



*Bugs & Drugs:
The Antibiotic
Review for Nurse
Practitioners*

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Disclosure

E. Monee' Reed, DNP, MA, RN, ACNP-BC has no financial relationships with commercial interests to disclose. Any unlabeled and/or unapproved uses of drugs or products will be disclosed.

Objectives

- Discuss the mechanism of action, spectrum of activity, and special considerations for the most common antibiotic drug classes.
- Identify commonly prescribed antibiotics within the drug classes and indication for prescribing.
- Practice appropriate prescribing for common bacterial infections

Antibiotic Drug Classes

- Penicillins
- Cephalosporins
- Carbapenems
- Monobactam
- Macrolides
- Fluoroquinolones
- Sulfonamides
- Tetracyclines

Penicillins

- Penicillins
 - Natural penicillins
 - Aminopenicillins
 - Anti-staphylococcal penicillins
 - Anti-pseudomonal penicillins

Penicillins

- Mechanism of action → bactericidal → interrupts cell wall synthesis

Natural Penicillins

Penicillin G
Penicillin V

- Spectrum of Activity
 - Gram positive organisms
 - *Streptococcus* species (e.g. *S. pyogenes*)
 - Some *enterococcus* species (e.g. *E. faecalis*)
 - *Staphylococci* → only minority; most are resistant
 - *Listeria monocytogenes*
 - Gram negative organisms → limited
 - Anaerobes
 - *Bacteroides*
 - *Fusobacterium* species

Drug	Dosage	Route	Indication
Penicillin G benzathine	1.2 – 2.4 MU	IM	Most commonly used to treat Group A strep (e.g. pharyngitis), and syphilis
Penicillin G procaine	2.4 MU x 1 dose	IM	
Penicillin G (parenteral)	12 – 24 MU daily	IV	
Penicillin V	125-500 mg every 6-8h	PO	

Aminopenicillins

Amoxicillin
Amoxicillin / Clavulanate
Ampicillin
Ampicillin / Sulbactam

- Spectrum of Activity
 - Same activity as natural penicillins → susceptible gram-positive organisms
 - Improved gram-negative coverage
 - *Enterobacteriaceae*
 - *H. pylori* → used as part of multi-drug treatment
 - *H. influenzae*

Drug	Dosage	Route	Indication
Amoxicillin (Amoxil)	250-500 mg every 8h 500-875 mg BID	PO	Sinusitis, meningitis, susceptible UTIs, Soft skin infections related to group A strep, Otitis media, pneumonia
Amoxicillin/Clavulanate (Augmentin)	250-500 mg every 8h 875 mg every 12h	PO	
Ampicillin	250-500 mg every 6h	PO, IM, IV	
Ampicillin/Sulbactam (Unasyn)	1.5-3 g every 6h	IM, IV	

Anti-staphylococcal Penicillins

Dicloxacillin
Nafcillin
Oxacillin

- Spectrum of Activity
 - Drug class also known as the Penicillinase-Resistant Penicillins
 - Gram-positive organisms
 - *Staphylococcal* species
 - MSSA*
 - *Streptococcal* species

Drug	Dosage	Route	Indication
Dicloxacillin	125-500 mg every 6h	PO	Drug of choice for MSSA infections → cellulitis, endocarditis, osteomyelitis, and bacteremia
Nafcillin	0.5-2 g every 4-6h	IV	
	0.5 g every 4-6h	IM	
Oxacillin	0.25-2 g every 4-6h	IM, IV	

Anti-pseudomonal Penicillins

Piperacillin
Piperacillin / tazobactam
Ticarcillin
Ticarcillin / clavulanate potassium

- Spectrum of activity
 - Typically referred to the extended-spectrum penicillins
 - Gram-positive activity
 - Staph. and Strep.
 - **NO** MRSA coverage.
 - Gram-negative activity
 - Including *Pseudomonas aeruginosa*
 - Also has coverage against Enterobacteriaceae.
- Anaerobic coverage

Drug	Dosage	Route	Indication
Piperacillin (Pipracil)	3-4 g every 4-6h	IV, IM	Intra-abdominal infections, pneumonia, severe soft/skin and tissue infections, sepsis, etc.
Piperacillin/tazobactam (Zosyn)	3.375-4.5 g every 6-8h	IV	
Ticarcillin +/- clavulanate potassium (Timentin)	0.25-2 g every 4-6h	IV	

