Antimicrobial Agents: Penicillin

After completion the reader should be able to:

1. Identify four categories of penicillin and appropriate indications for their use.
2. Relate general characteristics of penicillins to specific patient situations.
3. Apply nursing process considerations for penicillins to specific patient situations.
4. Correctly calculate dosage for penicillins.

Penicillins

Penicillins were first introduced into clinical practice in the 1940’s, and constitute the first group of effective antibiotics to become commercially available. Penicillins belong to a group of antibiotics known as beta-lactams, owing to the presence of the beta-lactam ring in their structure. This ring is essential for effective antibacterial action of the drug. This is clinically significant, as an increasing number of bacteria produce an enzyme, beta-lactamase, that breaks down this ring, rendering the drug ineffective. Over time, organisms that were previously sensitive to penicillin can develop the ability to produce beta-lactamase, becoming resistant to certain beta-lactam antibiotics. A beta-lactamase enzyme that is specific to penicillin is a penicillinase. A high percentage of Staph aureus strains currently produce penicillinase.

Antibiotic resistance is a serious problem in medicine today. There is great concern that resistant organisms may, at some point, not respond to any known antibiotics. This problem is currently being addressed, in part, by the development of drugs that are not affected by beta-lactamase. Since overuse of antibiotics is a major factor in development of resistance, education of healthcare providers and the public in avoiding overuse is also helpful in this effort.

There are four categories of penicillin, based on each group’s spectrum of activity:

**Natural penicillins:** These first generation penicillins include penicillin G and penicillin V, which are narrow-spectrum and readily inactivated by penicillinase. They are effective primarily against selected gram positive bacteria of the staph and strep species that do not produce penicillinase. They are also effective against the gram-negative Neisseria bacteria that cause meningitis and gonorrhea, as long as no penicillinase is produced. The natural penicillins are used less frequently today, primarily due to the development of newer, more effective types of penicillin. They do have some important clinical uses, however, such as prophylaxis against diphtheria, rheumatic fever, and bacterial endocarditis. These drugs are used in the treatment of sexually-transmitted diseases, such as gonorrhea and syphilis. Also, penicillin G is used in the treatment of pregnant women colonized with Group B strep.

Penicillin G is available in four salt forms—sodium, potassium, procaine and benzathine. These are normally administered parenterally, either IV or IM, since penicillin G loses much activity in gastric acids. The sodium and potassium forms, which are aqueous solutions, may be given via the IM or IV routes. Procaine and benzathine penicillins are the longer-acting forms, and must be given via the IM route only. Penicillin V is available only in oral forms.

**Aminopenicillins:** These are broad-spectrum agents, readily inactivated by penicillinase, and include ampicillin, amoxicillin and bacampicillin. They are similar in spectrum to the natural penicillins, but with enhanced activity against some gram-negative bacteria, such as E. Coli, Haemophilus influenzae, and Salmonella. They are commonly used to treat sinusitis, pharyngitis and otitis media. Ampicillin is administered via oral, IM or IV routes; the others are for PO use only.

**Anti-staphylococcal penicillins:** These agents are effective against penicillinase-producing Staph aureus, and include cloxacillin, dicloxacillin, oxacillin, and nafcillin. They are not as effective against penicillin-sensitive organisms as the natural penicillins, however, and have limited activity against most gram-negative organisms. These agents are used to treat conditions such as pneumonia, meningitis, and infections of the skin and soft tissue. Cloxacillin and dicloxacillin are available only in PO forms, while nafcillin and oxacillin are administered via the PO, IV, or IM routes.

**Anti-pseudomonal penicillins:** Also called extended-spectrum penicillins, these drugs include piperacillin, ticarcillin, carbenicillin and mezlocillin.
They are effective against the widest variety of bacteria, particularly the gram-negative Pseudomonas aeruginosa, Enterobacter and Proteus. These drugs are inactivated by penicillinase.

In addition to the above groups, several combination drugs have been developed. To increase their resistance to penicillinase, some penicillins are combined with other agents, such as clavulanic acid or sulbactam. For example:

- amoxicillin + clavulanic acid = Augmentin
- ampicillin + sulbactam = Unasyn.

**Indications**

Penicillins are indicated in the prevention and treatment of bacterial infections caused by susceptible organisms. They are generally more effective against gram-positive organisms, such as staphylococcus and streptococcus, than against gram-negative organisms.

**Pharmacodynamics**

Penicillins are bactericidal. They act by binding to proteins on the bacterial cell wall, causing cell lysis.

**Pharmacokinetics**

Absorption: Oral forms are generally well-absorbed via the GI tract.

