Gompf's Antibiotics Redux

A Pocket Tool for the Medical Student, or Resident on the Infectious Diseases Clinical Rotation
or
Just about anyone who could use a pocket antibiotic tool

By

Sandra G. Gompf, MD
Professor, Infectious Diseases
University of South Florida
Morsani College of Medicine
Tampa, FL

Updated APR 2024

ANTIBIOTIC PEARLS

1. Penicillins generally cover Gram +s, anaerobes, certain Gram –s depending on the antibiotic.

2. Cephalosporins generally cover Gram +s (EXCEPT Enterococcus!), Gram –s, & *oral* anaerobes--those *above* the diaphragm. ONLY ceftazidime/cefepime/ceftolozane cover Pseudomonas..

3. Aztreonam, a monobactam, covers ONLY Gram –s, incl. Pseudomonas. Reserve for beta lactam-allergic patients.

4. Aminoglycosides generally cover Gram +s (except tobramycin) & Gram –s, NO anaerobes, some Mycobacteria. Increasing resistance. Best in combination with beta lactams unless uncomplicated cystitis/pyelonephritis, but most use is declining due to nephrotoxicity & dual beta lactam options.

5. Quinolones cover Gram –s best (except moxifloxacin/delafloxacin, which are "respiratory quinolones" most active against Gram +s & anaerobes), some Mycobacteria.

6. Trimethoprim/sulfamethoxazole (TMP/SMX) generally covers MSSA/MRSA, Nocardia, Listeria, Pneumocystis, most Gram –s except Pseudomonas. Probably *OK* for Streptococcus pyogenes/agalactiae cellulitis as well.

7. Clindamycin generally covers Gram +s, incl anaerobes except Clostridia, like anaerobic/microaerophilic Strep/Peptostrep, Actinomyces (better for infections above the diaphragm).

8. Metronidazole covers *gut* anaerobes like Bacteroides, Prevotella, Clostridia; +/-Peptostrep (infections *below* the diaphragm).

9. Carbapenems in general are very broad & among our "last line" beta lactams. Use sparingly. Ertapenem covers most organisms except Pseudomonas. Imipenem, meropenem, & doripenem include Pseudomonas. Resistance in one carbapenem doesn't predict resistance in others.

10. Separate tetracyclines, quinolones, & Biktarvy at least 2+ hours from food & multivalent cations/mineral supplements

Shameless plug:

Visit www.gompfsidpearls.net for more regularly updated ID clinical tools & links I find useful in practice. :}

Do's & DON'Ts

1. ***Don't use an antibiotic if you don't need to.***
   - ***If a bacterial infection is not high in the differential and the patient is not clinically toxic, forgo antibiotics. They are poor antipyretics.***
2. ***Persistent fevers require work-up, not more antibiotics.***
   If you are treating with broad antibiotics and fevers persist, ***stop them***; they aren't helping.
   - Look for undrained foci of infection/pus → drain it.
   - Look for non-infectious cause → treat it.
   - True FUO in a rapidly deteriorating patient may warrant empiric anti-TB therapy → Call ID.
3. ***DO use an oral antibiotic when you can; use one narrow antibiotic when you can; stop antibiotics when you can.***
   - Antibiotics are not cheap; switch to PO when reasonable.
   - Two antibiotics don't always prevent resistance better than one, and neither do broad spectrum drugs. More drugs = more resistance.
     - But NEVER give Rifampin alone! Rapid high-level resistance occurs.
     - TB/Atypical mycobacteria: *NEVER* use 1 drug in *active* TB
   - DON'T treat viral infections (or noninfectious syndromes) with antibiotics beyond the point at which you have ruled out bacterial infection.

4. ***Don't combine 2 of the same class of antibiotics (e.g. 2 beta lactams, 2 quinolones) unless you have data or your friendly neighborhood ID specialist to back it up. They may unpredictably antagonize, synergize, or double the adverse effects.*** E.g. Clindamycin-rifampin combo dramatically reduces clindamycin serum concentration.
   [https://doi.org/10.1016/j.jinf.2015.03.013; http://dx.doi.org/10.1684/ejd.2013.2213]

5. ***Always monitor for antibiotic adverse effects.***
   - Antibiotics are a double-edged sword. Respect them.
   - Watch for hypersensitivity/bone marrow suppression/interstitial nephritis/hepatotoxicity/drug fever with beta lactams, acute tubular necrosis/irreversible ototoxicity with aminoglycosides, & Clostridium difficile with almost all of them.
   - Watch for yeast overgrowth/Candidemia with prolonged/multiple antibiotic therapy.
   - C. diff. is easy to miss in 2 situations:
     - Colostomies – stumps/small bowel can be infected with C.diff.!
     - Spinal cord injured patients – unexplained abdominal distension & leukocytosis are a clue
   - RIFAMPIN REDUCES EFFECTIVENESS OF ORALCONTRACEPTIVES! Tell female patients to *add barrier contraception until the next new pill pack* after finishing antibiotics.

Antifungal coverage in general:

fluconazole = Cryptococcus, Coccidioides, dermatophytes, Candida EXCEPT Candida krusei/auris/some glabrata and all molds; high CSF/urine levels
itraconazole = Candida, Histoplasma, Crypto, Cocci, Aspergillus, Sporothrix, Paracocci, Talaromyces
voriconazole = Candida, Histo, Crypto, Aspergillus (except a few rare species, Fusarium, NOT initially for Mucor/Rhizopus, but OK as step-down after ampho B/source control; good CSF/poor urine levels
posaconazole = same as vori, + Mucor/Rhizopus; variable CSF levels
isavuconazonium 372mg (= isavuconazole 200mg) = same as posa, some Mucor, INFERIOR to caspofungin for *candidemia; few drug interactions; poor CSF/urine levels*
enchinocandins (caspofungin/micafungin/anidulafungin) = Candida incl C. auris, Aspergillus, SOME Cryptococcus, NOT Fusarium/Mucor/Rhizopus/Trichosporon, NOT Histo/Blasto/Coccidioides; poor levels in CSF/urine/vitreous humor. Poor urine penetration, but does penetrate renal parenchyma, so may be effective in pyelonephritis, maybe cystitis. May allow you to avoid ampho B in the case of fluconazole resistant Candida.
amphotericin B = all, +/- Fusarium, NOT Candida lusitaniae (variable)/guillermondi/auris, NOT Scedosporium (Pseudallescheria), Lomentospora (Scedosporium); Aspergillus terreus
flucytosine (5-flourocystosine) - increases penetration of above drugs, rapid resistance alone; good CSF/eye/urine levels

