

AHRQ Safety Program for Telemedicine: Improving Antibiotic Use

Antibiotics and What They Treat



Objectives

By the end of this presentation, participants will be able to—

- Describe the spectrum of activity of commonly prescribed antibiotics used in children and adults in the telemedicine setting¹
- Describe common antibiotic-associated adverse events in children and adults
- Describe common indications for oral antibiotics in children and adults in the telemedicine setting

Overview of Beta-Lactam Agents

- Gram-positive and gram-negative bacteria have cell walls made of peptidoglycans
 - Penicillin binding proteins (PBPs) cross-link peptidoglycans
 - Beta-lactams inhibit activity of PBPs
 - *Mycoplasma pneumoniae*, *Chlamydia pneumoniae*, and *Legionella pneumophila* do not have a cell wall and are not inhibited by beta-lactams
- Bacteria inhibits beta-lactam antibiotics by limiting their entry, actively pumping them out, altering PBPs, and producing inactivating enzymes

- **Common adverse events**

- Rashes
- Diarrhea
- Cytopenias
- Seizures



Penicillin²

- Penicillin VK (oral), penicillin G benzathine (IM), penicillin G aqueous (IV)
- Oral formulation: short half-life requiring frequent administration, limited absorption
- Intramuscular formulation: long half-life
- **Common outpatient indications of IM penicillin**
 - Early and late syphilis

Spectrum of Activity

Gram-positive	<i>Streptococcus pyogenes</i> (group A <i>Streptococcus</i>), <i>Streptococcus agalactiae</i> (group B <i>Streptococcus</i>), <i>Streptococcus pneumoniae</i>
Gram-negative	<i>Neisseria meningitidis</i>
Spirochetes	<i>Treponema pallidum</i> (syphilis)

Amoxicillin³⁻⁵

- β -lactamase production can cause resistance in gram-negative organisms
- Not appropriate empiric therapy for urinary tract infections (UTIs)
- **Common outpatient indications**
 - Group A Streptococcus pharyngitis
 - Group A Streptococcus skin and soft tissue infection (culture confirmed)
 - Community-acquired pneumonia
 - Acute otitis media
 - UTIs (antibiotic susceptibilities confirmed)
 - Lyme disease

Spectrum of Activity

Gram-positive	<i>Streptococcus pyogenes</i> (group A <i>Streptococcus</i>), <i>Streptococcus agalactiae</i> (group B <i>Streptococcus</i>), <i>Streptococcus pneumoniae</i> , <i>Enterococcus faecalis</i> , <i>Listeria monocytogenes</i>
Gram-negative	<i>Haemophilus influenzae</i> , enteric gram-negatives (e.g., <i>Escherichia coli</i>)
Spirochetes	<i>Borrelia burgdorferi</i> (Lyme disease)

Amoxicillin-Clavulanic Acid⁵⁻⁸

- Commonly referred to as Augmentin[®]
- **Notable adverse events:** diarrhea (20%)⁹
- **Common outpatient indications**
 - Sinusitis
 - Community-acquired pneumonia
 - Moderate chronic obstructive pulmonary disease exacerbation
 - Acute otitis media (if recent use of amoxicillin)
 - Moderate diverticulitis
 - Skin infections from animal bites
 - Urinary tract infections (if antibiotic susceptibilities confirmed)

Spectrum of Activity

Gram-positive	(All the gram-positives covered by amoxicillin) as well as MSSA
Gram-negative	<i>Haemophilus influenzae</i> , <i>Moraxella catarrhalis</i> , enteric gram-negatives (e.g., <i>Escherichia coli</i>)

First-Generation Cephalosporins¹⁰

- Cephalexin (Keflex[®]), and cefadroxil (Duricef[®])
- Cross-allergenicity between penicillin and cephalosporins <5%
- **Common outpatient indications**
 - Skin and soft tissue infections (when MRSA unlikely)
 - UTIs