Penicillins

- Special Considerations
 - Dosage considerations for patients with renal dysfunction
 - Probenecid decreases renal clearance of penicillins
 - MSSA coverage with Amoxicillin/Clavulanate but **none** with Amoxicillin only
 - No MRSA coverage
 - Allergy

Cephalosporins

- Cephalosporins
 - 1st Generation
 - 2nd Generation
 - 3rd Generation
 - 4th Generation
 - 5th Generation

Cephalosporins

- Mechanism of action → bactericidal → interrupts cell wall synthesis

1st Generation Cephalosporins

Cefadroxil
Cefazolin
Cephalexin
Cephradine

- Spectrum of Activity
 - Primarily active against gram-positive cocci.
 - *Staphylococcus*
 - *Streptococcus*
 - **NO** MRSA coverage.
 - Minor gram-negative activity
 - *E. coli*
 - *H. influenzae*
 - *Klebsiella*

Drug	Dosage	Route	Indication
Cefadroxil (Duricef)	1-2 g/daily in two divided doses	PO	Skin and soft tissue infections, respiratory infections, some UTIs, and otitis media
Cefazolin (Ancef)	1-2g every 8h	IM, IV	
Cephalexin (Keflex)	250-1000mg every 6-12h	PO	
Cephadrine (Velosef)	250-500mg every 6-12h	PO	

2nd Generation Cephalosporins

Cefaclor
Cefotetan
Cefoxitin
Cefprozil
Cefuroxime

- Spectrum of Activity
 - Gram-positive coverage
 - *Staphylococcus*
 - *Streptococcus*
 - Extended gram-negative coverage
 - Same as 1st generation but **ADD** coverage against *Neisseria*, *Proteus*
 - Anaerobic coverage
 - Cefoxitin
 - Cefotetan

Drug	Dosage	Route	Indication
Cefaclor	250-500mg every 8h	PO	Skin & soft tissue infections, UTIs, respiratory tract infections
Cefotetan	1-2g every 12h	IM, IV	
Cefoxitin	1-2g every 6-8h	IM, IV	
Cefprozil	250-500mg every 12-24h	PO	
Cefuroxime	PO: 250-500mg every 12h IM, IV: 0.5-1g every 6-8h	PO, IM, IV	

3rd Generation Cephalosporins

Cefdinir
Cefditoren
Cefixime
Cefotaxime
Cefpodoxime
Ceftazidime
Ceftibuten
Ceftriaxone

- Spectrum of Activity
 - Broader activity against gram-negative organisms
 - There are some exceptions.
 - Some have broader gram-negative coverage compared to others.
 - Some gram-positive coverage **BUT** minimal
 - *Streptococcus pneumoniae*
 - *Staphylococcus aureus*
 - Minimal anaerobic coverage

Drug	Dosage	Route	Indication
Cefdinir	300mg every 12h 600mg every 24h	PO	Respiratory tract infections, skin & soft tissue infections, UTIs, sepsis*, intra-abdominal infections*, CNS infections*
Cefditoren	200-400mg every 12h	PO	
Cefixime	400mg daily	PO	
Cefotaxime	1-2g every 4-12h	IM, IV	
Cefpodoxime	100-400mg every 12h	PO	
Ceftazidime	500mg to 1g every 8h	IM, IV	
Ceftibuten	400mg/daily	PO	
Ceftriaxone (Rocephin)	1-2g every 12-24h	IM, IV	

4th Generation Cephalosporin

Cefepime

- Spectrum of Activity
 - Good gram-positive activity
 - *Staphylococcus*
 - *Streptococcus*
 - Good gram-negative activity
 - *Enterobacteriaceae*
 - *Escherichia*
 - *Klebsiella*
 - *Pseudomonas*
 - *Enterobacter*
 - *Proteus*

Drug	Dosage	Route	Indication
Cefepime	IM: 0.5-1g every 12h IV: 1-2g every 8-12h	IM, IV	Pneumonia, intra-abdominal infections, UTI, and skin & soft tissue infections

5th Generation Cephalosporin

Ceftaroline

- Spectrum of Activity
 - Gram-positive activity
 - *Staphylococcus aureus*
 - *Streptococcus pneumoniae*
 - Gram-negative activity
 - Relatively similar coverage to other cephalosporins.
 - NO *Pseudomonas* coverage.