Fusarium: Vori 6mg/kg IV Q24H or 300mg PO x 1 d, then 4mg/kg/d IV or 200mg PO BID + Ampho B 1.2 mg/kg/d or ABLC 5mg/kg/d
Mucor: Ampho B 1.5mg/kg/d or liposomal ampho B or ABLC 5mg/kg/d + posaconazole/isuvaconazole (active metabolite of isuvaconazonium); NOT other azoles/enchinocandins

BacteriCIDAL vs. BacterioSTATIC
A consideration in choosing treatments for serious infection like severe sepsis, bacteremia, meningitis, pneumonia, endocarditis, neutropenic fever. A "cidal" drug kills quickly; a "static" drug slows or stops replication and/or toxic production. Whether it matters is somewhat controversial.

Beta lactams are CIDAL and penetrate tissues and inflamed meninges well. They are preferable in serious infection, including bacteremia, endovascular infection, CNS infection, and streptococcal cellulitis. Their microbial action is *time-dependent*, meaning that they are most effective the longer the concentration of drug in the affected site remains above the MIC of the bacteria. Thus, they can be dosed by *continuous or extended infusion*, which may also facilitate home & hemodialysis dosing. (UpToDate has a helpful chart; most drug databases like ePocrates, etc, don't offer alternative dosing recommendations.) Ceftazidime, cefepime, and ertapenem are stable enough to be given 3 times a week after hemodialysis. Ampicillin is stable at least 24 hrs for extended and continuous infusion.

Extended Spectrum Beta Lactamase (ESBL)-Producing Gram Negative Bacilli: It's complicated & evolving as fast as these organisms!

SPICE/SPACE/KEC are mnemonics for bacteria that *may* either have *intrinsic* (chromosome-based, aka "constitutive") and/or *inducible* beta lactamases (chromosome- OR mobile genetic element/plasmid-mediated beta lactamases). **These organisms may demonstrate variable resistance to commonly prescribed beta lactams and may require carbapenem* treatment**. In addition, *inducible* beta lactamases in KEC organisms may become reversibly de-repressed (or "switched on") upon 1- 7 days' exposure to a beta lactam and result in treatment failure. **Cefepime is a weak AmpC inducer** and stands up to hydrolysis by AmpC β-lactamase, so is generally a good choice if the organism is susceptible.

	Strong Inducers	Weak Inducers
Good Substrates	Aminopenicillins, first-generation cephalosporins, cefoxitin, cefotetan	Ceftazidime, ceftriaxone, cefotaxime, piperacillin, ticarcillin, aztreonam
Poor Substrates	Imipenem	Cefepime, meropenem

TL/DR: If suspecting severe sepsis, use ceftolozane-taz, ceftaz-avibactam, meropenem, or piperacillin-taz if MIC <16mg/L**; otherwise, can deescalate to cefepime if MIC ≤ 1 mg/L if stabilized, off pressors, etc. Some beta lactams are weak inducers of

KEC(Y) – Grouped by Family Enterobacteriaceae with **moderate-high risk of *inducible*, chromosomal beta-lactamase (AmpC, Group C, cephalosporinase)—KNOW that these may trick you by testing S to ceftriaxone/ceftazidime→ treatment with cephalosporins may *induce* R**. Inducible beta lactamases may become reversibly de-repressed (or "switched on") upon 1- 7 days' exposure to a beta lactam and result in treatment failure.

[Aside: Klebsiella pneumoniae & some E.coli often acquire a non-inducible, plasmid-based Group A beta lactamase (TEM) with a narrow spectrum against ampicillin & 1st-gen cephalosporins. Just be aware that this pattern comes up often in susceptibility testing & does not confirm or rule out an inducible ESBL.]

Klebsiella aerogenes (formerly Enterobacter)
Enterobacter cloacae
Citrobacter freundii
Yersinia enterocolitica

SPACE/SPICE – **Treat based on susceptibility report and severity.** [These species' ampC mutations are ***usually not inducible***, so **these DO test R to ceftriaxone/ceftaz**idime, so *this mnemonic has fallen out of favor*.] **Consider:** Severity of infection (bacteremia, meningitis), high inoculum/source control (UTI/pyelonephritis vs endocarditis), presence of biofilm (infected device), & MICs to cefepime (≤ 1 mg/L) & pip-tazobactam (≤ 16 mg/L)** can help guide whether to use cefepime, pip-taz, or a carbapenem. Quinolones (bactericidal), trimethoprim-sulfamethoxazole (TMP-SMX), tetracyclines, and aminoglycosides are options if susceptible.

Presence of **chromosomal ("constitutive", "intrinsic")** or **mobile genetic element-**acquired (**plasmid-**mediated) beta lactamases.
Serratia/**S**almonella/**S**higella
Proteus (non-P. mirabilis/"**I**ndole +")/**P**rovidencia
Pseudomonas
Acinetobacter baumanii complex
Citrobacter species
Enterobacter complex
(**Y**ersinia enterocolitica – not enough data)

E. coli and Klebsiella are the most common ESBL producers, so many labs screen those isolates if MIC for ceftazidime is >/= 2 mg/L. Remember that **Klebsiella** almost all have a constitutive chromosome-based beta lactamase (usually SHV-1) & test R to ampicillin/ticarcillin.