Spectrum of Activity

Gram-positive	MSSA, <i>Streptococcus pyogenes</i> (group A <i>Streptococcus</i>), <i>Streptococcus agalactiae</i> (group B <i>Streptococcus</i>)
Gram-negative	Some enteric gram-negatives (e.g., <i>Escherichia coli</i> , <i>Klebsiella pneumoniae</i>)

Cefuroxime⁵⁻⁸

- Second-generation cephalosporin
- **Common outpatient indications**
 - Sinusitis (penicillin allergy)
 - Community-acquired pneumonia (penicillin allergy)
 - Moderate chronic obstructive pulmonary disease exacerbation
 - Acute otitis media (if severe penicillin allergy)

Spectrum of Activity

Gram-positives	<i>Streptococcus pyogenes</i> (group A <i>Streptococcus</i>), <i>Streptococcus agalactiae</i> (group B <i>Streptococcus</i>), <i>Streptococcus pneumoniae</i> MSSA
Gram-negatives	<i>Haemophilus influenzae</i> , <i>Moraxella catarrhalis</i>

Third-Generation Cephalosporins²

- IM ceftriaxone and several oral antibiotics
 - Examples: cefdinir (Omnicef[®]), cefpodoxime (Vantin[®]), cefixime (Suprax[®])
- Ceftriaxone preferred for gonococcal infections; resistance is a concern
- **Common outpatient indications**
 - IM ceftriaxone: gonorrhea
 - Oral third-generation cephalosporins: UTIs, bacterial respiratory tract infections

Spectrum of Activity

Gram-positives	<i>Streptococcus pyogenes</i> (group A <i>Streptococcus</i>), <i>Streptococcus agalactiae</i> (group B <i>Streptococcus</i>), <i>Streptococcus pneumoniae</i>
Gram-negatives	<i>Haemophilus influenzae</i> , <i>Moraxella catarrhalis</i> , <i>Neisseria gonorrhoeae</i> , gram-negative enterics
Spirochetes	<i>Borrelia burgdorferi</i> (Lyme disease)

Fluoroquinolones¹¹

- Calcium, magnesium, iron salts reduce absorption
- **Notable adverse events (all up to 10%)**
 - *Clostridioides difficile* infections
 - QTc prolongation (generally in patients with underlying arrhythmias)
 - Tendinopathy
 - CNS toxicities (dizziness, confusion, hallucinations)
- **Common outpatient indications**
 - Ciprofloxacin: UTIs
 - Levofloxacin, moxifloxacin: bacterial respiratory tract infections
 - Delafloxacin: skin and soft tissue infections, bacterial respiratory tract infections

Spectrum of Activity

Ciprofloxacin	Gram-negative enteric organisms, <i>Pseudomonas aeruginosa</i> , <i>Haemophilus influenzae</i>
Levofloxacin	Gram-negative enteric organisms, <i>P. aeruginosa</i> , <i>H. influenzae</i> , <i>Streptococcus pneumoniae</i> , atypical bacteria
Moxifloxacin	Gram-negative enteric organisms, <i>Haemophilus influenzae</i> , <i>Streptococcus pneumoniae</i> , atypical bacteria, moderate activity against intestinal anaerobes
Delafloxacin	Gram-negative enteric organisms, <i>H. influenzae</i> , MRSA, MSSA, <i>S. pneumoniae</i>

Doxycycline¹²⁻¹⁴

- Calcium, magnesium, iron salts reduce absorption
- Poor urinary excretion
- **Notable adverse events (all up to 10%)**
 - Gastrointestinal upset
 - Photosensitivity
 - Increased intracranial pressure
 - Pill esophagitis
- Safe to administer in children for ≤ 21 days