Drug	Dosage	Route	Indication
Ceftaroline	600mg every 12h	IV	Pneumonia (CAP), skin & soft tissue infection

Cephalosporins

- Special Considerations
 - If cross-sensitivity reaction is to occur with a penicillin, most likely to occur with 1st generation.
 - Cefazolin and Cefepime can cross the blood-brain-barrier in severe renal dysfunction/failure → neurotoxicity → encephalopathy, seizures
 - Encephalopathy
 - Seizures
 - Cefotetan → possible disulfiram-like reaction with alcohol
 - Ceftriaxone → calcium salt precipitate in the gallbladder that can be mistaken for gallstones
 - Cholelithiasis

Carbapenems

- Doripenem
- Ertapenem
- Imipenem/cilastatin
- Meropenem
- Meropenem/vaborbactam

Carbapenems

- Mechanism of action → bactericidal → interrupts cell wall synthesis

Carbapenems

Doripenem
Ertapenem
Imipenem/cilastatin
Meropenem
Meropenem/vaborbactam

- Spectrum of Activity
 - Broad spectrum activity against gram-positive and gram-negative bacteria.
 - *Pseudomonas aeruginosa* coverage EXCEPT Ertapenem
 - ESBL (extended spectrum beta-lactamases) coverage

Drug	Dosage	Route	Indication
Doripenem	500mg every 8h	IV	Skin & soft tissue infections*, intra-abdominal infections*, respiratory infections*, UTI*, sepsis*
Ertapenem	1g daily	IM, IV	
Imipenem/cilastatin	500-1000mg every 6-8h	IV	
Meropenem	1.5 to 6g daily in 3 divided doses	IV	
Meropenem/vaborbactam	4g every 8h	IV	

Carbapenems

Doripenem
Ertapenem
Imipenem/cilastatin
Meropenem
Meropenem/vaborbactam

- Special Considerations
 - The dose must be adjusted in patients with renal disease
 - Ertapenem → CrCl less than 30 ml/min
 - Meropenem → CrCl less than 50 ml/min
 - Imipenem/cilastatin → less than 90 ml/min
 - Increased seizure risk in patient with CNS/seizure disorders.

Monobactam

- Aztreonam

Monobactam

- Mechanism of action → bactericidal → interrupts cell wall synthesis

Monobactam

Aztreonam

- Spectrum of Activity
 - Gram-negative organisms
 - Enterobacteriaceae (e.g. *Citrobacter*, *Enterobacter*, *Proteus*, *Serratia*, etc.)
 - *Pseudomonas aeruginosa*
 - *Haemophilus influenzae*

Drug	Dosage	Route	Indication
Aztreonam	1-2g every 8-12h	IM, IV	UTI, respiratory tract infections, sepsis, skin & soft tissue infections, intra-abdominal infections, gynecological infections

Monobactam

Aztreonam

- Special Considerations
 - Recommend pretreating patient with bronchodilator prior to inhalation administration
 - Not uncommon to use double coverage with *Pseudomonas* infections
 - Studies has indicated tolerance in patients with penicillin and cephalosporin allergy
 - ?Ceftazidime cross-allergy reaction

Macrolides

- Erythromycin
- Clarithromycin
- Azithromycin
- Fidaxomicin

Macrolides

- Mechanism of action → bacteriostatic* → inhibits protein synthesis

Macrolides

Azithromycin
Clarithromycin
Erythromycin
*Fidaxomicin**

- Spectrum of Activity
 - Atypical bacteria
 - *Chlamydia*
 - *Legionella*
 - *Mycoplasma*
 - *Mycobacterium*
 - *Neisseria*
 - Gram-positive bacteria
 - Gram-negative bacteria
 - *Haemophilus*
 - *Moraxella*

Drug	Dosage	Route	Indication
Azithromycin	PO: 250-600mg daily IV: 250-500mg daily	IV, PO, ophthalmic drops	COPD, CAP, MAC, skin & soft tissue infections, streptococcal pharyngitis, <i>N. gonorrhoea</i>
Clarithromycin	250-500mg every 12h	PO	<i>H. pylori</i> , CAP, MAC, skin & soft tissue infections
Erythromycin	Varies drastically depending on the base.	IV, PO, ophthalmic drops, topical	All bacterial infections, colorectal surgical prophylaxis
Fidaxomicin	200mg twice daily	PO	<i>Clostridium difficile</i> infections

Macrolides
 Azithromycin
 Clarithromycin
 Erythromycin
 Fidaxomicin*

- Special Considerations
 - Monitor for QT prolongation
 - Liver disease
 - Avoid erythromycin estolate is contraindicated 2/2 to hepatic dysfunction with or without jaundice
 - Reversible deafness has occurred with Clarithromycin
 - Significant drug interactions can occur with Erythromycin and Clarithromycin
 - Inhibitors of CYP_{3A4}

