance occurs. Antibiotics are designed to eradicate specific bacteria; they are not mutagenic and do not directly cause the genetic changes that underlie drug sensitivity. However, with continuous use, spontaneous mutation and conjunction will occur. The CDC reiterates the concept and estimates that the major factor in the emergence of antibiotic resistance bacteria is attributed to the overseuse and misuse of antibiotics [7]. The more antibiotics are used, the faster drug resistance will emerge in our society. Antibiotics may be a double-edged sword when they are overused; although they can heal, they also can promote emergence of resistant pathogens and the overgrowth of normal flora that possess the ability to develop resistance [33]. It is important to understand this concept and to avoid prescribing antibiotics when they are not needed because normal flora can transfer resistance to potential pathogens. Due to the complexity and importance of certain contributing factors to the development of antimicrobial drug resistance, some causes will be further elaborated throughout this chapter.

Remember, anytime antibiotics are used, one or more microorganisms may survive. As these bacteria reproduce, they pass this antibiotic resistance to subsequent generations. Stronger antibiotics are then used, which can escalate the cycle of antibiotic resistance. It is more likely to occur when antibiotics are stopped prematurely (before all bacteria are killed), or when prescribed inappropriately. Therefore, people must understand that if it is not bacterial in nature, they must let the viral infection run its course. The CDC speculates that many providers are sometimes quick to prescribe antibiotics for all sorts of symptoms, even though antibiotics work only against bacterial infections – not viruses such as those that cause the flu or the common cold. Most biologists do not consider viruses to be living things, but instead as infectious particles. More than 50 million of the 150 million antibiotic prescriptions written each year for patients outside of hospitals are unnecessary, according to a recent CDC study (see chart) [39].

### History of antimicrobials

During ancient times, researchers note that human cultures used alternative measures to control microbes, such as boiling water, burying wastes and burying or embalming the deceased. In addition, primitive medications, such as potions, poultices and mud plasters, were extracted from various plants, animals and mineral products with a trial-and-error approach [33]. Although their life expectancy was shorter, people attempted to halt the growth of microbes based upon the minimal opportunities that they had available to them at that time. It was not until the last century, a revolutionary time of technological growth, that physicians had the tools available to research and discover antimicrobial therapy.

The first antimicrobials discovered were antibiotics. Interestingly, the first antibiotic, penicillin, was initially discovered by a French medical student, Ernest Duchesne in 1896, and then rediscovered between the years of 1928-1929 by Sir Alexander Fleming. Mr. Fleming discovered the antibiotic penicillin while observing the inhibition of staphylococci on an agar plate contaminated by a penicillium mold. Although he was able to slow the growth of the mold, he was unable to isolate it. Over a decade later, in 1939, Ernst Chain and Howard Florey developed a way to isolate the penicillin and used it to treat bacterial infections during World War II. Although penicillin began to be used to treat and eradicate horrendous wounds inflicted during the war by gram-positive bacteria, such as staphylococci and streptococci, within four years of use, microbes began appearing that could resist the drug. By the 1960s, as many as 80 percent of staphylococcus aureus (S. aureus), a gram-positive bacteria, was resistant to penicillin.

With the discovery and implementation of penicillin, other physicians began to synthesize other classes of antibiotics. In the late 1930s, Gerhard Domagk, a German doctor, announced the discovery of a synthetic molecule with antibacterial properties that he named prontosil, a sulfonamide (sulfa) drug. Prontosil was introduced to clinical use in the 1930s and was used to combat urinary tract infections, pneumonia and other conditions. Then, in the late 1940s and early 1950s, new antibiotics were introduced by different physicians, including streptomycin (an aminoglycoside), chloramphenicol (a bacteriostatic antibiotic) and tetracycline (a broad-spectrum antibiotic), and the age of antibiotic chemotherapy came into full being. Once various classes of antibiotics were discovered and implemented, various forms of bacterial pathogens, such as gram-positive, gram-negative, intracellular parasites and the tuberculosis bacillus, were being eradicated, saving endless lives.

### Classification of antimicrobial drugs

Regardless of the venue or specialty a nurse pursues in his or her career, each professional will be responsible for administering antimicrobials. Prior to implementing the order written by the provider, the nurse needs to be familiar with the classification, action and purpose for administering the antimicrobial. In general, antibiotics are chemical compounds that interfere with the specific bacteria’s internal processes, inducing cell damage or death, thus eradicating it from the body. While not all antibiotics work the same way, the goal is to disrupt the cell process or structure of the microbe to prevent replication of the invading bacteria [33].

Antibiotics are complex medications that require the nurse to be knowledgeable about the drug and to be diligent during the administration process. There are some antimicrobials that are active against only a few microbes called narrow-spectrum antibiotics; others are active against a wide variety and are broad-spectrum. To add to the complexity, there are over 260 different antimicrobial drugs that are currently classified in 20 drug families. The most commonly used classes will be explored as they relate to potential antimicrobial resistance [22, 33]:

1. **Antibacterial drugs that weaken the bacterial cell wall** (penicillin, cephalosporins, carbapenem and vancomycin).

a. Penicillin Antibiotics are a large and diverse group of compounds that end in the suffix -cillin. All penicillin drugs consist of three parts: a thiazolidine ring, a beta-lactam ring and a variable side chain that dictates its microbialic activity. For a penicillin drug to be effective, the cell wall must be permeable with a mesh-like structure within it. Inside the cytoplasmic membrane the osmotic pressure is extremely high,
Allergic reactions. As many as 1 in 10 patients who receive penicillins will experience an allergic response. Reactions may appear as a mild rash to a systemic anaphylactic reaction. To date, there has been no direct relationship between the size of the dose and the intensity of the allergic response [22].

- Penicillins are considered the drug of choice for infections by known sensitive, gram-positive cocci, such as streptococci and gram-negative bacteria (meningococci and the spirochete of syphilis).
- Synthetic penicillins, such as ampicillin, carbenicillin and amoxicillin are broader spectrum; therefore they can be used to treat infections by gram-negative enteric rods (haemophilus influenzae, Escherichia coli, salmonella and shigella) because they are able to penetrate the outer membrane.
- Extended-spectrum penicillins (antipseudomonal penicillins) consist of four drugs, ticarcillin, carbenicillin indany1, mezlocillin and pipercillin. These drugs are susceptible to the aminopenicillins plus pseudomonas aeruginosa, enterobacter species, proteus, bacteriodes fragilis and klebsiella. All are susceptible to beta lactamases, hence ineffective against most strains of S. aureus.
- Penicillnase-resistant penicillins, such as methicillin, naftillin and cloxacillin, are useful in treating infections caused by some penicillnase-producing bacteria.

The major problems with penicillins include:

- Allergic reactions. As many as 1 in 10 of all patients who receive penicillins will experience an allergic response. Reactions may appear as a mild rash to a life-threatening anaphylactic reaction. To date, there has been no direct relationship between the size of the dose and the intensity of the allergic response [22].
- Resistant strains of pathogens, especially bacteria encapsulated by a beta-lactamase ring. Beta-lactamase activity can occur in gram-positive organisms (staphylococcus aureus and staphylococcus epidermidis); gram-negative organisms (haemophilus influenzae, neisseria gonorrhoea, moraxella [formerly branhamella] catarrhalis, Escherichia coli, and proteus, serratia, pseudomonas and klebsiella species); and anaerobic organisms (bacteriodes species) [21]. Bacteria encapsulated by a beta-lactamase ring are eliminated by combining a penicillin or cephalosporin with a beta-lactamase inhibitor, such as one of the following combinations [33]:
  - Ampicillin + sulbactam = unasyn.
  - Amoxicillin + clavulanic acid = augmentin.
  - Ticarcillin + clavulanic acid = timentin.
  - Piperacillin + tazobactam = zosyn.

Clavulanic acid is a chemical that inhibits beta-lactamase enzymes, thereby increasing the longevity of beta-lactam antibiotics in the presence of penicillinase-producing bacteria. Beta-lactamase inhibitors have a minimal risk of toxicity and any adverse reactions that may occur with the combination drugs are related to the penicillin component.

Bacterial resistance to penicillins develops by two factors [22]:

1. Inability of the penicillins to reach their targets.
2. Inactivation of penicillins by bacterial enzymes.

It is important to note that although all bacteria are surrounded by a cell envelope, the envelopes differ in gram-positive and gram-negative bacteria [22]:

- The cell envelope of gram-positive bacteria has only two layers, the cytoplasmic membrane plus a relatively thick cell wall. Although the membrane is thick, it can be easily penetrated by penicillins.
- The cell envelope of gram-negative bacteria has three layers; the cytoplasmic membrane, a thin cell wall and an additional outer membrane. The penicillins can penetrate the first two layers of the gram-negative wall, but have difficulty reaching and breaking through the outer layer. Therefore, penicillins are typically inactive against gram-negative organisms.

2. Cephalosporins are a newer group of antibiotics that currently account for the majority of all antibiotics administered today. Cephalosporins are similar to penicillins in their beta-lactamase structure, bactericidal and active against a broad spectrum of antibiotics. Similar to penicillins, cephalosporins bind to penicillin-binding proteins and activate enzymes that cleave to the cell wall, therefore damaging the cell wall. The generic names of cephalosporins have the root of cef-, ceph-, or kef-.

- Cephalosporins are versatile drugs that are relatively broad-spectrum and resistant to most penicillins. Cephalosporins typically have fewer, less severe adverse reactions compared to penicillins, such as a maculopapular rash that develops in several days. Although adverse reactions are lower in cephalosporins, research has provided ranges from a 5-30 percent risk of crossover sensitivity in patients who are allergic to penicillin [22]. If a patient has suffered a severe, immediate hypersensitive penicillin reaction, a cephalosporin should never be administered [33].
- There are four generations of cephalosporins that exist. Cephalosporins develop antimicrobial resistance due to the production of beta-lactamases, which is further discussed in the descriptions of each generation [33]
  - First-generation cephalosporins, such as cefalothin and cefazolin, are most effective against gram-positive cocci but few gram-negative bacteria. Although all cephalosporins are capable of destroying the beta-lactamase, they are not all equally susceptible. For instance, most first-generation cephalosporins are destroyed by beta-lactamases.
  - Second-generation cephalosporins, such as cefaclor and cefonicid, are more effective than the first-generation cephalosporins in treating infections induced by gram-negative bacteria, such as enterobacter, proteus and haemophilus.
  - Third-generation cephalosporins, such as cephalaxin (Kelex) and cefotaxime, are broad-spectrum antibiotics that are stable in the presence of bacteria with a beta lactamase ring. A newer semi-synthetic broad spectrum, ceftriaxone (rocephin) treats a wide variety of respiratory, skin, urinary and nervous system infections. The third- and fourth-generation cephalosporins are highly resistant to destroying beta lactamases. Although the third generations are stable in the presence of beta-lactamase, they should not be used routinely and instead used only when specific conditions arise to prevent the emergence of organisms to resist the antibiotic.
  - Fourth-generation cephalosporins, such as ceftazidime, may be prescribed as needed. The majority of prescriptions written are the third-generation cephalosporins.
Antibacterial drugs that inhibit protein synthesis (tetracyclines, macrolides, clindamycin, zyvox and aminoglycosides). These drugs suppress bacterial cell growth and replication, but do not kill the bacteria. The following drugs are considered “second-line drugs” due to emerging antimicrobial resistance.

1. **Tetracyclines** are broad-spectrum antibiotics that suppress bacterial growth by binding to ribosomes and blocking protein synthesis.

2. **Clindamycin** is active against most gram-positive and gram-negative bacteria, although gram-negative bacteria are developing resistance (B. fragilis). At this time, clindamycin is preferred for abdominal and pelvic infections caused by B. fragilis and/or as a substitute for penicillin G infections.

3. **Linezolid (zyvox)** is a new member; at this time it has excellent activity against multidrug-resistant gram-positive pathogens, including vancomycin-resistant enterococci (VRE) and MRSA. Therefore, avoid using it unless needed for the treatment of VRE or MRSA.

4. **Aminoglycoside** drugs are composed of two or more amino sugars and an aminocyclitol (6-carbon) ring. Aminoglycoside drugs have a relatively broad antimicrobial spectrum because they inhibit protein synthesis (in the bacterial cell 30S ribosomal subunit). However, they are used more for narrow-spectrum microbials, primarily against gram-negative bacilli. Sensitive organisms include Escherichia coli, klebsiella pneumoniae, serratia marcescens, proteus mirabilis and pseudomonas aeruginosa.

Although aminoglycosides have low gastrointestinal absorption, the patient needs to be closely monitored due to the potential toxicities (nephrotoxicity, ototoxicity).

- Tetracycline compounds include doxycycline and minocycline to primarily treat sexually transmitted infections (STI).
- Antimicrobial resistance occurs with tetracyclines because of reduced drug accumulation, increased drug inactivation, and decreased access by a drug to ribosomes.

2. **Macrolides** are big molecule, broad-spectrum antibiotics that act by suppressing bacterial synthesis.

- **Erythromycin (EES)** is one of the oldest and safest members of the family. Other macrolides include azithromycin, clarithromycin, dirithromycin, derivatives of erythromycin.

- **EES** is the drug of choice for streptococcus pneumoniae, group A streptococcus pyogenes, legionella pneumonia, bordetella pertussis and chlamydial infections.

3. **Others** include clindamycin (cleocin), which is notorious for causing pseudomembranous colitis.

- **Clindamycin** is active against most gram-positive and gram-negative bacteria, although gram-negative bacteria are developing resistance (B. fragilis). At this time, clindamycin is preferred for abdominal and pelvic infections caused by B. fragilis and/or as a substitute for penicillin G infections.

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Although aminoglycosides have low gastrointestinal absorption, the patient needs to be closely monitored due to the potential toxicities (nephrotoxicity, ototoxicity).

- **Aminoglycosides** are useful for treating infections induced by aerobic gram-negative rods and certain gram-positive bacteria. Aminoglycosides are typically prescribed for infections caused by enterobacteriaceae or P. aeruginosa. However, over the years, resistance has developed in P. aeruginosa.

- The most common aminoglycosides are streptomycin, gentamicin, tobramycin and amikacin. In the United States, gentamicin is the most commonly prescribed aminoglycoside.

- Aminoglycosides are typically prescribed in combination with beta lactamase agents.

Over the years, aminoglycosides have developed resistance caused by the presence of one or more mechanisms: inactivation of the drug by the aminoglycoside modifying enzymes (AMEs) produced by bacteria, ribosomal alterations that prevent the drug from binding to the site of action, or loss of permeability of the bacterial cell to the drug [3]. On a positive note, although a patient may have developed a resistance to one aminoglycoside, it is not predictive of resistance to another because they vary in their drug specificity.