Spectrum of Activity

Gram-positive	MSSA, MRSA, <i>Streptococcus pyogenes</i> (group A <i>Streptococcus</i>), <i>Streptococcus pneumoniae</i>
Gram-negative	<i>Haemophilus influenzae</i> , some enteric gram-negatives (e.g., <i>Escherichia coli</i> , <i>Klebsiella pneumoniae</i>)
Others	<i>Mycoplasma pneumoniae</i> , <i>Chlamydia pneumoniae</i> , <i>Legionella pneumophila</i> , <i>Borrelia burgdorferi</i> (Lyme disease), <i>rickettsia</i> (Rocky Mountain spotted fever, ehrlichiosis), Plasmodium species (malaria), <i>Chlamydia trachomatis</i> (chlamydia)

Doxycycline, Continued¹²⁻¹⁴

- **Common outpatient indications**

- Skin and soft tissue infections
- Osteoarticular infections
- Bacterial respiratory tract infections
- Tick-borne illnesses
- Malaria prophylaxis
- Chlamydia

Spectrum of Activity

Gram-positive	MSSA, MRSA, <i>Streptococcus pyogenes</i> (group A <i>Streptococcus</i>), <i>Streptococcus pneumoniae</i>
Gram-negative	<i>Haemophilus influenzae</i> , some enteric gram-negatives (e.g., <i>Escherichia coli</i> , <i>Klebsiella pneumoniae</i>)
Others	<i>Mycoplasma pneumoniae</i> , <i>Chlamydia pneumoniae</i> , <i>Legionella pneumophila</i> , <i>Borrelia burgdorferi</i> (Lyme disease), <i>rickettsia</i> (Rocky Mountain spotted fever, ehrlichiosis), <i>Plasmodium</i> species (malaria), <i>Chlamydia trachomatis</i> (chlamydia)

Clindamycin¹⁴⁻¹⁵

- Clindamycin-resistant streptococcal and staphylococcal species increasing
 - Active against ~60% of MRSA isolates
 - Active against ~80% of Group A streptococcal isolates
- **Notable adverse events**
 - *C. difficile* infection
 - Gastrointestinal distress
- **Common outpatient indications**
 - Skin and soft tissue infections (if high suspicion for MRSA)

Spectrum of Activity

Gram-positives	MSSA, MRSA, <i>Streptococcus pyogenes</i> (group A <i>Streptococcus</i>)
Anaerobes	Oral anaerobes

Trimethoprim-Sulfamethoxazole (TMP-SMX)¹⁶⁻¹⁷

- Newer data indicate TMP-SMX (Bactrim[®], Septra[®]) against >95% of *S. pyogenes* isolates
- **Notable adverse events (all up to 10%)**
 - Hypersensitivity reactions
 - Bone marrow suppression
 - Acute kidney injury
 - Hyperkalemia
- **Common outpatient indications**
 - Skin and soft tissue infections
 - UTIs

Spectrum of Activity

MSSA, MRSA, *Streptococcus pyogenes* (group A *Streptococcus*), gram-negative enterics, *Stenotrophomonas maltophilia*, *Pneumocystis jirovecii*, *Toxoplasma gondii*, *Listeria monocytogenes*, *Nocardia* species

Linezolid¹⁸⁻¹⁹

- Brand name Zyvox[®]
- Broad gram-positive coverage
- **Notable adverse events (more commonly with >2 weeks of therapy)**
 - Myelosuppression (most commonly thrombocytopenia)
 - Optic and peripheral neuropathy
 - Serotonin syndrome
 - Lactic acidosis
- **Common outpatient indications**
 - Skin and soft tissue infections
 - UTIs due to vancomycin-resistant *Enterococcus*

Spectrum of Activity

MSSA, MRSA, *Streptococcus* spp., *Enterococcus* spp., *Nocardia*, *Mycobacteria* spp.