Distribution: Widely distributed throughout most body fluids, except CSF; better able to enter CSF when inflammation increases tissue permeability; crosses the placenta; found in breast milk

Metabolism: Metabolized, in part, by the liver; further metabolism occurs in body tissues

Elimination: Excreted primarily via the kidneys

**Major Interactions**

- **Anticoagulant, thrombolytic and NSAID medications:** Bleeding may occur when drugs that affect coagulation, such as heparin, coumadin, and aspirin, are given concurrently with high-dose parenteral carbenicillin, piperacillin or ticarcillin.
- **Potassium supplements and potassium-sparing diuretics:** Medications that increase potassium levels may cause hyperkalemia with administration of penicillin G potassium.
- **Aminoglycosides:** Combining gentamicin, tobramycin, or others with penicillins in the same bag may inactivate both drugs.
- **Oral contraceptives (estrogen-containing):** Use of penicillin V, ampicillin or amoxicillin may reduce effectiveness of oral contraceptives.

**Adverse Effects/Toxicity**

Because human cells have no cell wall on which they can act directly, the penicillins are among the least toxic of medications in current use, and have few adverse effects. Side effects include GI disturbance, such as diarrhea, and bacterial or fungal superinfection, such as oral or vaginal yeast infection. Bleeding tendencies and damage to the liver and kidneys have been reported. Seizures have occurred with high doses or in the presence of renal impairment. The major concern, however, is penicillin allergy. Penicillins are responsible for more serious allergic reactions than any other drugs.

**Precautions/Contraindications**

Administer cautiously to patients with renal impairment—reduced doses may be required. Penicillins are contraindicated in cases of known hypersensitivity to these drugs. A patient who is allergic to one form of penicillin may exhibit cross-sensitivity to other penicillins or to cephalosporins. Also, patients allergic to procaine or other ester-type local anesthetics may exhibit a hypersensitivity reaction to penicillin G procaine.

**Nursing Process**

**Assessment**

*Determine baseline status:* As with any patient taking antimicrobial medication, a complete assessment of the presenting infection should be performed as a baseline for measurement of medication effectiveness. A current medication history is important to identify any interactions that may occur as a result of adding a penicillin to the patient’s regimen.

*Identify risk factors:* Assess all patients carefully for drug or other allergies. Patients with impaired renal function may require reduced dosage.

*Age-specific considerations:* Penicillins are generally considered safe for use in pediatric and geriatric populations, and during pregnancy—they are classified as FDA pregnancy category B. They are also considered safe for use during breastfeeding. While there is the potential for problems such as diarrhea, oral yeast infection, or hypersensitivity reaction in the nursing infant, these are rare.

**Planning and Analysis**

The goal of therapy is to ensure the patient is infection-free, with no adverse effects resulting from administration of penicillin medications.

**Intervention**

**Medication administration:** Obtain any ordered culture and sensitivity specimens before administering first dose. Be thoroughly familiar with the route and appropriate administration of the penicillin being administered. Do not mix in same bag with aminoglycosides

*Observe for therapeutic effects:* Measurement of therapeutic effect depends on the site of infection. If given for respiratory infection, for example, ongoing assessment should focus on improvement of pulmonary function.

*Observe for adverse effects:* Watch patient for signs of hypersensitivity reaction (itching, rash, hives, swelling, difficulty breathing) and discontinue medication immediately if any occur. When administering the sodium or potassium forms, watch for hypernatremia or hyperkalemia in patients who have impaired renal function or are receiving high doses.

**Patient/Family teaching:** Instruct patient to:

- Take the full course of medication ordered, even if symptoms subside
- Report worsening symptoms, diarrhea, or yeast infection
- Discontinue medication immediately and report to physician if itching, rash, hives, or other signs of hypersensitivity occur
- Consider using an additional method of contraception if taking oral contraceptives and certain penicillins concurrently
- Wear a Medic-Alert bracelet if allergic to penicillin

**Evaluation**

Through careful monitoring and therapeutic administration of penicillins, the expected outcomes of eliminating infection and avoiding adverse effects can be safely promoted.
Learning Objectives:

After completion, the reader should be able to:

1. Identify four categories of penicillin and appropriate indications for their use.
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Suggested Adjunct Activities:

1. Collect data from several patients in your area who are receiving penicillin antibiotics. Have the nurses discuss the type of penicillin, indications for the drug, the susceptible organism, possible drug interactions, and appropriate nursing care for these patients.