*Note that carbapenems and the monobactam, aztreonam *are* beta lactams, as they *all* have a beta lactam ring. This may be confusing initially when you read about beta-lactam resistance and recommendations to use a beta lactam "versus" carbapenem; many articles gloss over this.

**MERINO Trial 2018 suggested higher 30-day all-cause mortality with pip-taz vs meropenem, but other trials and post-hoc analysis of MERINO have suggested MIC > 16mg/L to pip-taz is responsible for the difference. If MIC is low, piperacillin-tazo may be acceptable as "carbapenem-sparing" in infections with source control (e.g. pyelonephritis without obstruction). See also Impact of the MIC of Piperacillin-

Tazobactam on the Outcome of Patients with Bacteremia Due to Extended-Spectrum-Lactamase Producing Escherichia coli, 2013; Association Between Minimum Inhibitory Concentration, Beta-lactamase Genes and Mortality for Patients Treated With Piperacillin/Tazobactam or Meropenem From the MERINO Study 10/27/2020; IDSA Guidance on the Treatment of Antimicrobial-Resistant Gram-Negative Infections: Version 2.0, 3/31/2022.)

Carbapenem (CP) Resistant Gram Negative Bacilli:
(Carbapenem attached to the beta lactam ring is what preserves activity against ESBL.) Affects mainly **Klebsiella pneumoniae, Pseudomonas aeruginosa and Acinetobacter baumannii (CRAB)**. May possess intrinsic vs mobile genetic element carbapenemase-encoding genes that inactivate enzymes, induce efflux pumps or limit porin channels. Carbapenems are not necessarily interchangeable.

Antibiotics for Resistant Gram + Cocci

- Vancomycin, teichoplanin (Europe) cover all but vancomycin-resistant Gram +s.
- Vancomycin is bacterioSTATIC against Enterococcus.
- Dalbavancin, oritavancin, televancin - same mechanism as vancomycin & susceptibility generally correlates with vancomycin susceptibility; they add VRE, VISA/VRSA coverage.
- Daptomycin is bacteriCIDAL for both MRSA and Enterococcus & penetrates biofilm.
- Linezolid & tigecycline are bacterioSTATIC, NOT a choice for bacteremia unless no other options are possible, and not as monotherapy, unless you can cite legitimate supportive data.
- Tigecycline is difficult to tolerate due to 20% nausea/vomiting & associated with higher mortality than comparators for FDA-approved indications in after-market review of pooled clinical trials.
- All but vancomycin are EXPENSIVE & generally reserved for vancomycin-resistant Gram +s.

Pseudomonas *other than* P. aeruginosa, Acinetobacter, Stenotrophomonas vs other GNR

- **Strict aerobes** that will *not* grow in anaerobic culture.
  - P. aeruginosa is *usually* aerobic but is facultatively anaerobic in the presence of nitrogen & L-arginine.
- Acinetobacter spp. are often intrinsically resistant to multiple antibiotics including **ertapenem** and may be variably susceptible to meropenem or imipenem (*susceptibility to one carbapenem does not predict susceptibility to another!*)
- Stenotrophomonas are intrinsically resistant to *carbapenems*; generally most susceptible to quinolones, sulfas, and tetracyclines.
- These species are not of the family Enterobacteriaceae & often affect patients whose microbiome has been altered by extensive antibiotic/healthcare exposure.

Beware of Enterococcus

Enterococcus in well-defined polymicrobial infections (cholecystitis, GI perforation, decubitus infections) tends to be somewhat of an opportunist & clears once source control is achieved, even if it spills into blood). Isolated Enterococcus faecalis/faecium bacteremia or hematogenous infection (septic arthritis, vertebral osteomyelitis, endocarditis, "community-acquired" bacteremia without an immediately source) should raise as much concern as Staphylococcus aureus. In that setting, even if reported as very ampicillin/penicillin-susceptible, and ampicillin is considered "drug of choice", know that these organisms have *lower*-affinity penicillin-binding proteins than other Gram + cocci, and "tolerance" may also occur with intermittent dosing of ampicillin/penicillin, which should be considered bacterioSTATIC. Synergistic combination therapy is preferred for these infections, such as amp + gentamicin. Amp + ceftriaxone/ceftaroline is increasingly preferred due to nephrotoxicity with gent & gent resistance. The combination of these beta lactams binds more PBPs that ampicillin alone & lowers the ampicillin MIC. In addition, know that vancomycin is bactericidal for most GPCs *except Enterococcus* (bacterioSTATIC).

Which antibiotics are bacterioSTATIC?

"In sepsis, restore **V**olume with a **L**iter of **ST**AT **NM**L (normal) **S**aline."

Vancomycin in Enterococcus – cidal for all other GPCs

Linezolid/**L**efamulin
Sulfas/trimethoprim (*especially static against Stenotrophomonas*)
Tetracyclines/**T**igecycline
Nitrofurantoin (cidal in cystitis if concentration > 2x MIC)
"MLS antibiotic group" – clindamycin, macrolides (Note: Streptogramins are bactericidal)

Everything else is bactericidal.
Note bene: Clindamycin & linezolid are best studied as *adjuncts* for Staph or Strep toxic shock, severe streptococcal cellulitis or suspected necrotizing infection; *halt protein synthesis*—stops production of toxins that mediate severe inflammation, necrosis, and toxic shock. Many Staphylococcus aureus strains carry *inducible* clindamycin resistance genes, so I suggest having susceptibilities available before relying on clindamycin alone for this pathogen (if your lab doesn't report inducible clindamycin resistance, check for erythromycin resistance--- *erm* mutation! ---as a clue). Other drugs whose mechanism of action is disruption of protein synthesis: doxycycline/minocycline/tigecycline.