Azithromycin^{2,20-21}

- Long half life
 - A 5-day “Z-pack” lasts in the body about 10 days
- **Notable adverse events (both <1%)**
 - QTc prolongation (generally in patients with underlying arrhythmias)
 - Liver dysfunction
- **Common outpatient indications**
 - Mild bacterial respiratory tract infections
 - Chlamydia (if unable to take doxycycline)
 - Travelers’ diarrhea

Spectrum of Activity

Mycoplasma pneumoniae,
Chlamydia pneumoniae,
Legionella pneumophila,
Haemophilus influenzae,
Streptococcus pneumoniae
(~70%), *Chlamydia trachomatis*,
atypical Mycobacteria

Nitrofurantoin²²⁻²⁴

- Common brand names: Macrobid[®] (twice daily), Macrochantin[®] (four times daily)
- **Notable adverse events (both <1%)**
 - Acute pneumonitis
 - Chronic pulmonary fibrosis
- Avoid if significant renal dysfunction
- Avoid for pyelonephritis
- **Common outpatient indication**
 - Uncomplicated cystitis

Spectrum of Activity

Escherichia coli and other enteric gram-negatives (not *Pseudomonas aeruginosa*), *Staphylococcus saprophyticus* (cause of UTIs)

Fosfomycin²⁵

- Brand name Monurol[®]
- Available as a powder that is added to water
- **Notable adverse events**
 - Diarrhea (10%)
- Generally avoid for pyelonephritis
- **Common outpatient indication**
 - Uncomplicated cystitis

Spectrum of Activity

Escherichia coli and
Enterococcus faecalis

Gepotidacin²⁶⁻²⁷

- Belongs to a novel antibiotic class (i.e., a triazaacenaphthylene) that inhibits bacterial DNA replication
- **Notable adverse events**
 - Nausea and diarrhea in <5% of patients
- **Common outpatient indication**
 - FDA-approved 2025 for treatment of uncomplicated UTIs (i.e., cystitis)
 - FDA-approved for gonorrhea for patients with limited or no alternative treatment options

Spectrum of Activity

Escherichia coli, *Klebsiella pneumoniae*, *Citrobacter freundii* complex, *Staphylococcus saprophyticus* (cause of UTIs), *Enterococcus faecalis*, and *Neisseria gonorrhoea*

Pivmecillinam²⁸⁻³⁰

- Semi-synthetic penicillin derivative
- Extensive safety data in pregnant women
- **Notable adverse events**
 - Nausea and diarrhea in <5% of patients
- **Common outpatient indication**
 - FDA-approved in 2025 for treatment of uncomplicated UTIs (i.e., cystitis)
 - Expected activity against ESBL-producing *E. coli* UTIs

Spectrum of Activity

Escherichia coli, *Proteus mirabilis*, and *Staphylococcus saprophyticus*

Sulopenem³¹⁻³⁵

- Antibiotic belonging to a novel class (i.e., thiopenem) that is coformulated with probenecid
- **Notable adverse events**
 - Nausea and diarrhea in <10% of patients
- **Common outpatient indication**
 - FDA approved 2024 for treatment of uncomplicated urinary tract infections (i.e., cystitis)

Spectrum of Activity

Escherichia coli, *Klebsiella pneumoniae*, *Proteus mirabilis*, *Citrobacter spp.*, *Enterobacter cloacae* complex, *Providencia species*, *Staphylococcus saprophyticus*, and *Streptococcus agalactiae*

Metronidazole

- Broad anaerobic coverage
- **Notable adverse events**³⁶⁻³⁷
 - Nausea, vomiting, diarrhea, metallic taste
 - Reversible peripheral neuropathy, confusion, seizures (1% for courses ~1 week; 18% for courses >4 weeks)
- Interactions
 - Disulfiram-like reaction with alcohol consumption
 - Inhibits warfarin metabolism

Spectrum of Activity

Gram-positive anaerobes	<i>Clostridium</i> species
Gram-negative anaerobes	<i>Bacteroides</i> species, <i>Fusobacterium</i> species
Others	<i>Trichomonas vaginalis</i> , <i>Entamoeba histolytica</i> , <i>Giardia lamblia</i> , <i>Helicobacter pylori</i>