Competency Assessment Tool Answer Key:

1. A. True
2. D. Anti-staphylococcal penicillins
3. C. taking antibiotics now will not cure the virus, and may result in drug resistance later on
4. B. reduce the effects of penicillinase
5. B. “I had a bad reaction to some numbing medicine the dentist gave me.”
6. B. hold the medication and notify the physician
7. D. use an additional method of contraception during this pill cycle
8. A. mixing gentamicin with ampicillin in 100 ml of D5W IV solution
9. C. 10 ml

\[
\frac{125 \text{ mg}}{5 \text{ ml}} = \frac{250 \text{ mg}}{X \text{ ml}} \quad 125 \times X = 1250 \quad X = 10 \text{ ml}
\]

10. A. 1.2 ml

\[
33 \text{ lb} \times 2.2 \frac{\text{ kg}}{\text{ lb}} = 73 \text{ kg} \quad 15 \text{ kg} \times 20 \frac{\text{ mg}}{\text{ kg}} = 300 \text{ mg} \quad \frac{250 \text{ mg}}{1 \text{ ml}} = \frac{300 \text{ mg}}{X \text{ ml}} \quad 250 \times X = 300 \quad X = 1.2 \text{ ml}
\]
Directions: Place the letter of the one best answer in the space provided.

1. Bacteria that were previously sensitive to penicillin may, over time, develop the ability to inactivate penicillin.
   A. True
   B. False

2. Which of the following penicillin groups is most effective against gram-positive bacteria that produce penicillinase?
   A. Aminopenicillins
   B. Natural penicillins
   C. Anti-pseudomonal penicillins
   D. Anti-staphylococcal penicillins

3. Mr. Carson comes to the physician’s office complaining of a sore throat. The physician diagnoses viral pharyngitis, and suggests measures to relieve the symptoms. Mr. Carson says to the nurse, “But I came here for an antibiotic—I want to get rid of this.” The nurse appropriately explains that:
   A. bacterial infections often subside on their own
   B. the physician did not prescribe antibiotics due to Mr. Carson’s history of multiple drug allergies
   C. taking antibiotics now will not cure the virus, and may result in drug resistance later on
   D. the side effects associated with taking an antibiotic are likely to be worse than the sore throat pain

4. Drugs, such as sulbactam and clavulanic acid, are combined with selected penicillins to:
   A. make them more stable in gastric acids
   B. reduce the effects of penicillinase
   C. decrease the likelihood of allergic reaction
   D. delay excretion from the body, resulting in more prolonged drug levels

5. The nurse is about to administer penicillin G procaine, and asks the patient about drug allergies. Which of the following statements, made by the patient, should most clearly alert the nurse to hold the medication until additional information is obtained?
   A. “I don’t have any allergies, but I’ve never taken penicillin before that I know of.”
   B. “I had a bad reaction to some numbing medicine the dentist gave me.”
   C. “I took erythromycin some years back, and it made me vomit.”
   D. “I use a cream for my eczema, but nothing else.”
6. A young adult is seen in the Emergency Department. He denies any drug allergies, and IV ampicillin is ordered as part of his treatment. When his mother arrives, she states, “He probably doesn't remember, but when he was 8, he had terrible hives after taking penicillin V.” The nurse should:
   A. anticipate a medication change to a cephalosporin
   B. hold the medication and notify the physician
   C. administer the ampicillin as ordered, since that is not the same drug as penicillin V
   D. inject a very small amount as a test dose, to see if allergic reaction occurs, before administering the dose

7. Barbara is a 32 year old mother of three who currently takes oral contraceptives. She receives a prescription for amoxicillin. In teaching Barbara about the appropriate use of amoxicillin, the nurse should suggest that she:
   A. take extra vitamin C, either from fruits, tablets, or juices, to help prevent a drug interaction
   B. stop taking the oral contraceptive when she starts the amoxicillin
   C. watch closely for blood clots in her legs
   D. use an additional method of contraception during this pill cycle

8. Which one of the following actions, performed by the nurse, constitutes a medication error when administering penicillins?
   A. mixing gentamicin with ampicillin in 100 ml of D5W IV solution
   B. continuing to administer ordered penicillin even though symptoms of infection are gone
   C. giving IM injection of penicillin G benzathine in the upper outer quadrant of the gluteal muscle
   D. administering cloxacillin by the oral route

9. Drug Order: amoxicillin oral suspension 250 mg PO q8h
   Drug Label: amoxicillin suspension 125 mg/5 ml
   Give:
   A. 2 ml
   B. 5 ml
   C. 10 ml
   D. 20 ml

10. Drug Order: nafcillin 20 mg/kg IV q8h
    Drug Label: nafcillin 250 mg/ml
    Patient Weight: 33 lbs
    Give:
    A. 1.2 ml
    B. 2.2 ml
    C. 3.4 ml
    D. 4.8 ml