What does the MIC mean & how do we use it?

The MIC is the lowest concentration of an antimicrobial agent that completely prevents visible growth of the test strain of an organism in culture. Each antibiotic will have a different MIC for each organism. The MIC value of an antibiotic must be compared with clinical outcomes for the disease caused by a given organism; in some cases, this is further drilled down to differentiate between clinical scenarios (e.g., meningitis vs UTI), and the pharmacokinetics of individual antimicrobials. This overview yields "*clinical breakpoints*" that define whether the strain is susceptible (S), susceptible dose dependent (SDD) or resistant (R) to the antibiotic. Clinical breakpoints are internationally reviewed & and adjusted yearly according to expert consensus, epidemiology, and clinical literature by EUCAST (European Committee on Antimicrobial Susceptibility Testing), the American CLSI (Clinical and Laboratory Standards Institute), and further updated by the FDA (Food and Drug Administration). Fortunately, your friendly hospital Micro lab and their automated systems do a LOT of the interpretation work for you. If Micro says it's susceptible, it usually is—just beware of SPICE/CEK (☝). And vancomycin "MIC creep" with S. aureus bacteremia—as MIC "creeps" above 1, so does treatment failure. Etc, etc.

Pharmacokinetics & Pharmacodynamics (PK/PD)

Important determinants of antibiotic dosing for maximal effect include time-dependent vs concentration-dependent activity, volume of distribution/Vd (obesity, serum albumin), and route of elimination (renal, hepatic [cytochrome P450 enzymes], GI).

Time-Dependent antibiotics depend on duration of time that free antibiotic levels remain in tissue above MIC, no post-antibiotic effect. Doses must be given at regular intervals to maintain activity. Low albumin levels may lower free antibiotic levels by allowing increased free antibiotic to be cleared before it gets into tissues (highly protein-bound antibiotics may need higher doses, esp with less susceptible organisms).

- All beta lactams, monobactam, carbapenems

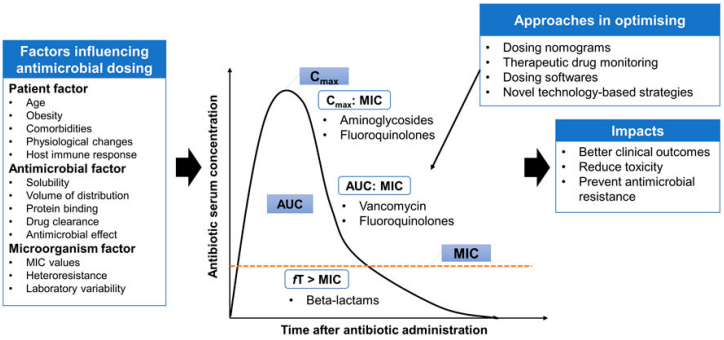
Concentration-dependent antibiotics act by achieving a high initial concentration & have a persistent "post-antibiotic effect"—i.e. bacterial growth is inhibited or "stunned" for a long time even after concentrations are no longer above MIC. Allows for extended dose intervals. Low albumin levels may lower free antibiotic levels by allowing increased free antibiotic to

be cleared before it gets into tissues. At higher doses, highly protein-bound antibiotics may maintain adequate serum concentration if enough free antibiotic is available; again, may need higher dose).

- Aminoglycosides
- Daptomycin
- Metronidazole
- Quinolones (mostly)

Combination of Time above MIC + Post-antibiotic Effect

- MLS group – macrolides, clindamycin, tetracyclines
- Linezolid
- Vancomycin – dosing is optimized by achieving certain concentration for certain period of time, or "area under the curve" (AUC) -based dosing



Protein binding of antibiotics & impact on "in vivo" MIC

Antibiotics must be able to cross from plasma into tissues to work, but beta lactams are variably protein-bound (mostly to albumin). The more highly protein bound, the lower the tissue level of free drug, e.g. "in vivo" MIC may be higher than that reported by Micro. Seriously ill/septic patients, those with high bacterial burden, or very immunosuppressed patients may not achieve adequate bactericidal levels of in tissues. In addition, hypoalbuminemia dilutes free drug in tissues (via "third spacing"), while free drug is cleared more rapidly by the kidney.

Table I. Protein binding of antibacterials commonly used in critically ill patients and of antibacterials in development (all protein binding data have been adapted from Donnelly et al.[26] and MIMS Australia[27]). We have also included data on antifungal agents for the reader's reference

Highly bound (>70%)	Moderately bound (70–30%)	Minimally bound (<30%)
Amphotericin B (90%)	Azithromycin (7–51%)	Amikacin (0–11%)
Anidulafungin (>99%)	Aztreonam (60%)	Amoxicillin (17–20%)
Caspofungin (97%)	Cefotaxime (40%)	Ampicillin (15–25%)
Cefazolin (75–85%)	Cefuroxime (33–50%)	Cefepime (16–19%)
Cefonicid (98%)	Cephalothin (55–75%)	Ceftazidime (17%)
Cefoperazone (90%)	Ciprofloxacin (20–40%)	Ceftobiprole (22%)
Cefoxitin (80–50%)	Clarithromycin (42–50%)	Cefpirome (9%)
Ceftriaxone (85–95%)	Chloramphenicol (60%)	Colistin (<10%)
Clindamycin (90% bound to α_1-acid glycoprotein)	Levofloxacin (50%)	Doripenem (8%)
Cloxacillin (94%)	Linezolid (31%)	Ethambutol (20–30%)
Dalbavancin (93%)	Moxifloxacin (30–50%)	Fluconazole (11–12%)
Daptomycin (90–93%, 30% to α_1-acid glycoprotein)	Nitrofurantoin (40%)	Fosfomycin (0%)
Dicloxacillin (97%)	Benzylpenicillin [penicillin-G] (65%)	Gentamycin (<30%)
Doxycycline (93%)	Piperacillin (30%)	Imipenem (20%)
Ertapenem (85–95%)	Sulfamethoxazole (68%)	Isoniazide (0–10%)
Erythromycin (73–81%)	Ticarcillin (55%)	Meropenem (2%)
Faropenem (96–99%)	Trimethoprim (45%)	Metronidazole (<20%)
Flucloxacillin (95%)	Vancomycin (30–60%)	Norfloxacin (10–15%)
Fusidic acid (95–97%)	Voriconazole (58%)	Polymyxin B (<10%)
Iclaprim (93%)		Quinupristin/dalfopristin (11–26%)
Itraconazole (99.8%)		Tobramycin (<30%)
Lincomycin (80–90%)		
Minocycline (75%)		
Nafcillin (90%)		
Oxacillin (93%)		
Posaconazole (>97%)		
Rifampicin [rifampin] (80%)		
Sulfisoxazole (92%)		
Teicoplanin (90–95%)		
Telavancin (92–94%)		
Tigecycline (71–89%)		