**Antibacterial drugs that disrupt the synthesis of tetrahydrofolic acid (sulfonamides)**

Bacterial growth is suppressed because the synthesis of folic acid (folate) is inhibited. Folate is a compound required by all cells for the biosynthesis of DNA, RNA and proteins.

1. **Sulfonamides**. Sulfonamides were the first drugs available for the systemic treatment of bacterial infections and are considered broad-spectrum antibiotics. Due to newer antimicrobial therapy and a high amount of drug resistance, sulfonamides are reserved for urinary tract infections (UTI). About 90 percent of UTIs are due to Escherichia coli, a bacterium that is highly sulfonamide sensitive.

- Sulfonamides have developed antimicrobial resistance by spontaneous mutation or by transfer of the R factor. Resistance is especially high among gonococci, meningococci, staphylococci, streptococci and shigellae.

**Miscellaneous antibacterial drugs (fluoroquinolones and metronidazole)**

1. Fluoroquinolones include drugs that end in -oxacin, such as ciprofloxacin (cipro) and ofloxacin.

- Ciprofloxacin inhibits bacterial DNA gyrase, an enzyme that converts closed circular DNA into a supercoiled configuration. To date, the precise mechanism of cell death is not completely understood.
Ciprofloxacin has great broad-spectrum activity, including gram-negative and gram-positive bacterium. Many urinary tract infections are sensitive, such as Escherichia coli and klebsiella.

Antimicrobial resistance has developed during treatment of staphylococcus aureus, serrata marcescens, C. jejuni and P. aeruginosa due to alterations in DNA gyrase and reduced ability of ciprofloxacin to cross bacterial membranes.

2. Metronidazole (flagyl) is used for protozoal infections caused by anaerobic bacterium. In order for it to be effective, the drug must be taken up by the cells and then converted to its active form. Only anaerobes can perform this unique function.

Metronidazole is active against many anaerobic bacterial infections.

Other antimicrobial drugs include the following:

1. Anti-mycobacterial agents.
   Mycobacteriums are slow-growing bacteria. Due to the prolonged therapy, patients typically develop drug toxicity, non-compliance and/or drug resistance.
   (See tuberculosis under “respiratory.”)

2. Antifungal drugs.
   Fungi cells are eukaryotic and there are currently four main drug classifications to treat fungal infections. Systemic mycoses are used to treat opportunistic infections (candidiasis, aspergillosis, cryptocoecosis and mucormycosis) and non-opportunistic infections that can occur in any host (sporotrichosis).

3. Anti-parasitic chemotherapy drugs.
   Due to the enormous diversity among protozoan and parasites, there are numerous approved and experimental drugs on the market.
   a. Antimalarial drugs.
      For over a hundred years, quinine has been utilized as the principle treatment for malaria. In past years, quinine has been extracted from the bark of cinchona tree, but later replaced by the synthesized quinolones.

b. Chemotherapy for other protozoan infections.
   The most common amebicide is metronidazole (flagyl), which is effective in treating mild and severe intestinal infections and hepatic disease.

Quincline (a quinine-based drug), sulfonamides and tetracyclines also have antiprotozoan activities.

c. Anti-helminthic drug therapy.
   Treating helminthic infections, such as flukes, tapeworms and roundworms, is accomplished by blocking the reproduction and inhibiting the metabolism of all stages of the life cycle.

4. Antiviral drugs.
   Viruses are unique because the infectious agent relies on the host cell for the majority of its metabolic functions. Therefore, in order to eradicate infections induced by certain viruses, the drug needs to disrupt the metabolism of the host cell. It should be noted, all viruses are not treated with antiviral agents; many resulting ailments typically run their course, such as colds, measles, and mumps. The majority of viral compounds need to exert their effects on the completion of the virus cycle by barring complete penetration of the virus into the host cell, blocking the transcription and translation of viral molecules and preventing the maturation of viral particles.

The most common antiviral medications prescribed include but are not limited to the following:

- Acyclovir (zovirax), which blocks DNA synthesis in a small group of viruses, especially the herpes virus. The herpes virus has developed resistance to acyclovir due to:
  - Decreased production of thymidine kinase.
  - Alteration of the thymidine kinase.
  - Alteration of viral DNA polymerase that is less sensitive to inhibition.
- AZT (zidovudine) and others are administered for human immunodeficiency virus (HIV).
  (See HIV under the section on antimicrobial drug resistance and antiviral agents)
- Amantadine and rimantadine are used for the treatment of viruses restricted exclusively to the influenza A virus (flu). Whereas relenza and tamiflu are effective prophylactic and standard treatments against influenza A and B, in order for the medication to be effective, it needs to be administered early in the virus infection to ensure that it can inhibit the fusion and uncoat the virus.

Other antimicrobial agents

- Azithromycin
- Clarithromycin
- Erythromycin
- Quinolones
- Ciprofloxacin
- Enoxacin
- Lomefloxacin
- Levofoxacin
- Norfloxacin
- Ofloxacin
- Sparfloxacin
- Tetracyclines
- Demeclocycline
- Doxycycline
- Minocycline
- Oxytetracycline
- Tetracycline
- Penicillins
- Ticarcillin
- Amoxicillin
- Penicillin V
- Piperacillin
- Tinidazole

Table 1: Actions of antibiotics

<table>
<thead>
<tr>
<th>Inhibit protein synthesis</th>
<th>Disrupt cell membrane</th>
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<tbody>
<tr>
<td>Aminoglycosides</td>
<td>Beta-lactamase inhibitors</td>
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<td>Cefoxitin</td>
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<tr>
<td>Macrolides</td>
<td>Imipenem/cilastatin</td>
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Managing the success of antimicrobial therapy

Prior to deciphering the most adequate antibiotic to give a patient, the practitioner must consider the patient’s age, allergies, potential microbes based upon the diagnosis, drug sensitivity, host factors, bacteria with a beta lactamase ring and risk of drug resistance. There is a vast array of variables to contemplate to ensure the bacteria will be eradicated and potential complications for the patient and/or the community. They include:

- Patient's age. While caring for a young child, pregnant woman or an elderly patient, it is important to consider the body's ability to absorb, distribute, metabolize and excrete the medication.
- Young children, such as neonates and infants, have a difficult time in the following [8]:
  - Absorbing drugs in their gastrointestinal system due to a variable and prolonged gastric emptying time, prolonged transit time and peristalsis. Gastric acidity reaches adult levels between 1 to 2 years of age, and the gastric emptying time once it reaches the adult level between 6 to 8 months.
  - Peripheral circulation is poorly developed, leading to...
vassel constriction, causing decreased absorption.

- Less muscle mass (25 percent of body weight versus 40 percent in adults) provides a smaller area for absorption of intramuscular (IM) medications. Therefore, IM and subcutaneous routes are not the best choices for the neonate.
- Immature enzymes systems (until 2 to 4 years of age), which affects drug metabolism.
- Smaller number of tubular cells, shorter tubules, decreased renal flow and a decreased glomerular filtration rate (GFR). Unfortunately, that results in a longer half life and increased absorption of drugs, especially penicillins and aminoglycosides.

**Pregnancy.** In pregnancy, certain medications are passed through the blood-brain barrier (BBB) into the placenta, posing a risk to the developing fetus. Therefore, it is important to assess the efficacy of the drug for the patient and the unborn patient if it crosses the blood-brain barrier, increasing the risk of tetragenic complications. The FDA has developed a pregnancy risk classification table to help providers choose the appropriate medication for their patients. (See the table on the following page). Most providers will only prescribe antimicrobials classified in category B, and avoid prescribing any antimicrobials in category D.

**FDA pregnancy risk classification in relation to antimicrobial therapy**

<table>
<thead>
<tr>
<th>Category</th>
<th>Controlled studies in women fail to demonstrate a risk to the fetus in the first trimester. There is no evidence of risk in later trimesters. The possibility of fetal harm appears remote.</th>
<th>No antimicrobials are in the category A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category B</td>
<td>Animal reproduction studies have not demonstrated a fetal risk, but there are no controlled studies in pregnant women. Or, animal reproduction studies have shown an adverse effect (other than a decrease in fertility), but which was not confirmed in controlled studies of women in the first trimester (and there is no evidence of risk in later trimesters).</td>
<td>1. Penicillins. 2. Beta-lactamase inhibitors (augmentin). 3. Macrolides (erythromycin, azithromycin). 4. Cephalosporins (all generations). 5. Metronidazole.</td>
</tr>
<tr>
<td>Category C</td>
<td>Either studies in animals have revealed adverse effects on the fetus (causing abnormalities or death) and there are no controlled studies in women or studies in women and animals are not available. Drugs in this category should be given only if the potential benefit justifies potential risk to the fetus.</td>
<td>1. Macrolides (clarithromycin). 2. Sulfos (bacitracin). 3. Aminoglycosides (gentamicin). 4. Other (vancomycin). 5. Fluoroquinolones.</td>
</tr>
<tr>
<td>Category D</td>
<td>There is positive evidence of human fetal risk, but the benefits from the use in pregnant women may be acceptable despite the risk – for example, if the drug is needed in a life-threatening situation or for a serious disease for which safer drugs cannot be used or are ineffective.</td>
<td>1. Tetracycline (doxycycline).</td>
</tr>
</tbody>
</table>

**Table Source [8]**

In addition, absorption is decreased due to a diminished gastric tone and motility, which may cause the drug to stay in the stomach longer.

- **Elderly.** Similar to the young, elderly patients have difficulty absorbing, distributing, metabolizing and excreting their medications [8]:
  - Common conditions affecting the absorption process in the elderly include malabsorption, diarrhea or constipation. Many times, the elderly have heightened drug sensitivity due to the decreased rate of metabolism and drug excretion.
  - There is a decrease in the liver mass, volume and blood flow, which affects the ability of the liver to eliminate the medication. As a rule of thumb, liver metabolic activity declines 1 percent every year after the age of 40.

- **Allergies.** The most common, severe drug allergy is with the penicillins. It is important to always ask the patient about any drug allergies. Asking the specifics:
  - What has happened when you have taken the medication in the past? A true allergy results in a hypersensitive response due to immunoglobulin E (IgE) mediators. The symptoms include [22]:
    - Respiratory: difficulty breathing and wheezing.
    - Cardiac: tachycardia and rapid pulse.
    - Skin: hives (urticaria) and rash.
    - Swelling (edema) of the lips, tongue or face.

- **Potential microbes.** A list of the most common pathogens, based upon various literature, can be found on the next page [24].
<table>
<thead>
<tr>
<th>Site</th>
<th>Most common bacteria identified</th>
<th>Preferred antimicrobial</th>
<th>Alternative treatment in resistant cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Otitis media (OM).</td>
<td>S. pneumonia (+) 49 percent. Over 10 percent resolve spontaneously without treatment.</td>
<td>If no previous antibiotics in the past month: Amoxicillin 20-40 mg/kg/day or erythromycin 50 mg/kg/day plus sulfonamide (150 mg/kg/day) for 10 days.</td>
<td>Increase resistance, especially among S. pneumonia (50 percent are resistant to macrolides). Cefaclor 20-40mg/kg/day or amoxicillin-clavulanate 20-40mg/kg/day.</td>
</tr>
<tr>
<td></td>
<td>H. influenzae (-) 29 percent. Over 50 percent resolve spontaneously without treatment.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M. catarrhalis (-) 28 percent. Over 90 percent resolve spontaneously without treatment.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sinusitis.</td>
<td>S. pneumonia 31 percent. (+).</td>
<td>Reserve antibiotic treatment for symptoms that persists over 7 days with maxillary/facial pain, purulent nasal discharge and/or severe pain/fever. Same antibiotics as used in the treatment of OM.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>H. influenzae 21 percent (-).</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M. catarrhalis 2 percent (-).</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Virus 15 percent.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sore throat.</td>
<td>Most common group A.</td>
<td>Penicillin V potassium 250 mg po three times/day or 500 mg twice day/ for 10 days.</td>
<td>Cephalosporins (cefoxime) , erythromycin or amoxicillin with clavulanate (augmentin). 25 percent are developing erythromycin resistance.</td>
</tr>
<tr>
<td></td>
<td>B-hemolytic streptococi (+)</td>
<td>If there is a penicillin allergy, erythromycin is prescribed (also effective against mycoplasma and chlamydia).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>If a virus is the contributing factor, no antibacterial should be prescribed.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other bacterial sources, neisseria gonorrhoeae, mycoplasma and chlamydia trachomatis.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bronchitis.</td>
<td>Typically viral in nature, therefore no antibiotics for teenagers and young adults with acute bronchitis. For acute bronchitis exacerbation, viruses (20-50 percent), C.pneumonia 5 percent, M Pneumonia &lt;1 percent.</td>
<td>Amoxicillin, doxycycline, bactrim for mild to moderate disease. If severe, azithromycin, clarithromycin or a fluoroquinolones.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Haemophilus influenzae; (-).</td>
<td>Cefotaxime, ceftriaxone, cefuroxime, doxycycline, azithromycin and bactrim.</td>
<td>Alternatives: fluoroquinolones and clarithromycin.</td>
</tr>
<tr>
<td></td>
<td>Staphylococcus aureus; (+).</td>
<td>If methicillin-susceptible treat with penicillin with or without rifampin.</td>
<td>Alternatives: cephalosporin, clindamycin, bactrim, vancomycin or fluoroquinolones. If methicillin-resistant strains, treat with vancomycin with or without gentamicin or rifampin.</td>
</tr>
<tr>
<td></td>
<td>Moraxella catarrhalis; -.</td>
<td>Cephalosporin 2nd or 3rd generation or a fluoroquinolones.</td>
<td>Bactrim, amoxicillin-clavulanic acid (augmentin) or a macrolides.</td>
</tr>
<tr>
<td></td>
<td>There are other sources, klebsiella pneumonia, Escherichia coli, legionella and chlamydia.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Genital tract.</td>
<td>Chlamydia.</td>
<td>Doxycycline 100 mg po BID x7 days or azithromycin 1 gram as a single dose. Alternative: Erythromycin 500 mg po BID x 7days.</td>
<td>Alternatives: fluoroquinolones and clarithromycin.</td>
</tr>
<tr>
<td></td>
<td>N. gonorrhoeae.</td>
<td>Ceftriaxone 1 gram. No fluoroquinolones due to an enormous amount of antimicrobial resistance.</td>
<td>Alternatives: cephalosporin, clindamycin, bactrim, vancomycin or fluoroquinolones. If methicillin-resistant strains, treat with vancomycin with or without gentamicin or rifampin.</td>
</tr>
</tbody>
</table>

Elite CME
Drug sensitivity. Optimal antimicrobial therapy is based upon the identified infecting organism and sensitivity of the medications. In order to assess drug sensitivity, a culture should be done if applicable. There are certain conditions in which a culture may not be feasible due to the location of the infecting organism, cost and decreased risk of drug resistance. At that time the patient is treated empirically, based upon a guess, as a result of the patient’s subjective complaints and the practitioner’s objective findings. However, if a potential invading organism has increased risk of drug resistance, a culture should be completed to assess for the sensitivity of the drug.