Fluroquinolones

- Besofloxacin
- Cinoxacin
- Ciprofloxacin*
- Delafloxacin
- Gatifloxacin → IV form removed from market
- Gemifloxacin → no longer available in US
- Levofloxacin*
- Moxifloxacin*
- Norfloxacin → no longer available in US
- Ofloxacin*

Fluroquinolones

- Mechanism of action → bactericidal → inhibits DNA synthesis

Fluroquinolones
 Ciprofloxacin
 Levofloxacin
 Moxifloxacin
 Ofloxacin

- Spectrum of Activity
 - Gram positive organisms
 - *Staphylococcus*
 - Gram negative organisms
 - *Enterobacteriaceae*
 - *Haemophilus*
 - *Pseudomonas*
 - Atypical organisms
 - *Legionella*
 - *Chlamydia*
 - *Mycoplasma*
 - *Mycobacterium*

Drug	Dosage	Route	Indication
Ciprofloxacin	PO: 250-750mg every 12h IV: 200-400mg every 12h	PO, IV, topical, ophthalmic	UTIs*, respiratory infections, skin & soft tissue infections, intra-abdominal infections*,
Levofloxacin	250-750mg daily	PO, IV, ophthalmic, inhalation	
Moxifloxacin	400mg daily	PO, IV, ophthalmic	
Ofloxacin	200-400mg every 12h	PO, ophthalmic	

Fluroquinolones
 Ciprofloxacin
 Levofloxacin
 Moxifloxacin
 Ofloxacin

- Special Considerations
 - Fluroquinolones are recommended for more severe infections 2/2 side effect profile.
 - Concurrent use with NSAIDs → may increase the risk of seizures
 - Can prolong QT interval → Ciprofloxacin, Levofloxacin, and Moxifloxacin
 - Antacids decrease absorption

Sulfonamides

- Sulfamethoxazole/trimethoprim

Sulfonamides

- Mechanism of action → bacteriostatic → inhibits steps in folate synthesis

Sulfonamides
Sulfamethoxazole/trimethoprim

- Spectrum of Activity
 - Gram positive coverage
 - *Staphylococcus*
 - *Streptococcus* → some
 - Gram negative coverage
 - *Enterobacteriaceae*
 - *Haemophilus*
 - Other organisms
 - *Pneumocystis* → yeast-like fungus
 - *Stenotrophomonas* → gram negative
 - *Toxoplasma* → parasite
 - *Nocardia* → gram positive

Drug	Dosage	Route	Indication
Sulfamethoxazole/trimethoprim (Bactrim)	PO: 800/160 mg every 12-24 hours IV: 8-20 mg/kg/day	PO, IV	UTI, COPD exacerbation, PJP prophylaxis and treatment, traveler's diarrhea, and shigellosis

Sulfonamides
Sulfamethoxazole/trimethoprim

- Special Considerations
 - The IV dosing is based on the trimethoprim component
 - Weight based dosing based on the trimethoprim component
 - Maximum 960 mg/day
 - Require renal-based dosing in setting of poor renal function
 - Total body clearance of trimethoprim is decreased in the elderly
 - Side effects

Tetracyclines

- Demeclocycline*
- Doxycycline
- Minocycline
- Tetracycline*

Tetracyclines

- Mechanism of action → bacteriostatic → inhibits protein synthesis

Tetracyclines

Doxycycline
Minocycline

- Spectrum of Activity
 - Gram positive organisms
 - *Staphylococcus*
 - *Streptococcus*
 - Gram negative organisms
 - *E. coli*
 - *Enterobacter*
 - *Klebsiella*
 - *Acinetobacter*
 - *Haemophilus*
 - Atypical organisms
 - *Mycoplasma*
 - *Chlamydia*

Drug	Dosage	Route	Indication
Doxycycline	PO: 100-200mg/ daily IV: 100mg every 12h	PO, IV	Respiratory tract infections, skin & soft tissue infections, cholera, STIs, rickettsial infections, cholera, meningitis, malaria prevention
Minocycline	Initial for PO/IV → 200 mg Maintenance PO: 100mg every 12h OR 50mg 4x daily Maintenance IV: 100mg every 12h	PO, IV	

Tetracyclines

Doxycycline
Minocycline

- Special Considerations
 - Minocycline → lupus-like reaction
 - Tetracyclines can increase liver enzymes.
 - Hepatitis and liver failure have been reported with Minocycline
 - Avoid in patients with hepatic insufficiency
 - Okay to use doxycycline in renal failure because only small percentage excreted renally

Other Antibiotics...