"drugs that are strongly protein bound (≥90%) may differ markedly from minimally protein-bound drugs in terms of tissue penetration and half-life. The concentration of albumin and other protein may be altered under stress, surgery, pregnancy, and liver or kidney diseases; in such circumstances, monitoring free drug is more useful for strongly protein-bound drugs. For these patients, free drug levels correlate better with clinical picture than traditionally monitored total drug level [4]." https://www.sciencedirect.com/science/article/pii/B9780128020258000118

IV ceftaroline (<20%)
PO cefpodoxime (18-30%; 30% urine excreted in urine; UTI indication)
PO cefadroxil (20%; 90% excreted unchanged in urine; UTI indication)

Inoculum Effect & impact on "in vivo" MIC

Inoculum effect (IE) is the phenomenon where infections fail to clear in the setting of high bacterial burden (abscesses, endocarditis, lack of source control) despite treatment with an antibiotic with low in vitro MIC. Mechanisms are not fully understood. Inoculum effect (IE) was first recognized in cefazolin when MSSA infections, especially "deep" infections like endocarditis, failed to clear despite low MIC in vitro. We now know that IE may occur with other antibiotics (mostly beta lactams):

HIGHER IE ----------→ LOWER IE

vancomycin	ampicillin	amp-sulbactam	ceftriaxone	ceftaroline
cefazolin	piperacillin	pip-tazobactam	cefepime	daptomycin
dalbavancin	amoxicillin	amox-clavulanate	ceftazidime	ertapenem
		ceftolozane	meropenem	ceftaz-avibactam

Synergistic IV Antibiotic Combinations against Specific Pathogens

Rule #1 – Don't wing it! Synergy is not that common. Some combos may be antagonistic, so combine with care (i.e. Use only combos supported by good literature).

Cell wall active agents + cell wall active agents

- serious GPC/GNR infections
  - **Beta lactams + aminoglycosides**
    - AG disrupts cell wall (superoxides) → increases beta lactam cell wall penetration
    - AG also disrupts cell wall protein production
- serious Enterococcus faecalis/faecium infections
  - **Ampicillin + cephalosporins/ertapenem**

        - amp binds PBP 1,4,5 + ceph/erta binds PBP 2,3 = lower amp MIC
        - beta lactam also enhances cationic peptide activity against cell wall
        - now preferred to avoid nephrotoxicity of amp + gentamicin combo
- MSSA/MRSA persistent bacteremia/endocarditis salvage
    - **daptomycin + cephalosporins (esp ceftaroline)/ertapenem**
        - daptomycin has + surface charge, as does cell wall
        - beta lactams reduce + cell surface charge = improved binding
    - **cefazolin/ceftaroline + ertapenem** (meropenem can be safely used with ceftaro if SA & GNR infection!)
        - binds more PBPs
        - ceph also enhances cationic peptide activity against cell wall
- KPC carbapenemase-producing GNR (bla_{KPC} mutation)
    - **ertapenem + meropenem**
    - erta acts as ("suicide antibiotic" preferential affinity for carbapenemase—erta resistance is often alerts Micro to test for KPC)
- Carbapenem-R Acinetobacter (CRAB)
    - **Meropenem + sulbactam** (as ampicillin-sulbactam—high dose 6-9g/d for most effective sulbactam dose) or sulbactam-durlobactam)
    - **Polymixin B or colistin + carbapenem, tigecycline, or amp-sulbactam** – more to come!
- Invasive Aspergillosis, when avoiding nephrotoxicity
    - Echinocandin + azole antifungal – in hematologic malignancy, combination may reduce mortality vs azole alone [Ann Intern Med. 2015;162:81-89. doi:10.7326/M13-2508]

Drugs that penetrate the prostate:

- quinolones with Gram negative coverage
- trimethoprim-sulfamethoxazole
- doxycycline
- fosfomycin
- azithromycin
- beta lactams

THE CLASSES (not an exhaustive list)

Penicillins – beta lactams are CIDAL, good tissue penetration

DRUG	COVERAGE	USES	TOXICITY	Cerebral Spinal Fluid (CSF)
Natural Penicillins (PCN) $ IV penicillin G (benzylpenicillin) PO penicillin VK CIDAL -targets PCN binding proteins (PBPs)→cell wall disruption	Group A Strep (no resistance) Strep viridans Neisseria Capnocytophagia Actinomyces Fusobacterium Clostridia perfringens/tetani Pasteurella Treponema/ Leptospirosis NOT MSSA (resistant)	Skin/soft tissue (SST) Oral/dental infections	Hypersensitivity Stevens Johnson Interstitial nephritis Seizures (if high level) Bone marrow suppression C.difficile	YES if inflamed
Penicillinase-resistant PCN $ IV methicillin nafcillin oxacillin PO dicloxacillin CIDAL -targets PCN binding proteins (PBPs)→cell wall disruption -enhances cationic (cathelicidin) host peptide activity (PMNs) -resists PCNase (narrow spectrum beta lactamase)	MSSA MS S.epidermidis/other coagulase-negative Staphylococci S. lugdunensis Strep pyogenes (grp A) Strep agalactiae (grp B) Strep grp C,F,G Strep anginosus grp Strep pneumoniae (if susceptible)	SSTI Bacteremia Endovascular infections	Fever Hypersensitivity Stevens Johnson Interstitial nephritis Seizures (if high level) Bone marrow suppression Hepatotoxicity C.difficile	