- **Disk diffusion tests** also known as the Kirby-Bauer test. It is performed by inoculating an agar plate with the infecting organism and then placing on that plate several small disks, each impregnated with a different antibiotic [22].

- **Broth dilution procedure** is similar to the Kirby-Bauer, but the bacteria are grown in tubes containing different concentrations of antibiotics. Both tests measure the drug sensitivity, assessed in two clinical values [22].

- **Minimum inhibitory concentration** (MIC), defined as the lowest concentration of antibiotic that produces complete inhibition of bacterial growth, but does not kill the bacteria.

- **Minimum bactericidal concentration** (MBC), defined as the lowest concentration of drug that produces a 99.9 percent decline in the number of bacterial colonies, indicating a bacterial kill.

- **Host factors.** In addition to matching the drug with the infecting bug and determining the drug sensitivity, the host factors (host defenses and site of infection) must be considered [22].

  - Host defenses consist primarily of the immune system and phagocytic cells (macrophages and neutrophils). In order for antimicrobial therapy to be successful, it requires collaboration of the host defense system to subdue the infection.

  - To be effective, the antibiotic must be present at the site of the infection in a concentration greater than the MIC. It may pose a challenge if the bacteria are in a difficult area, such as the blood-brain barrier, endocarditis and infected abscesses.

- **Bacteria with a beta-lactamase ring.** Beta-lactamases (ß-lactam) are enzymes that cleave to a beta-lactam ring, thus rendering the prescribed antibiotics inactive. ß-lactam antibiotics include penicillins, cephalosporins, monobactams and carbapenams. (See previous discussion under penicillins).

Risk of drug resistance. Unfortunately, antimicrobial drug resistance is prevailing globally. Every individual is at risk of developing resistance to antimicrobials. However, there are certain risk factors that increase the risk: [33].

- Overuse of antibiotics.
- Overuse of broad-spectrum antibiotics.
- Use of higher doses of antibiotics. In combination with the use and high doses of antibiotics, the faster drug-resistant organisms will emerge. Not only do antibiotics eliminate the targeted bacterium, they also affect normal flora that possess mechanisms for resistance.

However, all antimicrobial drugs are at risk of becoming resistant as they promote the emergence of drug-resistant organisms. Over time, organisms become less susceptible to previously effective prescribed antimicrobials. However, broad-spectrum antibiotics are more prone to induce this phenomenon because they kill off more organisms than narrow-spectrum antibiotics. At this time, the organisms for which drug resistance has the most serious clinical problem include the following [28, 33]:

- VRE – vancomycin-resistant enterococci.
- MRSA – methicillin/oxacillin-resistant staphylococcus aureus.
- ESBLs – extended-spectrum beta-lactamases (which are resistant to cephalosporins and monobactams).
- PRSP – penicillin-resistant streptococcus pneumoniae.

According to the National Institute of Allergy and Infectious Diseases, the most dangerous, emerging microbes affecting the community at large include vancomycin-resistant enterococci (VRE) and methicillin-resistant staphylococcus aureus (MRSA) [20]. Because each organism can increase the patient’s risk of complications and/or death, each will be explored in depth.

In June 2008, the United States (U.S.) Department of Health and Human Services provided a testimony based upon unpublished data from the CDC’s National Nosocomial Infection Surveillance System indicating that [37]:

- More than 90 percent of staphylococcus aureus strains are no longer treatable with penicillin (See the section on staphylococcus aureus under hospital acquired antimicrobial drug resistance).
- One third of streptococcus pneumoniae isolates, a common cause of ear infections, pneumonia and meningitis, are also no longer treatable with penicillin (See the section on streptococcus pneumonia under hospital acquired antimicrobial drug resistance).
- There are many penicillin-resistant strains that, in fact, multiply resistance to other commonly used drugs such as ceftriaxone, erythromycin and trimethoprim-sulfamethoxazole (bactrim).

On the rise, other resistant strains include:

- Strains of salmonella Newport, which cause infections in food animals, such as dairy cows, and have been shown to be resistant to as many as seven antibiotics.
- Although still small, there is a growing subset of the gram-negative bacterial strains that cause health care-associated infections such as acinetobacter baumannii and pseudomonas aeruginosa, which have become resistant to all available antimicrobial agents.
- Worldwide, tuberculosis caused by strains resistant to the two most commonly used anti-tuberculosis agents, isoniazid and rifampin, was recently estimated to affect approximately half a million persons annually.
- Recently, in the upper Midwestern U.S. the first ciprofloxacin-resistant strains of neisseria meningitides was reported. Due to the prevalence and delicate matter of antimicrobial drug resistance, each of the major bacteria will be analyzed in the subsequent sections.

Hospital-acquired antimicrobial drug resistance (enterococci, staphylococcus aureus, extended spectrum beta lactamases)

According to the CDC (2008), antibiotic-resistant infections are a prevalent problem for hospitals and nursing homes because it can spread from one patient to another from open wounds and impaired immune systems. In 2007, the Journal of American Medical Association estimated that 94,360 patients in the U.S. developed an invasive infection from antibiotic resistant MRSA in 2005; nearly one in five, or 18,650 of them, died [7]. Failure to control and/or eradicate MRSA leads to prolonged hospitalization stays and the possible risk of death.

According to the CDC (2006), in American hospitals alone, health care-associated infections account for an estimated 1.7 million infections and 99,000 associated deaths each year. Of these infections [5]:

- 32 percent of all health care-associated infections are urinary tract infections.
- 22 percent are surgical site infections.
- 15 percent are pneumonia (lung infections).
- 14 percent are bloodstream infections.

Anyone can be colonized with drug-resistant microorganisms. Environmental cultures have shown vancomycin-resistant enterococci (VRE) and methicillin-resistant staphylococcus aureus (MRSA) on linens as well as hard surfaces such as bedrails, bedside stands, and medical devices. For example, use techniques that avoid contamination when collecting wound cultures [5]:

1. Rinse wound with saline to expose wound bed.
2. Do not culture wound exudates/drainage.
3. Situations in which the use of vancomycin should be discouraged:
• Routine surgical prophylaxis other than in a patient who has a life-threatening allergy to beta-lactam antibiotics.
• Empiric antimicrobial therapy for a febrile neutropenic patient, unless initial evidence indicates that the patient has an infection caused by gram-positive microbes (i.e., at an inflamed exit site of Hickman catheter) and the prevalence of infections caused by MRSA in the hospital is substantial.
• Treatment in response to a single blood culture positive for coagulase-negative staphylococcus, if other blood cultures taken during the same time frame are negative (i.e., if contamination of the blood culture is likely). Because contamination of blood cultures with skin flora (i.e., S. epidermidis) could result in inappropriate administration of vancomycin, phlebotomists and other personnel who obtain blood cultures should be trained to minimize microbial contamination of specimens.
• Continued empiric use for presumed infections in patients whose cultures are negative for beta-lactam-resistant gram-positive microbes.
• Systemic or local (i.e., antibiotic lock) prophylaxis for infection or colonization of indwelling central or peripheral intravascular catheters.
• Selective decontamination of the digestive tract.
• Eradication of MRSA colonization.
• Primary treatment of antibiotic-associated colitis.
• Routine prophylaxis for very low birth-weight infants (i.e., infants who weigh less than 1,500 grams,

3. Swab edges and base of the wound.
4. Use culture tube swab; do not substitute cotton swab.

Postoperative wound infections may be the result of contamination of the surgical wound during the procedure or migration of an infection from another infection site. It could also be a reactivation of an infection that occurred previously. For example, a common site of hospital-acquired infection is the urinary tract, secondary to a procedure or catheterization. Infection can occur when a microorganism moves to a location where it is not normally found.

Some people are more susceptible to infection. These same people are often patients in a clinic or hospital. At-risk populations include [18]:
• The elderly.
• Individuals with suppressed immune systems.
• Individuals with orthopedic implant surgery.
• Individuals with other infection sites.
• The morbidly obese.
• Those using IV, catheter, feeding tube or other invasive lines or tubes.
• A history of long-term and/or frequent use of antibiotics, multiple hospitalizations and long-term inpatient care.

1. Enterococci drug resistance
Enterococci, previously called group D strep, can cause everything from urinary tract to heart valve infections. enterococci are typically colonized in the gastrointestinal tract and female genital tract, but in patients with poor hygiene, it may be found on the skin surfaces. The most common resistant Enterococci include E. faecalis and E. faecium [19]. Enterococci have become resistant to antimicrobials, especially penicillin, ampicillin, piperacillin, imipenem and vancomycin, which are among the few antibiotics that show consistent inhibitory, but not bactericidal, activity against E. faecalis [22]. E. faecium are less susceptible to β-lactam antibiotics than E. faecalis because the penicillin-binding proteins of the former have markedly lower affinities for the antibiotics.

• Vancomycin, also known as vancomycin-resistant enterococci (VRE) is related to intrinsic and acquired variables. In the hospital setting, E. faecium is the most isolated species of VRE producing high vancomycin (more than 128 ug/ml) MIC [19]. VRE is typically colonized in the gastrointestinal (GI) tract and occasionally in the urinary tract. It is important to note that a patient may colonize the bacterium but not show any signs or symptoms of infection. Risk factors for VRE infection and colonization include [17, 19 20]:
  • Previous vancomycin and/or multiantimicrobial therapy.
  • Severe underlying disease or immunosuppression.
  • Long-term intravenous lines or urinary catheters.

• Third-generation cephalosporin utilization.
• Anti-anaerobic antibiotics (such as clindamycin).
• Fluoroquinolones (such as ciprofloxacin).
• Intra-abdominal surgery.

Since enterococcus is typically found in the normal gastrointestinal and female genital tracts, most infections have been attributed to endogenous sources within the individual patient. However, recent reports of outbreaks and endemic infections caused by enterococcus, including VRE, have indicated that patient-to-patient transmission of the microorganisms can occur either through direct contact or through indirect contact via [19]:
• Hands of personnel.
• Contaminated patient-care equipment and/or environmental surfaces.

Therefore, the CDC recommends that health care facilities screen for VRE with all new admitted or high-risk patients (intensive care, oncology and surgical patients) [22]. Screening for VRE includes swabbing the perirectal/anal area or collecting a stool specimen. If any patient tests positive for VRE, the physician and infection control team need to be notified immediately.

In 1995, the CDC provided recommendations for the Hospital Infection Control Practices Advisory Committee (HICPAC) to be implemented nationwide in order to reduce the spread of VRE [14]. To date, the CDC has not updated or revised its recommendations:
2. Situations in which the use of vancomycin is appropriate or acceptable:
• For treatment of serious infections caused by beta-lactam-resistant gram-positive microorganisms. Vancomycin may be less rapidly bactericidal than are beta-lactam agents for beta-lactam-susceptible staphylococci.
• For treatment of infections caused by gram-positive microbes in patients who have serious allergies to beta-lactam antimicrobials.
• When antibiotic-associated colitis fails to respond to metronidazole therapy or is severe and potentially life-threatening.
• Prophylaxis, as recommended by the American Heart Association (AHA), for endocarditis following certain procedures in patients at high risk for endocarditis.
• Prophylaxis for major surgical procedures involving implantation of prosthetic materials or devices (e.g., cardiac and vascular procedures and total hip replacement) at institutions that have a high rate of infections caused by MRSA or methicillin-resistant S. epidermidis. A single dose of vancomycin administered immediately before surgery is sufficient unless the procedure lasts greater than six hours, in which case the dose should be repeated. Prophylaxis should be discontinued after a maximum of two doses.
which is equivalent to 3 pounds 4 ounces.)
- Routine prophylaxis for patients on continuous ambulatory peritoneal dialysis or hemodialysis.
- Treatment (chosen for dosing convenience) of infections caused by beta-lactam-sensitive gram-positive microbes in patients who have renal failure.
- Use of vancomycin solution for topical application or irrigation.

4. Enhancing compliance with recommendations:
- Although several techniques may be useful, further study is required to determine the most effective methods for influencing the prescribing practices of physicians.
- Key parameters of vancomycin use can be monitored through the hospital’s quality assurance/improvement process or as part of the drug-utilization review of the pharmacy and therapeutics committee and the medical staff.

Preventing and controlling VRE transmission in all hospitals requires the following recommendations:

5. Initiate the following isolation precautions to prevent patient-to-patient transmission of VRE:
- Place VRE-infected or colonized patients in private rooms or in the same room as other patients who have VRE.
- Wear gloves (clean, nonsterile gloves are adequate) when entering the room of a VRE-infected or colonized patient because VRE can extensively contaminate such an environment. When caring for a patient, a change of gloves might be necessary after contact with material that could contain high concentrations of VRE (e.g., stool).
- Wear a gown (a clean, nonsterile gown is adequate) when entering the room of a VRE-infected or colonized patient because VRE can contaminate via glove leaks or during glove removal, and bland soap does not always completely remove VRE from the hands.
- Ensure that after glove and gown removal and hand washing that clothing and hands do not contact environmental surfaces in the patient’s room that are potentially contaminated with VRE (e.g., a doorknob or curtain).
- Treatment (chosen for dosing convenience) of infections caused by beta-lactam-sensitive gram-positive microbes in patients who have renal failure.

6. Dedicate the use of noncritical items (e.g., a stethoscope, sphygmomanometer, or rectal thermometer) to a single patient or cohort of patients infected or colonized with VRE. If such devices are to be used on other patients, adequately clean and disinfect these devices first.

7. Obtain a stool culture or rectal swab from roommates of patients newly found to be infected or colonized with VRE to determine their colonization status, and apply isolation precautions as necessary. Perform additional screening of patients on the ward at the discretion of the infection-control staff.

8. Adopt a policy for deciding when patients infected or colonized with VRE can be removed from isolation precautions. The optimal requirements remain unknown; however, because VRE colonization can persist indefinitely, stringent criteria might be appropriate, such as VRE-negative results on at least three consecutive occasions (greater than or equal to one week apart) for all cultures from multiple body sites (including stool or rectal swab, perineal area, axilla or umbilicus, and wound, Foley catheter and/or colostomy sites, if present).

9. Because patients with VRE can remain colonized for long periods after discharge from the hospital, establish a system for highlighting the records of infected or colonized patients so they can be promptly identified and placed on isolation precautions upon readmission to the hospital. This information should be computerized so that placement of colonized patients on isolation precautions will not be delayed because the patients’ medical records are unavailable.