Metronidazole, Continued

- **Common outpatient indications of metronidazole**
 - Mild–moderate *Clostridioides difficile* infection
 - Component of peptic ulcer disease treatment
 - *Giardia* diarrhea
 - *Trichomonas* sexually transmitted infection

Spectrum of Activity

Gram-positive anaerobes	<i>Clostridium</i> species
Gram-negative anaerobes	<i>Bacteroides</i> species, <i>Fusobacterium</i> species
Others	<i>Trichomonas vaginalis</i> , <i>Entamoeba histolytica</i> , <i>Giardia lamblia</i> , <i>Helicobacter pylori</i>

Take-Home Messages

- ✓ Up to 40 percent of patients seen via telemedicine receive antibiotics
- ✓ Although antibiotics are necessary for many bacterial infections, all antibiotics also have associated harm
- ✓ It's important to understand the spectrum of activity, common antibiotic-associated adverse events, and common indications for oral antibiotics in the telemedicine setting

Disclaimer

- The findings and recommendations in this presentation are those of the authors, who are responsible for its content, and do not necessarily represent the views of AHRQ. No statement in this presentation should be construed as an official position of AHRQ or of the U.S. Department of Health and Human Services.
- Participants have an implied responsibility to use the newly acquired information to enhance patient outcomes and their own professional development. The information presented in this activity is not meant to serve as a guideline for patient management. Any procedures, medications, or other courses of diagnosis or treatment discussed or suggested in this activity should not be used by clinicians without evaluation of their patient's conditions and possible contraindications and/or dangers in use, review of any applicable manufacturer's product information, and comparison with recommendations of other authorities.

References – 1

1. Wittman SR, Hoberman A, Mehrotra A, et al. Antibiotic receipt for pediatric telemedicine visits with primary care vs direct-to-consumer vendors. *JAMA Netw Open*. 2024 Mar 4;7(3):e242359. PMID: 38483387.
2. Workowski KA, Bachmann LH, Chan PA, et al. Sexually transmitted infections treatment guidelines, 2021. *MMWR Recomm Rep*. 2021 Jul 23;70(4):1-187. PMID: 34292926.
3. Heilmann KP, Rice CL, Miller AL, et al. Decreasing prevalence of beta-lactamase production among respiratory tract isolates of *Haemophilus influenzae* in the United States. *Antimicrob Agents Chemother*. 2005 Jun;49(6):2561-4. PMID: 15917574.
4. Pormohammad A, Nasiri MJ, Azimi T. Prevalence of antibiotic resistance in *Escherichia coli* strains simultaneously isolated from humans, animals, food, and the environment: A systematic review and meta-analysis. *Infect Drug Resist*. 2019 May 8;12:1181-97. PMID: 31190907.
5. Lieberthal AS, Carroll AE, Chonmaitree T, et al. The diagnosis and management of acute otitis media. *Pediatrics*. 2013 Mar;131(3):e964-99. Epub 2013 Feb 25. PMID: 23439909.
6. Metlay JP, Waterer GW, Long AC, et al. Diagnosis and treatment of adults with community-acquired pneumonia. An official clinical practice guideline of the American Thoracic Society and Infectious Diseases Society of America. *Am J Respir Crit Care Med*. 2019 Oct 1;200(7):e45-e67. PMID: 31573350.
7. Chow AW, Benninger MS, Brook I, et al. IDSA clinical practice guideline for acute bacterial rhinosinusitis in children and adults. *Clin Infect Dis*. 2012 Apr;54(8):e72-e112. Epub 2012 Mar 20. PMID: 22438350.
8. Global Initiative for Chronic Obstructive Lung Disease (GOLD). Global Strategy for the Diagnosis, Management, and Prevention of Chronic Obstructive Pulmonary Disease: 2024 Report. <https://goldcopd.org/2024-gold-report/> Accessed April 6, 2026.