AminoPCN $$ IV ampicillin amp/sulbactam PO amoxicillin ampicillin amox/clavulanate CIDAL -targets PCN binding proteins (PBP 1, 4, 5)→cell wall disruption -enhances cationic (cathelicidin) host peptide activity (PMNs)	Add to the above: Enterococci (PBP 5 can assume PBP1-3 roles) Listeria MSSA Most Pneumococcus Proteus Hemophilus influ. (beta lactamase negative) Salmonella/Shigella Anaerobes *Klebsiella are intrinsically resistant to amp/amox* (clavulanate/sulbactam don't add much activity) Note: High-dose amp-sulbactam may used as a source of *sulbactam* in treating MDR Acinetobacter	Otitis media Sinusitis SST Meningitis in elderly	Above	
CarboxyPCN $$ IV ticarcillin/clav (Europe) piperacillin piperacillin/tazobactam CIDAL	Adds to the above: Pseudomonas Enterobacteriaceae* Stenotrophomonas (ticar) Gut anaerobes MSSA Pip & Pip/tazo more potent for GNRs & more resistant to AmpC/ESBLs (See "SPICE" above) **Klebsiella is intrinsically R to ticarcillin*	Adds to above: Gut/ surgical infections Nosocomial pneumonia Prostate Osteomyelitis	Above	

Cephalosporins – Think of progressive broadening of spectrum from Gram + to Gram - with each generation. Beta lactams are CIDAL. [☺= can be dosed 3 times weekly in dialysis patients]
CROSS-ALLERGY (same side chains) between aztreonam – ceftazidime – cefiderocol

DRUG	COVERAGE	USES	TOXICITY	CSF
1st Generation $$ IV/IM cefazolin ☺ PO cephalexin cefadroxil CIDAL -targets PCN binding proteins (PBP 1,2)→cell wall disruption -enhances cationic (cathelicidin) host peptide activity (PMNs)	GPC/MSSA/streptococci, E. coli, Proteus, some Klebsiella (increasingly ampC+/ESBL) NOT Enterococci	SSTI Uncomplicated/Non-diabetic osteomyelitis PreOP prophylaxis	Hypersensitivity Bone marrow suppression Diarrhea C.difficile	POOR
2nd Generation $$ PO cefuroxime cefaclor IV cefuroxime cefamycins: cefoxitin cefotetan CIDAL -targets PCN binding proteins (PBP 2, 3)→cell wall disruption -enhances cationic (cathelicidin) host peptide activity (PMNs)	Streptococci, uncomplicated MSSA Pneumococcus Neisseria Some GNR except Pseudomonas **Cefamycins are the only ones that reliably cover *anaerobes*** NOT Enterococci	Community acquired pneumonia (CAP) meningitis OM/sinusitis Gonorrhea	Hypersensitivity RASH/Stevens Johnson w/ cefaclor High INR/PT w/ cefoxitin/ cefotetan Bone marrow suppression C.difficile	YES if strongly inflamed -- ceftriaxone >90% protein bound, low BBB penetration

3rd Generation $$ PO cefpodoxime cefdinir ceftibutinen cefixime IV ceftriaxone cefotaxime ceftazidime ☺ cefoperazone-sulbactam CIDAL -targets PCN binding proteins (PBP 2, 3)→cell wall disruption -enhances cationic (cathelicidin) host peptide activity (PMNs)	Above; covers viridans streptococci, pneumococcus, but reduced PBP binding in MSSA **Anti-pseudomonal:** ceftazidime cefoperazone-sulb (adds beta lactam-R Bacteroides)	Meningitis CAP Most community-acquired infections Gonorrhea Pyelonephritis Best *PO* ceph for GU is cefpodoxime (20-30% protein-bound, vs PO cefdinir, which is poorly excreted in urine & up to 70% protein-bound)	Above Ceftriaxone: *Pseudo-cholelithiasis* (biliary sludge)	
4th Generation $$ IV cefepime ☺ CIDAL	Above, plus Pseudomonas More resistant to beta lactamases/ESBLs (See "SPICE" above) because it is not porin-dependent NOT Enterococci	Above, plus neutropenic fever	Above Cefepime: *Encephalopathy*, non-convulsive status epilepticus	

4th-ish Generation Siderophore cephalosporin IV cefiderocol Similar side chains as cefep & ceftaz CIDAL -targets PCN binding proteins PBP 3, PBP1a (PSA), PBP2 (KPC)→cell wall disruption -Trojan horse siderophore: Chelates Fe++, so drug is actively transported with Fe++ via siderophore channels	Reliably covers XDR/carbapenem-R: *Metallobetalactamase* producers (MBL) Klebsiella pneumoniae (KPC+) Pseudomonas aeruginosa (CRPA) Enterobacteriaceae (CRE) Acinetobacter baumanii (CRAB) Stenotrophomonas Burkholderia cepacian Colistin-R GNRs NO GPC!	Complicated UTI/pyelo HAP		Yes if inflamed
5th Generation Anti-pseudomonal $$$ IV ceftazidime-avibactam ceftolozane-tazobactam CIDAL -targets PCN binding proteins (PBP 2, 3)→cell wall disruption -enhances cationic (cathelicidin) host peptide activity (PMNs)	Viridans streptococci NOT Enterococci or Staphylococci ceftoloz-taz covers GNRs incl Pseudomonas, ESBLs, *some* carbapenemase producing P. aeruginosa (CRPA), NOT KPC+ ceftaz-avi covers ESBL & KPC+ carbapenemase (1st line agent) ceftaz-avi covers GNRs incl Pseudomonas, adds coverage for ceftaz-R, ESBLs, some ampC-R, *some* carbapenemases (NOT metallobetalactamase)	Complicated UTI/pyelo Complicated intraabdominal infection ceftaz-avi adds HAP	Above Nausea, diarrhea, headache, fever, renal insufficiency (ceftolaz-taz)	ceftazidime --- CSF: YES if inflamed (NOT avibactam) --- 90% renal excretion, unchanged (avibactam 97%) --- <10% protein bound metolazone --- CSF UNKNOWN --- > 95% renalexcretion, unchanged --- 30% protein bound