10. Local and state health departments should be consulted when developing a plan regarding the discharge of VRE-infected or colonized patients to nursing homes, other hospitals, or home-health care. This plan should be part of a larger strategy for handling patients who have resolving infections and patients colonized with antimicrobial-resistant microorganisms [33].

2. Staphylococcus aureus

Staphylococcus aureus has been prevalent for over a hundred years [24]. Staphylococcus normally resides on the skin and mucous membranes, including the linings of the respiratory, intestinal, and genitourinary tracts. Healthy individuals with intact skin are able to prevent infection caused by staphylococci; however any break in skin integrity may lead to staphylococcal infection. Approximately 25 to 30 percent of the population is colonized with staphylococcus aureus, especially in the nose; however they do not have an infection. Staphylococcus aureus bacteria are one of the most common causes of skin infections in the United States.

Once penicillin was discovered, many patients infected by staphylococcus aureus were prescribed penicillin and responded very well. Physicians were so impressed by the success that penicillins were being prescribed all the time, and unfortunately led to the resistance in the late 1940s. Methicillin, a form of penicillin, was introduced to counteract the penicillin resistant to staphylococcus aureus. In 1961, Methicillin developed resistance to staphylococcus aureus, leading to the birth of MRSA.

The danger with MRSA is the bacterium is resistant to the entire class of penicillins, including the beta-lactamases. In 2002, there were outbreaks of vancomycin-resistant staphylococcus aureus (VRSE) in the U.S., presenting physicians with a serious problem. According to the National Institute of Allergy and Infectious Diseases, there have been few additional cases, all occurring in Michigan and reported to the CDC [29].

MRSA is prevalent within the community (CA) and hospitals (HA). According to the Association for Professionals in Infection Control (APIC), the risk of MRSA is 46.3 per 1,000 inpatients in the U.S., which includes infection or colonization. In 2007, the Journal of the American Medical Association estimated that 94,360 patients in the U.S. developed an invasive infection due to an antibiotic-resistant staphylococcus (MRSA) in 2005 and nearly one of every five, or 18,650, died [7]. The alarming statistics are approximately eight to 11 times higher than previous estimates [2].

- Community-acquired MRSA has been around since the 1990s. The media has publicized CA-MRSA over the past few years, since so many healthy people have been infected, such as high-school athletes and young children. It just reiterates that MRSA can affect anybody, as the CDC implies “even the strong.” Transmission of CA-MRSA is elusive as it may occur in crowded...
settings, close skin-skin contact, areas where personal contact may be prevalent (razors, towels, sporting equipment) and with personal hygiene. The CDC has noted that CA-MRSA is increased among athletes, military recruits, children, Pacific Islanders, Alaskan Natives, Native Americans, men who have sex with men, and prisoners.

- **Hospital-acquired MRSA** has been prevalent for decades, especially in elderly patients with weakened immune systems and/or who have recently had surgery or implanted surgical medical devices. Other risk factors include patients with urinary tract infections, pneumonia caused by staphylococcus aureus or kidney failure. Patients admitted to the hospital typically are prescribed intravenous antibiotics, approximately 25 to 40 percent, increasing their chance of a resistant germ originating within their own bodies. According to the CDC, in 2005, 1 percent of all hospital in-patient stays, or 292,045 patients a year, were associated with staphylococcus aureus based upon a study of 14 million discharges between 2000 and 2001 [7]. Patients infected with staphylococcus aureus had about three times the length of hospitalization, three times the cost and five times the risk of in-hospital death. Approximately, 14,000 patients died from staphylococcus aureus.

Another growing population that may be community- or hospital-acquired MRSA includes our soldiers returning from Afghanistan and Iraq. Unfortunately, many soldiers have been burned by explosions, bombings and/or gunshot wounds, leading to severe infections, including MRSA. Many also have also been affected by drug-resistant MRSA due to the complexity of their injuries and antimicrobials administered overseas.

According to the CDC, nurses and health care providers can differentiate community-acquired MRSA and hospital-acquired MRSA by adhering to the following criteria to confirm community-acquired MRSA [8]:

- Diagnosis of MRSA was made in the outpatient setting or by a culture positive for MRSA within 48 hours after admission to the hospital.
- No medical history of MRSA infection or colonization.
- No medical history in the past year of:
  - Hospitalization.
  - Admission to a nursing home, skilled nursing facility or hospice.
  - Dialysis.
  - Surgery.
- No permanent indwelling catheters or medical devices that pass through the skin into the body.

MRSA is diagnosed based upon the culture results obtained from the infection site and sent to the microbiology laboratory. Depending upon the potential site, the CDC recommends the cultures be taken in the following way [8]:

- **Skin infection**: Obtained by a small biopsy or the drainage cultured from the infected site.
- **Pneumonia**: Obtained by a sputum culture (expectorated purulent sputum, respiratory lavage or bronchoscopy).
- **Bloodstream infection**: Obtained by blood cultures using aseptic techniques.
- **Urinary infection**: Obtained by collecting urine cultures using aseptic techniques.

Some states require mandatory reporting of all positive MRSA outbreaks; verify the recommendations of the local health department in the jurisdiction of employment.

Once S. aureus and/or MRSA are speculated and/or identified, immediate treatment is required. Since 2006, the CDC recommends the following treatment protocol [16]:

- **Clindamycin** is FDA-approved for the treatment of S. aureus.
- **Tetracyclines** (e.g., tetracycline, doxycycline, and minocycline) are FDA approved for the treatment of S. aureus, but not specifically to MRSA.
- **TMP-SMX (Bactrim)** is not FDA-approved for the treatment of any form of staphylococcal infection. However, the medical literature contains several case reports of the successful use of TMP-SMX in the treatment of S. aureus infections, including MRSA. In a case-series of CA-MRSA skin infections in Los Angeles, prompt resolution of symptoms was achieved in six (50 percent) of 12 patients initially treated with double-strength TMP/SMX alone (in addition to incision and drainage of abscesses) and in all of six patients treated initially with a combination of TMP/SMX and rifampin.
- **Rifampin** (should not be used as a single agent): Resistant strains of S. aureus are observed rapidly when rifampin is used as a single agent. Rifampin has been used in combination with other antimicrobial agents that are active against S. aureus to treat staphylococcal infections.
- **Linezolid** (Consultation with an infectious disease specialist suggested): Linezolid is FDA-approved for the treatment of complicated skin infections and hospital-acquired pneumonia due to MRSA in adults.

If it is CA-MRSA and/or speculated to be resistant to anti-microbial therapy, the CDC recommends treating the infection with a fluoroquinolone or a macrolide.

In addition to prescribing appropriate antimicrobial therapy, the CDC recommends enforcing standard infection control precautions for all patients in outpatient and inpatient health-care settings. The process includes performing hand hygiene (hand washing or using alcohol hand gel) after touching body fluids or contaminated items (whether or not gloves are worn), between patients, and when moving from a contaminated body site to a clean site on the same patient; wearing gloves when managing wounds; and wearing gowns and eye protection as appropriate for procedures that are likely to generate splashes or sprays of body fluids. In addition, contact precautions, which involve greater spatial separation of patients (through placing infected patients in private rooms or cohorting patients with similar infection status), use of gown and gloves for all contact with the patient or their environment, and use of dedicated noncritical patient-care equipment, have been recommended for empiric use in patients with abscesses or draining wounds in which wound drainage cannot be contained.

According to data per the CDC (2008), there has been a 60 percent reduction in the rate of MRSA infections since the implementation of a series of infection control procedures. In addition, new national data from CDC’s National Healthcare Safety Network (NHSN), a surveillance tool for hospitals and state health departments that measures health care-associated infections (HAIs), show that there has been a significant drop in the incidence of both MRSA and methicillin-susceptible S. aureus (MSSA) central line-associated blood stream infections among intensive care unit patients in U.S. hospitals over the last five years. The incidence of MRSA bloodstream infections per 1,000 central line days (i.e., a measurement of infection burden derived from the number of patients who have a central line, or catheter, whether infected or not) decreased by 49.6 percent, while the incidence of central line-associated MSSA infections decreased even more substantially, by 70.1 percent. Data on invasive MRSA infections from the Active Bacterial Core Surveillance system for 2005-2006 also show a decrease in hospital-onset and health care-associated MRSA infections, confirming this downward trend. Thus, it appears that these practical efforts to reduce the transmission of MRSA in hospitals are working, thereby further reducing the need for antibiotic usage [34].

3. **ESBLs – Extended-spectrum beta-lactamas**

ESBLs are enzymes that mediate resistance to extended-spectrum (third-generation) cephalosporins (e.g., cefazidime, cefotaxime, and ceftriaxone) and monobactams (e.g., aztreonam), but do not affect cephamycins (e.g., cefoxitin and cefotetan) or carbapenems (e.g., meropenem or imipenem) [12]. It is important to recognize the presence of ESBL-producing organisms in certain clinical infections (klebsiella pneumonias, K. oxytoca, or Escherichia coli) to avoid treatment failure. According to the CDC, the
choice of the antimicrobial agent to test is critical:
• Actively hydrolyze ceftazidime, resulting in ceftazidime minimum inhibitory concentrations (MICs) of 256 µg/ml, but have poor activity on cefotaxime, producing MICs of only 4 µg/ml. If an ESBL is detected, all penicillins, cephalosporins, and aztreonam should be reported as resistant, even if in-vitro test results indicate susceptibility.

According to the National Committee for Clinical Laboratory Standards (NCCLS), each isolate should be considered a potential ESBL-producer if the test results are as follows:

<table>
<thead>
<tr>
<th>Disk diffusion</th>
<th>MICs</th>
</tr>
</thead>
<tbody>
<tr>
<td>cefpodoxime &lt; 22 mm.</td>
<td>cefpodoxime &gt; 2 µg/ml.</td>
</tr>
<tr>
<td>ceftazidime &lt; 22 mm.</td>
<td>ceftazidime &gt; 2 µg/ml.</td>
</tr>
<tr>
<td>aztreonam &lt; 27 mm.</td>
<td>aztreonam &gt; 2 µg/ml.</td>
</tr>
<tr>
<td>cefotaxime &lt; 27 mm.</td>
<td>cefotaxime &gt; 2 µg/ml.</td>
</tr>
<tr>
<td>ceftriaxone &lt; 25 mm.</td>
<td>ceftriaxone &gt; 2 µg/ml.</td>
</tr>
</tbody>
</table>

The treatment of choice is typically a fourth-generation cephalosporin and/or an antimicrobial specific to the organism based upon the microbiological analysis. Therefore, it is customized in each patient.

**Respiratory antimicrobial drug resistance**

Pneumonia is the second-most common nosocomial infection in the U.S. and is associated with substantial morbidity and mortality. The majority of patients who have nosocomial pneumonia include the following [10]:

- Infants.
- Young children.
- Persons greater than 65 years of age.
- Persons who have severe underlying disease, immunosuppression, depressed sensorium, cardiopulmonary disease.
- Persons who have had thoracoabdominal surgery.

Another potential risk factor includes patients receiving mechanically assisted ventilation. Although they do not represent the majority of patients who have nosocomial pneumonia, they are the highest risk for acquiring the infection. Most bacterial nosocomial pneumonias occur by aspiration of bacteria colonizing the oropharynx or upper gastrointestinal tract of the patient. Since intubation and mechanical ventilation alter first-line patient defenses, they greatly increase the risk for nosocomial bacterial pneumonia.

Traditional preventive measures for nosocomial pneumonia include decreasing aspiration by the patient, preventing cross-contamination or colonization via hands of personnel, appropriate disinfection or sterilization of respiratory-therapy devices, use of available vaccines to protect against particular infections, and education of hospital staff and patients. New measures being investigated involve reducing oropharyngeal and gastric colonization by pathogenic microorganisms. Several large studies have examined the potential risk factors for nosocomial-acquired bacterial pneumonia related to mechanically assisted ventilation and endotracheal intubation [10]:

- In many studies, the administration of antacids and H-2 blockers for prevention of stress bleeding in critically ill, postoperative, and/or mechanically ventilated patients has been associated with gastric bacterial overgrowth. Sucralfate, a cytoprotective agent that has little effect on gastric power of Hydrogen (pH) and may have bactericidal properties of its own, has been suggested as a potential substitute for antacids and H-2 blockers. In most randomized trials, intensive care unit (ICU) patients receiving mechanically assisted ventilation who were treated either with only antacids or with antacids and H-2 blockers had increased gastric pH, high bacteria counts in the gastric fluid and increased risk for pneumonia in comparison with patients treated with sucralfate.
- Patients receiving continuous, mechanically assisted ventilation have six to 21 times the risk for acquiring nosocomial pneumonia compared with patients not receiving ventilatory support. One study indicated that the risk for developing ventilator-associated pneumonia increased by 1 percent per day. The rationale for the increased risk was attributed partially to carriage of oropharyngeal organisms upon passage of the endotracheal tube into the trachea during intubation, as well as to depressed host defenses secondary to the patient’s severe underlying illness. In addition, bacteria can aggregate on the surface of the tube over time and form a glycocalyx (i.e., a biofilm) that protects the bacteria from the action of antimicrobial agents or host defenses. Some researchers believe that these bacterial aggregates can become dislodged by ventilation flow, tube manipulation, or suctioning and subsequently embolize into the lower respiratory tract and cause focal pneumonia. Removing tracheal secretions by gentle suctioning and using aseptic techniques to reduce cross-contamination to patients from contaminated respiratory therapy equipment or contaminated or colonized hands of health care workers (HCWs) have been used traditionally to help prevent pneumonia in patients receiving mechanically assisted ventilation.
- Another risk for pneumonia also is increased by the direct access of bacteria to the lower respiratory tract, which often occurs because of leakage around the endotracheal cuff, thus enabling pooled secretions above the cuff to enter the trachea. In one study, the occurrence of nosocomial pneumonia was delayed and decreased in intubated patients whose endotracheal tubes had a separate dorsal lumen that allowed drainage (i.e., by suctioning) of secretions in the space above the endotracheal tube cuff and below the glottis. However, additional studies are needed to determine the cost-benefit ratio of using this device.
- Another factor to contemplate are the devices we use in the hospital that may be potential reservoirs and vehicles for harboring infectious microbes, such as:
  - **Nebulizers.** They can allow the growth of hydrophilic bacteria that subsequently can be aerosolized during use of the device. Gram-negative bacilli (e.g., pseudomonas sp., xanthomonas sp., flavobacterium sp., legionella sp., and nontuberculous mycobacteria) can multiply to substantial concentrations in nebulizer fluid and increase the risk for pneumonia in patients using such devices.
  - **Diagnostic examinations** (bronchoscopes and spirometers).
  - **Administration of anesthesia.** The internal components of anesthesia machines, which include the gas sources and outlets, gas valves, pressure regulators, flow meters and vaporizers, are not considered an important source of bacterial contamination of inhaled gases. Thus, routine sterilization or high-level disinfection of the internal machinery is unnecessary.
  - **Mechanical ventilators.** The potential risk for pneumonia in patients using mechanical ventilators that have heated bubble-through humidifiers stems primarily from the condensate that forms in the inspiratory-phase tubing of the ventilator circuit as a result of the difference in the temperatures of the inspiratory-phase gas and ambient air; condensate formation increases if the tubing is unheated. The tubing and condensate can rapidly become contaminated, usually with bacteria that originate in the patient’s oropharynx. In one study, 33 percent of inspiratory circuits were colonized with bacteria via this route within two hours, and 80 percent within 24 hours, after initiation of mechanical ventilation. Spillage of the contaminated condensate into the patient’s tracheobronchial tree, as can occur during procedures in which the tubing is moved (e.g., for suctioning, adjusting the ventilator setting, or feeding or caring for the patient), may increase the risk for pneumonia in the patient. Thus, in many hospitals, health care professionals are trained to prevent such spillage and to drain the fluid periodically.
  - **Breathing circuits, humidifiers, and heat-moisture exchangers.**
The Environmental Protection Agency (EPA) and FDA recommend sterilizing/disinfecting devices by steam autoclave, ethylene oxide or subjecting it to high-level disinfection by pasteurization at a temperature of 75 degrees Celsius (C) for 30 minutes or by use of liquid chemical disinfectants.