Clindamycin

- Mechanism of action → bacteriostatic → inhibits protein synthesis
- Can be given IM, IV, or PO
- Active against gram positive organisms and anaerobes
- Indications → bacteremia, skin & soft tissue infections, intra-abdominal infections, respiratory tract infections, & gynecological infections
- Side effects: site reaction, GI symptoms

Metronidazole

- Mechanism of action → bactericidal → inhibits DNA synthesis & degradation
- Can be given PO or IV
- Active against anaerobes and protozoal parasites
- Side effects: headache, dizziness, nausea, vaginitis

Nitrofurantoin

- Mechanism of action → bactericidal → inhibits DNA, RNA, and cell wall protein synthesis
- Given PO
- Antibiotic coverage varies slightly based on medication.
 - Macrobid → *E. Coli* and *Staphylococcus*
 - Macrochantin → *Enterococcus*, *Staphylococcus*, *E. Coli*, *Klebsiella*, *Enterobacter*
- Indications → acute uncomplicated cystitis
- Side effects: GI symptoms, headache

Vancomycin

- Mechanism of action → bactericidal → inhibits cell wall synthesis
- Can be given PO or IV
- Active against **gram positive organisms only**
- Side effects:
 - PO: nausea, abdominal pain, & hypokalemia

Prescribing Case Studies

Case Study #1

- Ms. Jones is a 52-year-old woman with no significant past medical history who presents with complaints of fever, productive cough, mild chest discomfort and shortness of breath.
- Vital signs of unremarkable with exception of a fever with temperature 100.1F.
- On physical exam she has rales to the left lower lobe and dullness to percussion.
- She has no recent history of antibiotic use.
- She reports an allergy to Levofloxacin (Levaquin).
- The NP diagnoses her with a community acquired pneumonia.

Case Study #1

- **Common bacteria implicated are: *Streptococcus pneumoniae*, *Haemophilus influenzae*, and *Moraxella catarrhalis*.**
- Based on what is known about Ms. Jones, what is the most appropriate antibiotic to prescribe?
 - a) Augmentin 2g twice daily
 - b) Doxycycline 100mg twice daily
 - c) Azithromycin 500 mg x 1 dose, followed by 250 mg x 4 days
 - d) Moxifloxacin 400 mg PO

Case Study #2

- Mr. Post is a 37-year-old man with no significant medical history who presents with nasal drainage, congestion, facial pain/pressure, cough, and scratchy throat x 3-4 days.
- He has no known drug allergies.
- His vital signs are unremarkable.
- The NP diagnoses an upper respiratory infection and sinusitis.
- What is the most appropriate antibiotic to prescribe for his sinusitis?

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Case Study #2

- Mr. Post returns approximately 1-1.5 weeks later with resolution of the cough and scratchy throat, but now reports purulent nasal drainage, congestion, and facial pain/pressure that has failed to improve.
- He has no known drug allergies.
- His vital signs are unremarkable.
- The NP diagnoses a sinusitis.
- **Common bacteria implicated are: *Staphylococcus*, *Streptococcus*, or *Haemophilus influenzae*.**
- What is the most appropriate antibiotic to prescribe for his sinusitis?
 - a) Amoxicillin
 - b) Ceftriaxone
 - c) Ampicillin/Sulbactam
 - d) Azithromycin

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Case Study #3

- Mrs. Reno is a 75-year-old woman with extensive past medical history/multiple co-morbid conditions admitted to the hospital for symptomatic atrial fibrillation with a syncopal episode prior to presentation. She has no recent hospitalizations.
- On Day 4, the plan was to discharge her, however, on evaluation, the patient has a low-grade fever, shortness of breath, and is requiring 2L oxygen to maintain sats >92%.
- On CBC → presence of leukocytosis.
- CXR reveals a right lower lobe infiltrate.
- The NP diagnoses her with a hospital acquired pneumonia (HAP).

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Case Study #3

- **In HAP, you want to ensure you cover for gram-negative organisms. Gram positive coverage (especially if concerned for resistance) is necessary if high gram-positive isolates or recent antibiotic therapy within 90 days.**
- What is the most appropriate antibiotic therapy for Mrs. Reno?
 - a) Ceftriaxone plus azithromycin
 - b) Doxycycline
 - c) Levofloxacin
 - d) Cefepime

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Questions??

Thank you!