5th Generation Anti-MRSA $$$ IV ceftaroline ceftibiprole CIDAL MOA: -Targets PCN binding proteins, esp PBP2a (MRSA) & PBP 2b, 2x, 1a (PCN-R pneumo)→cell wall disruption -increases host cethelicidin peptide activity (PMNs)	Similar to 3rd generation, plus MRSA, VISA/VRSA/VRE faecalis (NOT E. faecium), PCN-R pneumococcus, beta-lactamase + H.flu, Moraxella Listeria NO Pseudomonas	Complicated SSTI, CAP (NOT MRSA-insufficient data)	Above	YES if strongly inflamed

Monobactam

DRUG	COVERAGE	USES	TOXICITY	CSF
aztreonam $$ IV CIDAL -targets PCN binding proteins (PBP 3)→cell wall disruption	ONLY GNRs, incl Pseudomonas Covers metallobetalactamase carbapenemases, but not ESBL (resistance usually occurs together)—combination of aztreonam + ceftazavibactam might be used in salvage cases (CID 2021;72:1871)	GNR infections; NOT a replacement for all aminoglycoside uses (no synergy for GPC, NO Enterococcal coverage)	Low Good alternative for beta lactam allergies EXCEPT with ceftazidime, cefiderocol	YES if inflamed [Modal J et al. AAC. 1986;29:281-3.]

Carbapenems (Beta lactams reserved for Multidrug Resistant Organisms – MDRO)

[☺ = can be dosed 3 times weekly in dialysis patients]

DRUG	COVERAGE	USES	TOXICITY	CSF
$$$ IV imipenem-cilastin meropenem meropenem-vaboractam imipenem-cilastin-relebactam CIDAL -targets PCN binding proteins (PBP 1,2,3,4) →cell wall disruption	GPCs EXCEPT MRSA GNRs EXCEPT Stenotrophomonas/Burkholderia ESBL+ & "SPICE" GNRs Anaerobes (incl Cutibacterium) Listeria Pneumococcus Nocardia asteroides (NOT brasiliensis) Legionella Mycobacterium avium Enterococcus (NOT E. faecium) mero-vaboractam adds *carbapenemase+ Klebsiella pneumonia (KPC)*, class A carbap-R Enterobacteraciae (NOT metallobetalactamase/OXA carbap-R, NOT carbap-R Pseudomonas/Acinetobacter) Relebactam is not active against Morganellacea group (Morganella, Proteus, Providentia)	Resistant GNR infections Serious gut infections Necrotizing pancreatitis	IV/IM Hypersensitivity (~10% cross-allergy with beta lactams) Seizures with imipenem (if renal insufficiency or high levels used) Candida overgrowth/ infections C.difficile	YES
$$$ IV doripenem CIDAL	Above, possibly lower MICs to Pseudomonas & Acinetobacter	Above Higher mortality than imipenem in VAP	Above	
$$$ IV/IM ertapenem ☺ CIDAL	Above, without Pseudomonas coverage	Postpartum uterine infections Postsurgical Abdominal infections (not Pseudomonas)	Above *Encephalopathy*	

Aminoglycosides

DRUG	COVERAGE	USES	TOXICITY/ MISC	CSF
$-$$$ IV gentamicin streptomycin spectinomycin tobramycin amikacin Nebulized tobramycin liposomal amika-cin CIDAL -disrupts cell wall (superoxides) → increases beta lactam cell wall penetration -disrupts cell wall protein production	Gent: VSE/VRE/variable Staph, GNRs incl Pseudomonas Tobra/Amik: GNRs incl Pseu-domonas Amik: TB, non-TB Mycobacteria Strepto -Yersinia -MDR Mtb Gent/Strepto -Tularemia Spectino -Gonorrhea NO coverage for: Acinetobac-ter/Stenotropho-monas Anaerobes Pneumococcus	Synergy with beta lactams for GPC/Pseud-omo-nas infections Usually not used alone except for UTIs	IV/Aerosol Acute tubular ne-crosis (reversible) Cochlear toxicity (genetic predispo-sition) Vestibular toxicity (irreversible) When possible: -stop after 3-5 d -use once-daily dosing -avoid in elderly Liposomal amik – hypersensitivity pneumonitis, hemoptysis, bron-chospasm, exac-erbation of lung disease Neuromuscular blockade (may exacerbate myas-thenia gravis & paralytic agents)	NO or UNKNOWN (use intrathecal)
$$ IV in Europe/Asia fosfomycin PO only in U.S. fosfomycin CIDAL	EUCAST 2021 breakpoints: E.coli, Enterococ-cus faecalis Other data, mostly Europe/Asia: MRSA ESBL Enterobac-teriaceae Possibly Pseudo-monas aeruginosa	Simple cystitis in women Off-label q3days for complicated or MDR GNRs, VRE if susceptible *Prostatitis*	PO only Above, significant diarrhea	
$$ IV plazomicin CIDAL	GNRs incl MDR/KPC/meta-lobetalact/CRE GNRs,variable Pseudomonas (use only if known susceptible), NOT	Complicated UTI/pyelonephritis	IV only Above Limited data	