There are many variables that may exacerbate and/or increase the vulnerable patient to nosocomial pneumonia while they are hospitalized. It is our duty as nurses to be conscious of each potential risk and to do our part in preventing nosocomial infections from occurring. Failure to prevent will only further exacerbate our antimicrobial resistance problem.

1. Penicillin resistant streptococcus pneumoniae (PRSP or pneumococcus)

Although streptococcus pneumonia (S. pneumonia) is prevalent in general, there is limited recent data available on penicillin-resistant S. pneumonia. The majority of the literature is based upon data from the 1990s to the early turn of the century. It is speculated that the majority of health care professionals are aware of the risk of drug-resistant S. pneumonia with penicillins, perhaps abating the notion that they over-write prescriptions for high-risk patients. Researchers have discovered that the resistance of pneumococcus to penicillin and cephalosporins is through alteration in the cell wall penicillin-binding proteins (PBPs). By altering these sites (where the antibiotics bind), the antibiotic affinity is decreased, subsequently decreasing the susceptibilities. This type of resistance can be overcome if the serum or site levels of the antibiotic exceed the minimum inhibitory concentration (MIC) of the organism for 40-50 percent of the dosing interval [26].

According to the CDC, for more than 25 years, isolates of S. pneumoniae were initially susceptible to penicillin. However, since 1967, there has been a gradual increase in penicillin-resistant S. pneumoniae, on average a 25 percent risk. In certain areas of the U.S., PRSP strains become widespread during the 1990s; Alaska had the highest reported prevalence at 26 percent. According to the CDC and New England Journal of Medicine (NEJM), a study conducted in Atlanta found a 25 percent prevalence of PRSP in the community. In 2004, 21.4 percent of all isolates obtained showed intermediate or resistant susceptibility patterns to penicillin (up from 20 percent in 2003). Outside the United States, an even higher (33 to 58 percent) prevalence of PRSP has been reported [26].

Pneumococcal infections are a leading cause of morbidity and mortality in the U.S.; S. pneumoniae causes more than 500,000 cases of pneumonia, 55,000 cases of bacteremia and 6,000 cases of meningitis annually, which result in 40,000 deaths. The death rate from pneumococcal bacteremia approaches 30 percent, despite the use of appropriate antimicrobial therapy. Reports of refractory illness due to resistant pneumococci demonstrate the clinical relevance of these strains. Identifying risk factors in the development of PRSP infections is important for both the prevention and treatment of these infections [26].

Streptococcus pneumoniae, or pneumococcus, is a bacterium that causes many different kinds of infections in people, ranging from ear infections and sinus infections to pneumonia, meningitis and sepsis. Up to 30 percent of the strains of the bacterium are at least partially resistant to antibiotics in the penicillin family. Although the names (and bacterial genuses) are similar, S. pneumoniae is quite different from group A streptococcus (the bacteria that causes strep throat and rheumatic fever). S. pneumoniae infections are on average much more serious; pneumococcus is the most common cause of bacterial meningitis in the U.S., and about 8 percent of children with pneumococcal meningitis die of the infection. While one of four children will survive, they will suffer from neurologic damage including hearing loss after “getting over” the infection. Pneumococci are the most common cause of ear infections and sinus infections, as well as the most common bacteria found in the blood of children under 2 years old with fevers, many of whom have no obvious site of infection. Many people have pneumococci in their noses and throats but have no symptoms. The bacteria are transmitted from one person to another, usually by droplets.

Like viral upper respiratory infections, pneumococcal infections are more common in winter. Infection can begin as little as one to three days after exposure. Studies of ear fluid cultures suggest that anywhere from 20 to 40 percent of ear infections are caused by pneumococcus. The signs of pneumococcal meningitis and sepsis can be the same as those of meningococcal meningitis. Often, however, pneumococcal infection can appear first as a high fever with a very high white blood cell count (where almost all of the white cells are neutrophils or bacteria-fighting cells) and no obvious site of infection.

There are also some people who are more susceptible to pneumococcal infections than others. The risk factors include:

- Lack of a spleen due to injury or disease.
- Sickle-cell anemia because repeated sickle-cell crises cause damage to the red blood cells and destruction to the spleen tissue. Most doctors assume that the spleen of patients with sickle-cell disease will not be working by time they are in their 20s, at the latest. So sickle-cell patients are usually vaccinated against bacteria, such as pneumococcus and meningococcal, which the spleens of healthy people help kill.
- Immunodeficiencies, such as AIDS, decreased production of white blood cells and/or chronic illnesses.

Although S. pneumonia is prevalent in various bacterial infections (upper, lower respiratory infections, meningitis, etc.) and a leading cause of death, it is highly resistant to not only penicillins, but also cephalosporins, sulfonylamides, trimethoprim-sulfamethoxazole (through amino acid changes), macrolides (through methylation or via an efflux pump), quinolones (through decreased permeability, efflux pumps, and alteration of enzymes), and chloramphenicol (through inactivating enzymes) [26]:

- Resistance rates of pneumococcal isolates in the United States to trimethoprim-sulfamethoxazole, doxycycline and the macrolides are relatively high. Some isolates (less than 10 percent in the United States) that are resistant to macrolides are also resistant to clindamycin.
- No vancomycin-resistant pneumococcal isolates have been reported to date. The phenomenon of tolerance (survival but not growth in the presence of a given antibiotic) has been observed, but its clinical relevance is unknown. Fortunately, in the U.S., most pneumococcal isolates remain susceptible to fluoroquinolones, but in certain countries and specific populations in whom the use of fluoroquinolones is more prevalent (e.g., nursing homes), an increase in resistance has been seen. Although there is a 25 percent risk of penicillin drug resistance noted in streptococcus pneumonia, penicillin is still the mainstay drug of choice because 75 percent of the time it will work. Therefore, each patient is customized based upon his or her history and other risk factors. Depending upon the site and patient, the following guidelines are recommended [26]:

- **Otitis media/sinusitis** – Amoxicillin 80-90 mg/kg/day. If no improvement in 48-72 hours, re-evaluate the patient and switch to amoxicillin-clavulanate or a second- or third-generation oral cephalosporin, although highly resistant pneumococci may require treatment with parenteral ceftriaxone in order to achieve adequate serum levels of antibiotics.

- **Pneumonia**
  - Children – Amoxicillin or amoxicillin-clavulanate at dosages used for the treatment of otitis media is recommended. In school-aged children (older than 5 years), the addition of a macrolide for coverage of atypical organisms is advised.
  - In 2000, a new vaccine (prevnar) became available for children in the United States, and CDC began tracking the vaccine’s
impact on resistant pneumococcal infections. Since the vaccine was introduced into the routine childhood immunization program in the United States, penicillin-resistant pneumococcal infections declined by 35 percent. Not only has the vaccine been shown to prevent antibiotic-resistant infections, it has been shown to reduce the need for prescribing antibiotics for children with pneumococcal infection in the first place. CDC data also show that adults are getting fewer resistant pneumococcal infections because the vaccine is preventing spread of pneumococci from infected children to adult populations. Since 2001, it is estimated from CDC data that 170,000 severe pneumococcal infections and 10,000 deaths have been prevented by vaccine use. According to data published in the Archives of Pediatric Adolescent Medicine, the vaccine is highly cost-effective, saving an estimated $310 million in direct medical costs each year [50].

- Adults – Macrolide (or doxycycline) for outpatient therapy of previously healthy adults with no specific risk factors for resistant S. pneumoniae infection.

- Meningitis – The recommended initial therapy of presumed bacterial meningitis in children is with vancomycin and ceftriaxone or cefotaxime at increased doses. If S. pneumoniae is isolated from the blood or cerebral spinal fluid (CSF) and is susceptible to penicillin or ceftriaxone/cefotaxime, vancomycin should be stopped and therapy completed with penicillin G, ceftriaxone or cefotaxime as indicated. If the isolate is resistant to penicillin and cephalosporins, the regimen started initially should be continued through the completion of therapy, usually 10 days in uncomplicated cases.

Most pneumococcal isolates in the United States remain susceptible to certain fluoroquinolones, including moxifloxacin (most effective), levofloxacin, gatifloxacin and gemifloxacin. Ciprofloxacin and ofloxacin have limited activity against pneumococcal infections. Fluoroquinolones provide broad-spectrum treatment for CAP and achieve excellent serum drug levels and tissue penetration. Specific populations in whom the use of fluoroquinolones is traditionally increased (e.g., residents of nursing homes) have shown increased levels of pneumococcal resistance to fluoroquinolones, and their empiric use in respiratory infections should also be tempered by the concern for rapid development of resistance to this class by many organisms [26].

2. Multiresistant pseudomonas aeruginosa

Pseudomonas aeruginosa is noted for its environmental versatility, ability to cause disease in particularly susceptible individuals, and its resistance to antibiotics. The pathogens are widespread in nature, inhabiting soil, water, plants and animals, including humans. Pseudomonas aeruginosa has become an important cause of infection, especially in patients with compromised host defense mechanisms. It is the most common pathogen isolated from patients who have been hospitalized longer than one week, and is a frequent cause of nosocomial infections such as pneumonia, urinary tract infections (UTIs) and bacteremia. Pseudomonal infections are complicated and can be life-threatening.

The bacterium is capable of utilizing a wide range of organic compounds as food sources, thus giving it an exceptional ability to colonize ecological niches where nutrients are limited. P. aeruginosa can produce a number of toxic proteins that not only cause extensive tissue damage, but also interfere with the human immune system's defense mechanisms. These proteins range from potent toxins that enter and kill host cells at or near the site of colonization to degradative enzymes that permanently disrupt the cell membranes and connective tissues in various organs.

P. aeruginosa is an opportunistic pathogen. It rarely causes disease in healthy persons. In most cases of infection, the integrity of a physical barrier to infection (i.e., skin, mucous membrane) is lost or an underlying immune deficiency (i.e., neutropenia, immunosuppression) is present. Pseudomonas is both invasive and toxigenic. The three stages include:

1. Bacterial attachment and colonization.
2. Local infection.
3. bloodstream dissemination and systemic disease. The importance of colonization and adherence is most evident when studied in the context of respiratory tract infection in patients with cystic fibrosis and in those that complicate mechanical ventilation. Production of extracellular proteases adds to the organism’s virulence by assisting in bacterial adherence and invasion.

According to Centers for Disease Control and Prevention data collected from 1990-1996, P. aeruginosa was the second-most common cause of nosocomial pneumonia (17 percent of the isolates), the third-most common cause of UTI (11 percent), the fourth-most common cause of surgical site infections (8 percent), the seventh-most common isolated pathogen from the bloodstream (3 percent), and the fifth-most common isolate overall (9 percent) – obtained from all sites. Internationally, P. aeruginosa is common in patients with diabetes who are immunocompromised. Others at risk for P. aeruginosa include [1]:

- Cancer and burn patients, who also commonly suffer serious infections by this organism, as do certain other individuals with immune system deficiencies. Unlike many environmental bacteria, P. aeruginosa has a remarkable capacity to cause disease in susceptible hosts. It has the ability to adapt to and thrive in many ecological niches, from water and soil to plant and animal tissues.
- Elderly patients with vertebral osteomyelitis resulting from a pseudomonal infection.
- Young people who experiment with intravenous (IV) drug abuse.

All infections caused by P. aeruginosa are treatable and potentially curable. Acute fulminating infections, such as bacteremia pneumonia, sepsis, burn wound infections and meningitis, however, are associated with extremely high mortality. The clinical evaluation of the pneumococcal infections depends on the age and health of the patient, site and severity of the infection and the adequacy of the treatment. Penicillin was uniformly effective against pneumococci until three decades ago, when the first reports of clinical resistance were published. Since then, there has been a rapid increase in the level and rates of resistance to penicillin, which parallels to beta lactamase and antimicrobials.

3. Tuberculosis (TB)

Tuberculosis (TB) is a disease that is spread from person to person through the air, and it is particularly dangerous for people infected with HIV. Worldwide, TB is the leading cause of death among people infected with HIV. According to the CDC, there is an estimated 10 million to 15 million Americans infected with the TB bacteria, with the potential to develop active TB disease in the future. About 10 percent of these infected individuals will develop TB at some point in their lives.