References – 2

9. Kuehn J, Ismael Z, Long PF, et al. Reported rates of diarrhea following oral penicillin therapy in pediatric clinical trials. *J Pediatr Pharmacol Ther*. 2015 Mar-Apr;20(2):90-104. PMID: 25964726.
10. Khan DA, Banerji A, Blumenthal KG, et al. Drug allergy: A 2022 practice parameter update. *J Allergy Clin Immunol*. 2022 Dec;150(6):1333-93. Epub 2022 Sep 17. PMID: 36122788.
11. Hussen NHA, Qadir SH, Rahman HS, et al. Long-term toxicity of fluoroquinolones: a comprehensive review. *Drug Chem Toxicol*. 2023 Jul 28:1-12. Epub ahead of print. PMID: 37501614.
12. Todd SR, Dahlgren FS, Traeger MS, et al. No visible dental staining in children treated with doxycycline for suspected Rocky Mountain Spotted Fever. *J Pediatr*. 2015 May;166(5):1246-51. PMID: 25794784.
13. Committee on Infectious Diseases, American Academy of Pediatrics. Red Book, 2018–2021: Report of the Committee on Infectious Diseases. Itasca, IL: American Academy of Pediatrics; 2018:905-6.
14. <https://www.cdc.gov/abcs/bact-facts/data-dashboard.html>. Accessed April 6, 2026.
15. Khamash DF, Voskertchian A, Tamma PD, et al. Increasing Clindamycin and Trimethoprim-Sulfamethoxazole resistance in pediatric *Staphylococcus aureus* infections. *J Pediatric Infect Dis Soc*. 2019 Sep 25;8(4):351-3. PMID: 30011009.
16. Bowen AC, Tong SY, Andrews RM, et al. Short-course oral co-trimoxazole versus intramuscular benzathine benzylpenicillin for impetigo in a highly endemic region: An open-label, randomised, controlled, non-inferiority trial. *Lancet*. 2014 Dec 13;384(9960):2132-40. PMID: 25172376.

References – 3

17. Bowen AC, Carapetis JR, Currie BJ, et al. Sulfamethoxazole-trimethoprim (Cotrimoxazole) for skin and soft tissue infections including impetigo, cellulitis, and abscess. *Open Forum Infect Dis*. 2017 Nov 2;4(4):ofx232. PMID: 29255730.
18. Douros A, Grabowski K, Stahlmann R. Drug-drug interactions and safety of linezolid, tedizolid, and other oxazolidinones. *Expert Opin Drug Metab Toxicol*. 2015;11(12):1849-59. PMID: 26457865.
19. Gatti M, Fusaroli M, Raschi E, et al. Serious adverse events with tedizolid and linezolid: Pharmacovigilance insights through the FDA adverse event reporting system. *Expert Opin Drug Saf*. 2021 Nov;20(11):1421-31. PMID: 34280062.
20. Svanström H, Pasternak B, Hviid A. Use of azithromycin and death from cardiovascular causes. *N Engl J Med*. 2013 May 2;368(18):1704-12. PMID: 23635050.
21. Malhotra-Kumar S, Lammens C, Coenen S, et al. Effect of azithromycin and clarithromycin therapy on pharyngeal carriage of macrolide-resistant streptococci in healthy volunteers: a randomised, double-blind, placebo-controlled study. *Lancet*. 2007 Feb 10;369(9560):482-90. PMID: 17292768.
22. Mendez JL, Nadrous HF, Hartman TE, et al. Chronic nitrofurantoin-induced lung disease. *Mayo Clin Proc*. 2005 Oct;80(10):1298-1302. PMID: 16212142.
23. Kabbara WK, Kordahi MC. Nitrofurantoin-induced pulmonary toxicity: A case report and review of the literature. *J Infect Public Health*. 2015 Jul-Aug;8(4):309-13. PMID: 25747822.
24. Huttner A, Verhaegh EM, Harbarth S, et al. Nitrofurantoin revisited: A systematic review and meta-analysis of controlled trials. *J Antimicrob Chemother*. 2015 Sep;70(9):2456-64. PMID: 26066581.