The risk factors for developing TB include [35, 40]:

- Living in close proximity (i.e. incarcerated, group homes).
- Poverty (poor living conditions).
- Exposure to another with TB.
- HIV or acquired immunodeficiency diseases (AIDS). The risk of developing TB disease is much greater for those infected with HIV and living with AIDS. Because HIV infection so severely weakens the immune system, people dually infected with HIV and TB have a 100 times greater risk of developing active TB disease and becoming infectious compared to people not infected with HIV. CDC estimates that 10 to 15 percent of all TB cases and nearly.
Another problem with TB is the enormous resistance that has developed, called multidrug-resistant tuberculosis (MDR-TB). It is a form of tuberculosis that is resistant to two or more of the primary drugs used for the treatment of tuberculosis. Resistance to one or several forms of treatment occurs when the bacteria develop the ability to withstand antibiotic attack and relay that ability to their progeny. Since that entire strain of bacteria inherits this capacity to resist the effects of the various treatments, resistance can spread from one person to another. On an individual basis, however, inadequate treatment or improper use of anti-tuberculosis medications remains an important cause of drug-resistant tuberculosis [40]:

- In 2003, the CDC reported that 7.7 percent of tuberculosis cases in the U.S. were resistant to isoniazid, the first-line drug used to treat TB.
- The CDC also reported that 1.3 percent of tuberculosis cases in the U.S. were resistant to both isoniazid and rifampin. Rifampin is the drug most commonly used with isoniazid.
- The World Health Organization estimates that up to 50 million persons worldwide may be infected with drug-resistant strains of TB. Also, 300,000 new cases of MDR-TB are diagnosed around the world each year, and 79 percent of the MDR-TB cases now show resistance to three or more drugs.
- A strain of MDR-TB originally develops when a case of drug-susceptible tuberculosis is improperly or incompletely treated. This occurs when a physician does not prescribe proper treatment regimens or when a patient is unable to adhere to therapy. Improper treatment allows individual TB bacilli that have natural resistance to a drug to multiply. Eventually the majority of bacilli in the body are resistant.
- Once a strain of MDR-TB develops, it can be transmitted to others just like a normal drug-susceptible strain.
- Airborne transmission has been the cause of several well-publicized cases of nosocomial (hospital-based) outbreaks of MDR-TB in New York City and Florida. These outbreaks were responsible for the deaths of several patients and health care workers, a majority of whom were co-infected with HIV.
- MDR-TB has been a particular concern among HIV-infected persons. Some of the factors that have contributed to the number of cases of MDR-TB, both in general and among HIV-infected individuals, are:
  - Delayed diagnosis and delayed determination of drug susceptibility, which may take several weeks.
  - Susceptibility of immunosuppressed individuals for not only acquiring MDR-TB but also for rapid disease progression, which may result in rapid transmission of the disease to other immunosuppressed patients.
  - Inadequate respiratory isolation procedures and other environmental safety conditions, especially in confined areas such as prisons.
  - Noncompliance or intermittent compliance with anti-tuberculosis drug therapy.
  - MDR-TB is more difficult to treat than drug-susceptible strains of TB. The success of treatment depends upon how quickly a case of TB is identified as drug resistant and whether an effective drug therapy is available. The second-line drugs used in cases of MDR-TB are often less effective and more likely to cause side effects.
  - FDA has approved rifater, a medication that combines the three main drugs (isoniazid, rifampin and pyrazinamide) used to treat tuberculosis into one pill. This reduces the number of pills a patient has to take each day and makes it impossible for the patient to take only one of the three medications, a common path to the development of MDR-TB.
  - In June 1998, the FDA approved the first new drug for pulmonary tuberculosis in 25 years. The drug, rifapentine (Prifin), has been approved for use with other drugs to fight TB. One potential advantage of rifapentine is that it can be taken less often in the final four months of treatment – once a week compared with twice a week for the standard regimen.

Overall, the CDC’s message is that resistance can be slowed if patients take medications correctly.

Sexually transmitted infections (N. gonorrhoeae)

1. Neisseria gonorrhoeae

Neisseria gonorrhoeae (N. gonorrhoea) is the second-most common notifiable disease in the U.S with 339,593 cases documented in 2005[40]. Failure to control N. gonorrhoea can lead to cervicitis, urethritis, proctitis and pelvic inflammatory disease (PID) with long-term sequels including infertility, ectopic pregnancy and chronic pelvic pain – which all increase the risk of HIV.

According to the Annals of Internal Medicine (1998), N. gonorrhoea has developed resistance over the past 60 years to multiple antimicrobial classes [42]. In order to eradicate the infection and decrease transmission and complications to the patient, it is imperative that effective treatment be initiated immediately. Initially, in 1936, sulfanilamides were used for treatment, but were short-lived due to the emergence of resistance in the 1940s. Over the next 40 years, penicillin was the drug of choice; however in the 1980s, penicillin developed resistance due to the spread of plasmid-containing genes. Therefore, ceftriaxone (a cephalosporin) was recommended for uncomplicated gonococcal infections. By 1989, penicillin was no longer used because resistance was widespread; therefore ceftriaxone became the recommended treatment, with ciprofloxacin as an alternative treatment option. In the early 1990s, quinolone-resistant N. gonorrhea emerged in the U.S., then spread worldwide by the turn of the century. Therefore, the CDC no longer recommends fluoroquinolones for the treatment of N. gonorrhoea.

Due to the epidemiology and significant antimicrobial resistance in the treatment of N. gonorrhoea over the years, the CDC and WHO have recommended a change in the treatment when the prevalence of antimicrobial resistance exceeds 5 percent for a specific antibiotic [21]. The antimicrobial of choice requires a cure rate over 95 percent. In 2006, the CDC recommended cephalosporins as the primary treatment of choice [15, 42];
- Ceftriaxone injection 125 milligrams (mg) intramuscular (IM) for uncomplicated urogenital and anorectal infection or cefixime 400 mg as a single dose.
- If a patient has a cephalosporin allergy:
  - Azithromycin 2 grams orally.
  - Spectinomycin 2 grams in a single dose IM initiated in 2008.

History has proven that resistance eventually proliferates, especially in N. gonorrhoea. To prevent and/or to prepare for the possible emergence of cephalosporin resistance, research studies are being implemented. Possible future treatments may include macrolides combined with either an aminoglycoside or the drug rifampin. In the interim, nurses can help the effort to control and prevent N. gonorrhoea infection through proper education of patients and screening per the following recommendations [21, 42]:
- Primary screening. According to the U.S. Preventive Task Force (USPTF) and the American Academy of Family Physicians (AAFP), all sexually active men and women and any woman who is pregnant should be screened. The highest prevalence of N. gonorrhoea occurs in sexually active individuals under the age of 25; people with prior gonorrheal infection or other sexually transmitted infections; those with new partners; and people who use drugs or are inconsistent about condom use.
- Secondary screening. All partners should be screened to prevent repeated infections and/or complications.
**Clostridium difficile** (C. difficile) infections

C. difficile disease can range from mild to debilitating diarrhea to more severe, life-threatening infections. The development of C. difficile infections among patients treated with antibiotics has long been considered an unintended consequence of antibiotic use. Recognized in the 1970s as a cause of "antibiotic associated diarrhea" in the 1980s and 1990s, these anaerobic bacteria species caused increasing numbers of outbreaks of diarrheal disease in hospitals and long-term care facilities.

Recently, however, CDC and others have recognized the emergence of C. difficile disease, including more life-threatening forms of the disease, among otherwise healthy patients in the community. A number of community patients had not taken antibiotics prior to their illness. Based on data from Ohio, estimates suggest that currently there may be as many as 500,000 cases of C. difficile infection occurring annually in the United States, contributing to between 15,000 and 30,000 deaths. Some antibiotic-resistant strains of C. difficile, including those resistant to macrolides and fluoroquinolones, are emerging. These strains appear to be more virulent due to increased toxin production and the presence of a novel virulence factor called the binary toxin. Surveillance data from other public health agencies around the world show such strains are spreading globally. While this antimicrobial resistance does not directly affect therapy for the C. difficile infection, since such infections are treated with other drugs, the resistance may allow C. difficile to spread more readily among patients who have received either a macrolide or fluoroquinolone antibiotic. This broadens even further the number of people at risk for acquiring disease [34].

**Antimicrobial drug resistance and antiviral agents**

Antiviral drug resistance occurs due to a decrease in the susceptibility of the drug in a laboratory culture (a phenotype), change in the genetic makeup (genotype), and evolutionary changes over time (virus replicating over time) [11, 31]. The specific cause of antiviral drug resistance can be tested in the laboratory.

At this time, the most prevalent antiviral resistance noted in the U.S. occurs with the following:

- **Influenzae.** According to the CDC (2008), amantadine and rimantadine were NOT recommended for use in the United States during the 2008-09 influenza season because many influenza viruses are resistant to these drugs.

- **HIV.** The primary reasons HIV treatment fails is due to poor drug compliance, pharmacological factors and drug resistance, but in many cases, failure occurs with resistant virus [46]. It is estimated that some HIV patients may be prescribed up to 30 tablets a day. Due to the significant prevalence of HIV-antiviral drug resistance, the National Institute of Health (NIH) (2007) recommends the following guidelines [30]:
  - HIV drug-resistance testing is recommended for persons with HIV infection when they enter into care regardless of whether therapy will be initiated immediately. If therapy is deferred, repeat testing at the time of antiretroviral therapy initiation should be considered.
  - A genotypic assay is generally preferred for anti-retroviral-naive persons.
  - HIV drug-resistance testing should be performed to assist in selecting active drugs when changing anti-retroviral regimens in cases of virologic failure.
  - Drug-resistance testing should also be performed when managing suboptimal viral load reduction.
  - Drug-resistance testing in the setting of virologic failure should be performed while the patient is taking his/her antiretroviral drugs, or immediately (i.e., within four weeks) after discontinuing therapy.
  - Genotypic-resistance testing is recommended for all pregnant women prior to initiation of therapy and for those entering pregnancy with detectable HIV RNA levels while on therapy.
  - Drug-resistance testing is not advised for persons with HIV RNA less than 1,000 copies/ per milliliter (ml) because amplification of the virus is unreliable.

- **Herpes virus.** More than 45 million people nationwide have been infected by the genital herpes virus. The typical treatment for genital herpes includes drugs such as acyclovir, valaciclovir and famciclovir, which are widely used to treat infections with herpes simplex and varicella zoster. Researchers have noted drug resistance with acyclovir (5 to 10 percent), especially among patients with other immunocompromised disorders such as AIDS and recipients of bone marrow transplants [11].

  - **Hepatitis virus.** Although there are more than five types of hepatitis, researchers say hepatitis B has superseded as the one with the most-antiviral drug resistance. Drug resistance to lamivudine and famciclovir showed staggering increases over one year, 10 to 20 percent in patients with chronic hepatitis B [11]. It is speculated that the resistance occurs much like HIV because the viral polymerase catalytic site targeted by the drug is homologous between the two viruses.

**The impact of agriculture on antimicrobial resistance**

According to the United States Department of Agriculture (USDA) (2001), antimicrobial drugs have been fed to livestock at low levels to treat diseases, promote growth and to increase meat availability. Livestock fed antimicrobial therapy gain more weight, thus producing more meat. Cattle fed low levels of antimicrobial therapy have fewer diseases.

- The lack of low-dose antimicrobials could contribute to increased production risks. Death losses and reduced production from diseases that had been prevented by feeding low levels of antimicrobial drugs could be costly.

Due to the ever-increasing antimicrobial resistance, the USDA and FDA are likely to re-evaluate the research and data to ensure humans are not exacerbating their risk of developing resistance to potential life-saving treatments. At this time, as implied earlier, the USDA and FDA believe there are numerous factors that contribute to overall antimicrobial drug resistance and that the overall economic stability of America is dependent upon livestock being healthy and prosperous.

**Preventing antimicrobial drug resistance**

Due to the prevalence of antimicrobial drug resistance, the CDC and various other prestigious organizations have been collaborating to work to eradicate antimicrobial resistance. The public health task force committee is co-chaired by the CDC, FDA, National Institute of Health (NIH) and Agency for Healthcare Research and Quality (AHRQ), Centers for Medicare Medicaid Services (CMS), the Health Resources and Services Administration (HRSA), Department of Agriculture (USDA), the Department of Defense (DOD), Department of Veterans Affairs (VA) and the Environmental Protection Agency (EPA) [4].

The CDC’s Campaign to Prevent Antimicrobial Resistance aims to prevent antimicrobial resistance in health care settings. The campaign centers on four main strategies: prevent infection, diagnose and treat infection, use antimicrobials through the handling of animals or ingestion of food. It is estimated that 10 percent of the overall antimicrobial resistance is attributed to livestock. Many countries in Europe have already banned the growth-promoting use of antimicrobial drugs in livestock as a precaution to prevent resistant microbes from passing to humans.

Since the late 1990s, the U.S. has initiated the following steps [23]:

- In 1999, the Center for Science in the Public Interest, representing 37 health and consumer groups, petitioned the FDA to ban the use of penicillin, tetracycline, erythromycin, tylosin, lincomycin, virginiamycin and bacitracin in livestock production.

- In November 1999, the House of Representatives introduced a bill to ban subtherapeutic feeding of the same seven antimicrobials.

However, to date, the U.S. has not banned the use of low-dose antimicrobials, primarily citing economic consequences. The 2001 USDA report lists these reasons [23] why the bans were rejected:

- Doing so would cause higher prices for meat because it would make less total meat available. Livestock fed antimicrobial therapy gain more weight, thus producing more meat. Cattle fed low levels of antimicrobial therapy have fewer diseases.

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wisedly, and prevent transmission. Within the context of these strategies, multiple 12-step programs are being developed targeting clinicians who treat specialty-specific patient populations including hospitalized adults, dialysis patients, surgical patients, hospitalized children and long-term care patients. Educational tools and materials are being developed for each patient population. The 12-step program is available customized for various kinds of patients: those who are hospitalized, undergoing dialysis or surgeries, long-term patients, and children.

The CDC’s 12-step goals for hospitalized patients [13]:

<table>
<thead>
<tr>
<th>Step 1. Vaccinate staff and patients.</th>
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<tbody>
<tr>
<td>Get the influenza vaccine.</td>
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<tr>
<td>Give influenza and pneumococcal vaccine to patients in addition to routine vaccines (e.g. hepatitis B).</td>
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<tr>
<th>Step 2. Get the catheters out.</th>
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<tr>
<td>Use catheters only when essential.</td>
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<tr>
<td>Maximize use of fistulas/grafts.</td>
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<tr>
<td>Remove catheters when they are no longer essential.</td>
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<tr>
<td>Peritoneal dialysis</td>
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<tr>
<td>Remove/replace infected catheters.</td>
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<th>Step 3. Optimize access care.</th>
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<tr>
<td>Follow established KDQI and CDC guidelines for access care.</td>
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<tr>
<td>Use proper insertion and catheter-care protocols.</td>
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<tr>
<td>Remove access device when infected.</td>
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<tr>
<td>Use the correct catheter.</td>
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<th>Step 4. Target the pathogen.</th>
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<tr>
<td>Obtain appropriate cultures.</td>
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<tr>
<td>Target empiric therapy to likely pathogens.</td>
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<tr>
<td>Target definitive therapy to known pathogens.</td>
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<tr>
<td>Optimize timing, regimen, dose, route and duration.</td>
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<th>Step 5. Access the experts.</th>
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<td>Consult the appropriate expert for complicated infections.</td>
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<th>Step 6. Use local data.</th>
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<tr>
<td>Know your local microbiogram (most common microbes and/or resistance in your area).</td>
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<tr>
<td>Get previous microbiology results when patients transfer to your facility.</td>
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<tr>
<th>Step 7. Know when to say “no” to vancomycin.</th>
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<tbody>
<tr>
<td>Follow CDC guidelines for vancomycin use.</td>
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<tr>
<td>Consider first-generation cephalosporins instead of vancomycin.</td>
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<th>Step 8. Treat infection, not contamination or colonization.</th>
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<tr>
<td>Use proper antisepsis for drawing blood cultures.</td>
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<tr>
<td>Get one peripheral vein blood culture, if possible.</td>
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<tr>
<td>Avoid culturing vascular catheter tips.</td>
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<tr>
<td>Treat bacteremia, not the catheter tip.</td>
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<td>When infection is treated.</td>
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<td>When infection is not diagnosed.</td>
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<tr>
<th>Step 10: Follow infection control precautions.</th>
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<tr>
<td>Use standard infection control precautions for dialysis centers.</td>
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<tr>
<td>Consult local infection control expert.</td>
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<th>Step 11: Practice hand hygiene.</th>
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<tr>
<td>Wash your hands or use an alcohol-based hand rub.</td>
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<td>Set an example.</td>
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<th>Step 12: Partner with your patients.</th>
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<tr>
<td>Educate on access care and infection control measures.</td>
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<tr>
<td>Re-educate regularly.</td>
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### Isolating the patient in the hospital setting

Due to the prevalence and severity of various infections and antimicrobial drug resistance nationwide, the CDC has enforced stringent guidelines to prevent the spread of microbes in the hospital setting. As nurses, it is important to understand the implications for each precaution because nurses may be the ones initiating the recommendations, then collaborating with physicians. There are two tiers of HICPAC (Healthcare Infection Control Practices Advisory Committee) isolation precautions. In the first and most important tier, are those precautions designed for the care of all patients in hospitals, regardless of their diagnosis or presumed infection status, called “standard precautions.” It is important to always adhere to the standard precautions to prevent nosocomial infections. In the second tier are precautions designed only for the care of specified patients, called “transmission-based precautions.” These additional transmission-based precautions are for patients known or suspected to be infected by epidemiologically important pathogens spread by airborne or droplet transmission or by contact with dry skin or contaminated surfaces [32].

#### 1. Standard precautions

Standard precautions synthesize the major features of universal precautions (UP; blood and body fluid precautions, designed to reduce the risk of transmission of bloodborne pathogens) and BSI (designed to reduce the risk of transmission of pathogens from moist body substances) and applies them to all patients receiving care in hospitals, regardless of their diagnosis or presumed infection status. Standard precautions apply to:

- Blood.
- All body fluids, secretions and excretions except sweat, regardless of whether they contain visible blood.
- Nonintact skin.
- Mucous membranes.

Standard precautions are designed to reduce the risk of transmission of microorganisms from both recognized and unrecognized sources of infection in hospitals. The following are recommendations for standard precautions:

- **Hand washing**
  - Wash hands after touching blood, body fluids, secretions, excretions and contaminated items, regardless of whether gloves are worn. Wash hands immediately after gloves are removed, between patient contacts, and when otherwise indicated to avoid transfer of microorganisms to other patients or environments. It may be necessary to wash hands between tasks and procedures on the same patient to prevent cross-contamination of different body sites.

- **Gloves**
  - Wear gloves (clean, nonsterile gloves are adequate) when touching blood, body fluids, secretions, excretions and contaminated items. Put on clean gloves just before touching mucous membranes and nonintact skin. Change gloves between tasks and procedures on the same patient after contact with material that may contain a high concentration of microorganisms. Remove gloves promptly after use, before touching noncontaminated items and environmental surfaces and before going to another patient, and wash hands immediately to avoid transfer of microorganisms to other patients or environments.

- **Mask, eye protection, face shield**
  - Wear a mask and eye protection or a face shield to protect mucous membranes of the eyes, nose, and mouth during procedures and patient-care activities that are likely to generate splashes or sprays of blood, body fluids, secretions and excretions.

- **Gown**
  - Wear a gown (a clean, nonsterile gown is adequate) to protect skin and to prevent soiling of clothing during procedures and patient-care activities that are likely to generate splashes or sprays of blood, body fluids, secretions or excretions. Select a gown that is appropriate for the activity and amount of fluid likely to be encountered. Remove a soiled gown as promptly as possible and wash hands to avoid transfer of microorganisms to other patients or environments.

- **Patient-care equipment**
  - Handle used patient-care equipment soiled with blood, body fluids, secretions and excretions in a manner that prevents skin and mucous membrane exposures, contamination of clothing and
transfer of microorganisms to other patients and environments. Ensure that reusable equipment is not used for the care of another patient until it has been cleaned and reprocessed appropriately. Ensure that single-use items are discarded properly.

- **Environmental control**
  - Ensure that the hospital has adequate procedures for the routine care, cleaning and disinfection of environmental surfaces, beds, bed rails, bedside equipment and other frequently touched surfaces and ensure that these procedures are being followed.

- **Linen**
  - Handle, transport and process used linen soiled with blood, body fluids, secretions and excretions in a manner that prevents skin and mucous membrane exposures and contamination of clothing, and that avoids transfer of microorganisms to other patients and environments.

- **Occupational health and blood-borne pathogens**
  - Take care to prevent injuries when using needles, scalpels and other sharp instruments or devices; when handling sharp instruments after procedures; when cleaning used instruments; and when disposing of used needles. Never recap used needles or otherwise manipulate them using both hands or use any other technique that involves directing the point of a needle toward any part of the body; rather, use either a one-handed “scoop” technique or a mechanical device designed for holding the needle sheath. Do not remove used needles from disposable syringes by hand, and do not bend, break or otherwise manipulate used needles by hand. Place used disposable syringes and needles, scalpel blades and other sharp items in appropriate puncture-resistant containers located as close as practical to the area in which the items were used, and place reusable syringes and needles in a puncture-resistant container for transport to the reprocessing area. Use mouthpieces, resuscitation bags or other ventilation devices as an alternative to mouth-to-mouth resuscitation methods in areas where the need for resuscitation is predictable.

- **Patient placement**
  - Place a patient who contaminates the environment or who does not (or cannot be expected to) assist in maintaining appropriate hygiene or environmental control in a private room. If a private room is not available, consult with infection control professionals regarding patient placement or other alternatives.

2. **Transmission-based precautions**

Transmission-based precautions are designed for patients documented or suspected to be infected with highly transmissible or epidemiologically important pathogens for which additional precautions beyond standard precautions are needed to interrupt transmission in hospitals. There are three types of transmission-based precautions: Airborne precautions, droplet precautions and contact precautions. They may be combined for diseases that have multiple routes of transmission. When used either singularly or in combination, they are to be used in addition to standard precautions.

- **Airborne precautions** are designed to reduce the risk of airborne transmission of infectious agents. Airborne transmission occurs by dissemination of either airborne droplet nuclei (small-particle residue ≤5 um or smaller in size) of evaporated droplets that may remain suspended in the air for long periods of time) or dust particles containing the infectious agent. Microorganisms carried in this manner can be dispersed widely by air currents and may become inhaled by or deposited on a susceptible host within the same room or over a longer distance from the source patient, depending on environmental factors; therefore, special air handling and ventilation are required to prevent airborne transmission. Airborne precautions apply to patients known or suspected to be infected with epidemiologically important pathogens that can be transmitted by the airborne route. In addition to the standard precautions, the following should be implemented to adhere to the airborne precautions:
  - **Patient placement**
    - Place the patient in a private room that has monitored negative air pressure in relation to the surrounding area, 6 to 12 air changes per hour, and appropriate discharge of air outdoors or monitored high-efficiency filtration of room air before the air is circulated to other areas in the hospital. Keep the room door closed and the patient in the room. When a private room is not available, place the patient in a room with a patient who has active infection with the same microorganism, unless otherwise recommended, but with no other infection. When a private room is not available and cohorting is not desirable, consultation with infection control professionals is advised before patient placement.

- **Droplet precautions** are designed to reduce the risk of droplet transmission of infectious agents. Droplet transmission involves contact of the conjunctivae or the mucous membranes of the nose or mouth of a susceptible person with large-particle droplets (larger than 5 um in size) containing microorganisms generated from a person who has a clinical disease or who is a carrier of the microorganism. Droplets are generated from the source person primarily during coughing, sneezing or talking and during the performance of certain procedures such as suctioning and bronchoscopy. Transmission via large-particle droplets requires close contact between source and recipient persons, because droplets do not remain suspended in the air and generally travel only short distances, usually 3 feet or less, through the air. Because droplets do not remain suspended in the air, special air handling and ventilation are not required to prevent droplet transmission. Droplet precautions apply to any patient known or suspected to be infected with in a room with a patient(s) who has an active infection with the same microorganism but with no other infection (cohorting). When a private room is not available and cohorting is not achievable, maintain spatial separation of at least 3 feet between the infected patient and other patients and visitors. Special air handling and ventilation are not necessary, and the door may remain open.

- **Mask**
  - In addition to standard precautions, wear a mask when working within 3 feet of the...
3. **Contact precautions** are designed to reduce the risk of transmission of epidemiologically important microorganisms by direct or indirect contact. Direct-contact transmission involves skin-to-skin contact and physical transfer of microorganisms to a susceptible host from an infected or colonized person, such as occurs when personnel turn or bathe patients or perform other patient-care activities that require physical contact. Direct-contact transmission also can occur between two patients (i.e., by hand contact), with one serving as the source of infectious microorganisms and the other as a susceptible host. Indirect-contact transmission involves contact of a susceptible host with a contaminated intermediate object, usually inanimate, in the patient’s environment. Contact precautions apply to specified patients known or suspected to be infected or colonized (presence of microorganism in or on patient but without clinical signs and symptoms of infection) with epidemiologically important microorganisms that can be transmitted by direct or indirect contact.

**Patient placement**
- Place the patient in a private room. When a private room is not available, place the patient in a room with a patient(s) who has active infection with the same microorganism but with no other infection (cohorting). When a private room is not available and cohorting is not achievable, consider the epidemiology of the microorganism and the patient population when determining patient placement. Consultation with infection control professionals is advised before patient placement.

**Gloves and hand washing**
- In addition to wearing gloves as outlined under standard precautions, wear gloves (clean, nonsterile gloves are adequate) when entering the room. During the course of providing care for a patient, change gloves after having contact with infective material that may contain high concentrations of microorganisms (fecal material and wound drainage). Remove gloves before leaving the patient’s environment and wash hands immediately with an antimicrobial agent or a waterless antiseptic agent. After glove removal and hand washing, ensure that hands do not touch potentially contaminated environmental surfaces or items in the patient’s room to avoid transfer of microorganisms to other patients or environments.

- **Gown**
  - In addition to wearing a gown as outlined under standard precautions, wear a gown (a clean, nonsterile gown is adequate) when entering the room if you anticipate that your clothing will have substantial contact with the patient, environmental surfaces, or items in the patient’s room, or if the patient is incontinent or has diarrhea, an ileostomy, a colostomy, or wound drainage not contained by a dressing. Remove the gown before leaving the patient’s environment. After gown removal, ensure that clothing does not contact potentially contaminated environmental surfaces to avoid transfer of microorganisms to other patients or environments.

- **Patient transport**
  - Limit the movement and transport of the patient from the room to essential purposes only. If the patient is transported out of the room, ensure that precautions are maintained to minimize the risk of transmission of microorganisms to other patients and contamination of environmental surfaces or equipment.

- **Patient care equipment**
  - When possible, dedicate the use of noncritical patient-care equipment to a single patient (or cohort of patients infected or colonized with the pathogen requiring precautions) to avoid sharing between patients. If use of common equipment or items is unavoidable, then adequately clean and disinfect them before use for another patient.

In many instances, the risk of nosocomial transmission of infection may be highest before a definitive diagnosis can be made and before precautions based on that diagnosis can be implemented. The routine use of standard precautions for all patients should greatly reduce this risk for conditions other than those requiring airborne, droplet or contact precautions. While it is not possible to prospectively identify all patients needing these enhanced precautions, certain clinical syndromes and conditions carry a sufficiently high risk to warrant the empiric addition of enhanced precautions while a more definitive diagnosis is pursued.

The organisms listed under the column “potential pathogens” are not intended to represent the complete or even most likely diagnoses, but rather possible etiologic agents that require additional precautions beyond standard precautions until they can be ruled out. Infection control professionals are encouraged to modify or adapt this table according to local conditions. To ensure that appropriate empiric precautions are implemented always, hospitals must have systems in place to evaluate patients routinely according to these criteria as part of their preadmission and admission care.

In addition, the CDC has clarified some common terms in regards to the various types of transmission.

- **Contact transmission**, the most important and frequent mode of transmission of nosocomial infections, is divided into two subgroups: direct-contact transmission and indirect-contact transmission.
  - **Direct-contact transmission** involves a direct body surface-to-body surface contact and physical transfer of microorganisms between a susceptible host and an infected or colonized person, such as occurs when a person turns a patient, gives a patient a bath, or performs other patient-care activities that require direct personal contact. Direct-contact transmission also can occur between two patients, with one serving as the source of the infectious microorganisms and the other as a susceptible host.
  - **Indirect-contact transmission** involves contact of a susceptible host with a contaminated intermediate object, usually inanimate, with epidemiologically important microorganisms that can be transmitted by direct or indirect contact.

- **Droplet transmission**, theoretically, is a form of contact transmission. However, the mechanism of transfer of the pathogen to the host is quite distinct from either direct- or indirect-contact transmission. Therefore, droplet transmission will be considered a separate route of transmission in this guideline. Droplets are generated from the source person primarily during coughing, sneezing and talking, and during the performance of certain procedures such as suctioning and bronchoscopy. Transmission occurs when droplets containing microorganisms generated from the infected person are propelled a short distance through the air and deposited on the host’s conjunctivae, nasal mucosa or mouth. Because droplets do not remain suspended in the air, special air handling and ventilation are not required to prevent droplet transmission; that is, droplet transmission must not be confused with airborne transmission.

- **Airborne transmission** occurs by dissemination of either airborne droplet nuclei (small-particle residue [5 um or smaller in size] of evaporated droplets containing microorganisms that remain suspended in the air for long periods of time) or dust particles containing the infectious agent. Microorganisms carried
in this manner can be dispersed widely by air currents and may become inhaled by a susceptible host within the same room or over a longer distance from the source patient, depending on environmental factors; therefore, special air handling and ventilation are required to prevent airborne transmission. Microorganisms transmitted by airborne transmission include mycobacterium tuberculosis and the rubeola and varicella viruses.

- **Common vehicle transmission** applies to microorganisms transmitted by contaminated items such as food, water, medications, devices and equipment.

- **Vectorborne transmission** occurs when vectors such as mosquitoes, flies, rats and other vermin transmit microorganisms; this route of transmission is of less significance in hospitals in the United States than in other regions of the world.