References – 4

25. Gupta K, Hooton TM, Naber KG, et al. International clinical practice guidelines for the treatment of acute uncomplicated cystitis and pyelonephritis in women: A 2010 update by the Infectious Diseases Society of America and the European Society for Microbiology and Infectious Diseases. *Clin Infect Dis*. 2011 Mar 1;52(5):e103-20. PMID: 21292654.
26. Wagenlehner F, Perry CR, Hooton TM, et al. Oral gepotidacin versus nitrofurantoin in patients with uncomplicated urinary tract infection (EAGLE-2 and EAGLE-3): two randomised, controlled, double-blind, double-dummy, phase 3, non-inferiority trials. *Lancet*. 2024 Feb 24;403(10428):741-55. Epub 2024 Feb 8. PMID: 38342126.
27. Ross JDC, Wilson J, Workowski KA, et al. Oral gepotidacin for the treatment of uncomplicated urogenital gonorrhoea (EAGLE-1): a phase 3 randomised, open-label, non-inferiority, multicentre study. *Lancet*. 2025 May 3;405(10489):1608-20. Epub 2025 Apr 14. PMID: 40245902.
28. Hawkins BK, Ding H, Harriott MM, et al. New perspectives on antimicrobial agents: pivmecillinam. *Antimicrob Agents Chemother*. 2025 Aug 6;69(8):e0182424. Epub 2025 Jul 21. PMID: 40689785.
29. Kaye KS, Santerre Henriksen A, Sommer M, et al. Safety and tolerability of pivmecillinam during more than four decades of clinical experience: a systematic review. *Clin Infect Dis*. 2025 Feb 24;80(2):280-99. PMID: 39835818.
30. Graninger W. Pivmecillinam--therapy of choice for lower urinary tract infection. *Int J Antimicrob Agents*. 2003 Oct;22 Suppl 2:73-8. PMID: 14527775.
31. Karlowsky JA, Adam HJ, Baxter MR, et al. In vitro activity of sulopenem, an oral penem, against urinary isolates of *Escherichia coli*. *Antimicrob Agents Chemother*. 2018 Dec 21;63(1):e01832-18. PMID: 30397056.

References – 5

32. Dunne MW, Aronin SI, Das AF, et al. Sulopenem for the treatment of complicated urinary tract infections including pyelonephritis: a phase 3, randomized trial. Clin Infect Dis. 2023 Jan 6;76(1):78-88. PMID: 36068705.
33. Dunne MW, Aronin SI, Das AF, et al. Sulopenem or ciprofloxacin for the treatment of uncomplicated urinary tract infections in women: a phase 3, randomized trial. Clin Infect Dis. 2023 Jan 6;76(1):66-77. PMID: 36069202.
34. Maher JM, Huband MD, Blankers CG, et al. In vitro activity of sulopenem and comparator agents against Enterobacterales and anaerobic clinical isolates collected during the SENTRY Antimicrobial Surveillance Program. J Antimicrob Chemother. 2023 Jun 1;78(6):1406-14. PMID: 37042351.
35. Zhanel GG, Pozdirca M, Golden AR, et al. Sulopenem: an intravenous and oral penem for the treatment of urinary tract infections due to multidrug-resistant bacteria. Drugs. 2022 Apr;82(5):533-57. Epub 2022 Mar 16. PMID: 35294769.
36. Daneman N, Cheng Y, Gomes T, et al. Metronidazole-associated neurologic events: A nested case-control study. Clin Infect Dis. 2021 Jun 15;72(12):2095-2100. PMID: 32303736.
37. Goolsby TA, Jakeman B, Gaynes RP. Clinical relevance of metronidazole and peripheral neuropathy: A systematic review of the literature. Int J Antimicrob Agents. 2018 Mar;51(3):319-325. Epub 2017 Sep 5. PMID: 28887203.