**Nurses can help prevent the spread of infection in the hospital setting**

Even when used carefully, all organisms can develop some resistance to antibiotics over time. Therefore, preventing infection in the first place may be the best defense against an antibiotic-resistant infection [39]. Nurses, who are on the forefront, may hold a key to preventing the spread of infection and antimicrobial resistance. It is important to adhere to the following guidelines from the CDC [9]:

- **Hand washing.** Hand washing is frequently the single most important measure to reduce the risks of transmitting microorganisms from one person to another or from one site to another on the same patient. Washing hands for at least 15-30 seconds as promptly and thoroughly as possible between patient contacts and after contact with blood, body fluids, secretions, excretions and equipment or articles contaminated by them is perhaps the primary component of infection control and isolation precautions. In addition to adherence by nurses and health care professionals to the simple basics of hand washing, the CDC also recommends:
  - Use of alcohol-based hand rubs, which have been shown to terminate outbreaks in health care facilities to reduce transmission of antimicrobial resistant organisms (MRSA) and reduce overall infection rates.
  - Proper use of alcohol-based hand rubs requires the application of the product to palm of one hand and rubbing hands together, covering all surfaces of hands and fingers, until hands are dry. Note that the volume needed to reduce the number of bacteria on hands varies by product.
  - Alcohol-based hand rubs take less time to use than traditional hand washing. In an eight-hour shift, an estimated one hour of an ICU nurse’s time will be saved by using an alcohol-based hand rub.
  - Traditional hand washing with soap and water is considered the mainstream method, especially if hands are visibly soiled; always wash your hands with soap and water. Hand washing with soap and water remains a sensible strategy for hand hygiene in non-health care settings and is recommended by the CDC.
  - **Hand hygiene.** Health care personnel should adhere to certain recommendations to avoid transmitting nosocomial infections and microorganisms from patient to patient.
  - Those who care for patients at high risk of acquiring infections (e.g. patients in intensive care units or in transplant units) should avoid wearing artificial nails and keep natural nails less than one-quarter of an inch long.

- **Gloves.** The CDC recommends that in addition to hand washing, all health care personnel should wear gloves. Wearing gloves should never be in lieu of hand washing because gloves may have small, apparent defects or may be torn during use, and hands can become contaminated during removal of gloves. However, wearing gloves should be used in conjunction with hand washing to prevent the spread of microorganisms. Gloves reduce hand contamination by 70 percent to 80 percent, prevent cross-contamination and protect patients and health care personnel from infection. Hand rubs should be used before and after each patient, just as gloves should be changed before and after each patient.
  - Gloves are worn to provide a protective barrier and to prevent gross contamination of the hands when touching blood, body fluids, secretions, excretions, mucous membranes and nonintact skin; the wearing of gloves in specified circumstances to reduce the risk of exposures to blood-borne pathogens is mandated by the OSHA blood-borne pathogens final rule.
  - Gloves are worn to reduce the likelihood that microorganisms present on the hands of personnel will be transmitted to patients during invasive or other patient-care procedures that involve touching a patient’s mucous membranes and nonintact skin.
  - Gloves are worn to reduce the likelihood that hands of personnel contaminated with microorganisms from a patient or a fomite can transmit these microorganisms to another patient. In this situation, gloves must be changed between patient contacts, and hands should be washed after gloves are removed.

- **Isolating the patient.** In hospitals and nursing homes, drug-resistant microorganisms require that the patient be placed in contact isolation, a transmission-based isolation strategy recommended by the Centers for Disease Control and Prevention. In 1996, the CDC presented guidelines for a two-level approach to infection isolation. Appropriate patient placement is a significant component of isolation precautions. A private room is important to prevent direct- or indirect-contact transmission when the source patient has poor hygienic habits, contaminates the environment or cannot be expected to assist in maintaining infection control precautions to limit transmission of microorganisms (e.g., infants, children and patients with altered mental status). When possible, a patient with highly transmissible or epidemiologically important microorganisms is placed in a private room with hand washing and toilet facilities to reduce opportunities for transmission of microorganisms. In addition to isolating the patient, it is important to consider the following:
  - Linen and laundry. Although soiled linen may be contaminated with pathogenic microorganisms, the risk of disease transmission is negligible if it is handled, transported and laundered in a manner that avoids transfer of microorganisms to patients, personnel and environments. Rather than rigid rules and regulations, hygienic and common-sense storage and processing of clean and soiled linen are recommended. The methods for handling, transporting and laundering of soiled linen are determined by hospital policy and any applicable regulations.
  - **Dishes, glasses, cups and eating utensils.** No special precautions are needed for dishes, glasses, cups or eating utensils. Either disposable or reusable dishes or utensils can be used for patients on isolation precautions. The combination of hot water and detergents used in hospital dishwashers is sufficient to decontaminate dishes, glasses, cups and eating utensils.
  - **Routine and terminal cleaning.** The room or cubicle and bedside equipment of patients on transmission-based precautions are cleaned using the same procedures used for patients on standard precautions, unless the infecting microorganism(s) and the amount of environmental contamination indicate special cleaning. In addition to thorough cleaning, adequate disinfection of bedside equipment and environmental surfaces (e.g., bed rails, bedside tables, carts, commodes, doorknobs, faucet handles) is indicated for certain pathogens, especially enterococci, which can survive in the inanimate environment for prolonged periods of time. Patients admitted to hospital rooms that previously were occupied by patients infected or colonized with such pathogens are at increased risk of infection from contaminated environmental surfaces and bedside equipment if they have not been cleaned and disinfected adequately. The methods, thoroughness and frequency
of cleaning and the products used are determined by hospital policy [32].

If a private room is not available, an infected patient is placed with an appropriate roommate. Patients infected by the same microorganism usually can share a room, provided they are not infected with other potentially transmissible microorganisms and the likelihood of reinfection with the same organism is minimal. Such sharing of rooms, also referred to as cohorting patients, is useful especially during outbreaks or when there is a shortage of private rooms. When a private room is not available and cohorting is not achievable or recommended, it is very important to consider the epidemiology and mode of transmission of the infecting pathogen and the patient population being served in determining patient placement. Under these circumstances, consultation with infection control professionals is advised before patient placement. Moreover, when an infected patient shares a room with a noninfected patient, it also is important that patients, personnel and visitors take precautions to prevent the spread of infection. If the patient is placed into isolation, precautions are designed to prevent transmission of microorganisms by these routes in the hospital setting. The CDC has also recognized potential disadvantages for placing a patient in isolation. Isolation precautions may require specialized equipment and environmental modifications that add to the cost of hospitalization. Isolation precautions may make frequent visits by nurses, physicians and other personnel inconvenient, and they may make it more difficult for personnel to give the prompt and frequent care that sometimes is required. The use of a multipatient room for one patient uses valuable space that otherwise might accommodate several patients. Moreover, forced solitude deprives the patient of normal social relationships and may be psychologically harmful, especially to children. These disadvantages, however, must be weighed against the hospital’s mission to prevent the spread of serious and epidemiologically important microorganisms within the hospital.

**Protective barriers.** Dependent upon the type and location of the bacterium, the nurse may be required to wear protective gear, such as a mask, goggles, a face shield and/or gown to prevent the spread.

- **Mask.** A mask that covers both the nose and the mouth, and goggles or a face shield are worn by hospital personnel during procedures and patient-care activities that are likely to generate splashes or sprays of blood, body fluids, secretions or excretions to provide protection of the mucous membranes of the eyes, nose and mouth from contact transmission of pathogens. Use of masks, eye protection and face shields in specified circumstances to reduce the risk of exposures to blood-borne pathogens is mandated by the Occupational Safety and Health Administration (OSHA) blood-borne pathogens final rule. A surgical mask generally is worn by hospital personnel to provide protection against spread of infectious large-particle droplets that are transmitted by close contact and generally travel only short distances (up to 3 feet) from infected patients who are coughing or sneezing [32].

- **Respiratory protection currently requires the use of a respirator with N95 or higher filtration to prevent inhalation of infectious particles.** Respiratory protection is broadly regulated by OSHA under the general industry standard for respiratory protection, which requires U.S. employers in all employment settings to implement a program to protect employees from inhalation of toxic materials. OSHA program components include medical clearance to wear a respirator; provision and use of appropriate respirators, including fit-tested National Institute for Occupational Safety and Health (NIOSH)-certified N95 and higher particulate filtering respirators; education on respirator use and periodic re-evaluation of the respiratory protection program. The key is ensuring that the particular respirator is a good fit for the health care professional. The guidelines mandate that a user-seal check, formerly called a “fit check,” should be performed by the wearer of a respirator each time a respirator is donned to minimize air leakage around the face piece. The optimal frequency of fit-testing has not been determined [32].

- **Gowns are worn to prevent contamination of clothing and to protect the skin of personnel from blood and body fluid exposures.** Gowns specially treated to make them impermeable to liquids, leg coverings, boots or shoe covers provide greater protection to the skin when splashes or large quantities of infective material are present or anticipated. The wearing of gowns and protective apparel under specified circumstances to reduce the risk of exposures to blood-borne pathogens is mandated by the OSHA blood-borne pathogens final rule. Gowns also are worn by personnel during the care of patients infected with epidemiologically important microorganisms to reduce the opportunity for transmission of pathogens from patients or items in their environment to other patients or environments; when gowns are worn for this purpose, they must be removed before leaving the patient’s environment, and hands must be washed.

- **Transferring patients.** Limiting the movement and transport of patients infected with virulent or epidemiologically important microorganisms and ensuring that such patients leave their rooms only for essential purposes reduces opportunities for transmission of microorganisms in hospitals. When patient transport is necessary, it is important that:
  - Appropriate barriers (i.e. masks, impervious dressings) are worn or used by the patient to reduce the opportunity for transmission of pertinent microorganisms to other patients, personnel and visitors and to reduce contamination of the environment.
  - Personnel in the area to which the patient is to be taken are notified of the impending arrival of the patient and of the precautions to be used to reduce the risk of transmission of infectious microorganisms; and patients are informed of ways by which they can assist in preventing the transmission of their infectious microorganisms to others.

- **Education.** Nurses can help prevent the development of drug-resistant microorganisms by explaining antibiotic misuse to each of their patients in the hospital and in the outpatient setting. When involved in the provision of prescriptions for antibiotics, nurses should [12]:
  - Provide both the generic and trade name of the drug.
  - Explain the purpose of the medication (to fight or prevent infection).
  - Explain the dosage in easily understood terms, without abbreviations and/or medical jargon.
  - Explain whether medication should be given around the clock or only during waking hours, how often it should be taken and whether it should be taken with food. Also, patients being discharged from the hospital should be informed about their last antimicrobial dose to ensure they continue the same administration cycle at home.
  - Explain potential drug or food interactions and what to do if they miss a dose.
  - Explain that the patient must continue to take all medication, even when he or she feels better.
  - Confirm that the patient finished all of the prescribed medicine in appropriate dosages.

In addition, nurses need to do the following when caring for a patient who has been prescribed antimicrobial therapy [18]:

- Carefully monitor antibiotic therapy, checking the peak and low levels, and reviewing the data and recommendations based on the cultures.
- Encourage the use of narrow-spectrum antibiotics until culture findings are known.
- Always check the cultures before antibiotics are started, and review all culture reports to ensure that bacteria are sensitive to the antibiotics used. Failure to comply will skew the results.
- Advocate for restrictions on the use of certain antibiotics, like vancomycin, empirically for preoperative prophylaxis. As implied, vancomycin should be reserved only for antimicrobial drug resistance.
- Monitor adherence to medical staff guidelines for antibiotic use.

Research has demonstrated that although there are stringent guidelines in place to prevent the spread of microorganisms, the phenomenon is still occurring. Therefore, it is important to realize that each one of us can make a difference at all levels. If in doubt, ask the infection control nurse at the hospital. Never hesitate, as it is imperative that nurses diligently work together with all members of the health care team to prevent the spread of microorganisms that can further exacerbate the resistance to antimicrobial therapy.

Closing
It is inevitable that our society will continue to encounter antimicrobial drug resistance. Due to the prevalence and significance, it is imperative that everyone collaborates to prevent further resistance or to stall the process. Nurses need to be familiar with each classification of drugs, the manner in which they work and when they should be prescribed. It is also important to become aware of the most prevalent microbes within the community in which you reside by contacting your local health department.

Nurses need to empower each of their patients and families with the knowledge of their prescribed antimicrobial drugs, the importance of taking the full dose as prescribed and when to return to their primary care provider. In addition, every nurse can do his or her part in educating patients and families about antimicrobial drug resistance and the importance of abating unnecessary antimicrobials for viral infections. According to the CDC [18]:

- On average, adults get three to five colds a year; children even more. Most colds last one week, but it is unusual for symptoms to continue for as long as two to three weeks.
- We used to think that yellow or green mucus indicated a bacterial infection. We now know this is not true. It is common to have yellow or green mucus with a viral infection, such as a cold. Colored mucus does not mean that you have a bacterial infection or need antibiotics.

Each one of us holds the key to be knowledgeable about the reality and significance of antimicrobial drug resistance. We can make a difference.

References
# Nurses' Role in Preventing Antimicrobial Resistance

## Self Evaluation Exercises

Choose True or False for questions 1 through 10 and check your answers at the bottom of the page.

<table>
<thead>
<tr>
<th>Question</th>
<th>True</th>
<th>False</th>
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<tbody>
<tr>
<td>1. The CDC reiterates the concept and estimates that the major factor in the emergence of antibiotic resistance bacteria is attributed to the overuse and misuse of antibiotics.</td>
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<td>2. All penicillin drugs consist of two parts: a thiazolidine ring and a beta-lactam ring.</td>
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<td>3. Cephalosporins are a newer group of antibiotics that currently account for the majority of all antibiotics administered today.</td>
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<td>4. The most common severe drug allergy is with the penicillins.</td>
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<td>5. Less than 10 percent of staphylococcus aureus strains are no longer treatable with penicillins.</td>
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<td>6. Vancomycin-resistant enterococci (VRE) is most typically colonized in the gastrointestinal tract; however it may be found in the urinary tract.</td>
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<td>7. The danger with MRSA is the bacterium is resistant to the entire class of penicillins, including the beta-lactamases.</td>
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<td>8. Neisseria gonorrhoeae (N. gonorrhea) is the most common notifiable disease in the U.S. with 339,593 cases documented in 2005.</td>
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<td>9. Antiviral drug resistance occurs due to a decrease in the susceptibility of the drug in a laboratory culture (a phenotype), change in the genetic makeup (genotype), and evolutionary changes over time (virus replicating over time).</td>
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10. Nurses can help prevent the development of drug-resistant microorganisms by explaining antibiotic misuse with each of their patients in the hospital and in the outpatient setting. 

True    False