	Steno, Acineto-bacter			

Sulfonamides/Sulfas (*INTRACELLULAR* ACTIVITY)

DRUG	COVERAGE	USES	TOXICITY/MISC	CSF
$ IV/PO trimethoprim-sulfamethoxazole (co-trimoxazole) -synergistic combo -sequentially inhibit folic acid pathway→protein synthesis inhibition STATIC -each drug alone CIDAL? -GNRs in urine -variable depending on organism; may not be cidal for Staph	Staph. aureus (incl MRSA) *(NOT Enterococcus, Pseudomonas, Acinetobacter)* *Legionella* *Stenotrophomonas* *Listeria* *Pneumocystis* *Nocardia* Burkholderia cepacia Moraxella Yersinia Francisella tularensis *Toxoplasma* Atypical mycobacteria (*M. marinum*) Some common coliforms	Cystitis/pyelonephritis *Prostatitis* MRSA SSTI Specific agents at left *Dosing depends on what you're treating*	IV/PO RASH/Stevens Johnson Nausea Fever Bone marrow suppression Hemolysis (if G6PD deficient) Hepatotoxicity *Elevated creatinine despite normal GFR* (competes with Cr for tubular secretion *Hyperkalemia* (blocks Na+ channels & thus K+ excretion) Kernicterus in neonates C.difficile Sun sensitivity	YES

Pleuromutilins (*INTRACELLULAR* ACTIVITY)

DRUG	COVERAGE	USES	TOXICITY/MISC	CSF
$$$ IV/PO Lefamulin** STATIC -Protein synthesis inhibitor – multiple binding sites to ribosome, higher resistance barrier	S. pneumoniae MSSA, ?MRSA Hemophilus influenzae Mycoplasma pneumoniae Chlamydia pneumoniae Legionella pneumophila	CAP/community-acquired pneumonia ** Bacteriostatic – be aware of this when empirically treating serious infections.	Nausea, hepatotoxicity, CNS Hypokalemia Prolonged QTc Teratogenicity C. difficile	UNKNOWN 70% fecal excretion

Macrolides/Lincosamides (Macrolide-Lincosamide-Streptrogramin B class, or MSL—all bind 50s ribosome subunit & share resistance genes)

DRUG	COVERAGE	USES	TOXICITY/MISC	CSF
Macrolides $$ IV/PO Erythromycin PO clarithromycin azithromycin STATIC -protein synthesis inhibitor, binds 50s ribosomal subunit	Pneumococcus IF local resistance is <25% MSStaph. aureus (not MRSA) Legionella Listeria Hemophilus Moraxella Mycoplasma *Pertussis* Neisseria meningitis Chlamydia/Hemophylus ducreyi Campylobacter Helicobacter pylori Salmonella/Shigella *Bartonella* Borrelia burgdorpheri (*Lyme* disease *Babesia* microti Actinomyces Atypical mycobacteria	LRTI/ bronchitis Sinusitis Dental/ oral infections *Prostatitis* Atypical mycobacteria (incl MAC prophy in HIV)	IV/PO Nausea/ vomiting Abdominal cramps/ diarrhea (Lowest with Azithro) C.difficile Ototoxicity with chronic use Rare association with cardiovascular mortality with QTc prolongation, low Mg++/K+. Interactions: Ery/Clari induce P450! Neuromuscular blockade with Ery (may exacerbate myasthenia gravis & paralytic agents)	Adequate – better for Mycoplasma, Legionella, Chlamydia

<u>Lincosamides</u> $$ IV/PO clindamycin STATIC -protein synthesis inhibitor, binds 50s ribosomal subunit	CIDAL for Group A streptococcus, MSStaph. aureus (MRSA, but watch for inducible *erm* resistance. Clue is resistance to erythromycin) Pneumococcus Inhibits toxic proteins in severe Strep A & S. aureus/ necrotizing fasciitis. Oral anaerobes: Gram + such as Peptostreptococcus, Fusobacterium, Prevotella, Actinomyces, & Clostridial spp other than Clostridium difficile Gram – such as Bacteroides (may not cover in up to 25% of cases or strains with MIC >/= 8 mcg/mL) Babesiosis	Severe SSTI, necrotizing fasciitis, MRSA *"Infections above the diaphragm"* Head and neck/dental infections Lung abscess/ aspiration pneumonia (*tip: no teeth = no anaerobes*) Bacterial vaginosis Babesiosis Toxoplasma in HIV	IV/PO <u>C.difficile!!</u> (>30% develop it on a week of clinda) Dysgeusia Rash, fever, eosinophilia Erythema multiforme Reversible neutropenia/thrombocytopenia Watch for hepatitis/obstructive jaundice, severe liver injury Neuromuscular blockade (may exacerbate myasthenia gravis & paralytic agents)	POOR except for Toxoplasmosis in HIV

Nitrofuran

DRUG	COVERAGE	USES	TOXICITY/MISC	CNS
$ PO nitrofurantoin CIDAL in urine -multiple targets including protein synthesis	GNRs EXCEPT Pseudomonas, Proteus, and Enterococcus incl susceptible VRE Multiple sites of action, inhibits synthesis of DNA, RNA, proteins, cell wall – higher resistance barrier than most antibiotics	Cystitis Susceptible ESBL GNRs ONLY reaches therapeutic level in URINE	PO only Nausea/ vomiting C.difficile Pulmonary – acute, chronic, reversible Hepatotoxicity Neuropathy if prolonged use	NONE

Quinolones (Resistance is rising due to overuse; single-step mutation→ resistance may arise *while on therapy*; *INTRACELLULAR* ACTIVITY; high concentration in bone, prostate, CSF)

DRUG	COVERAGE	USES	TOXICITY/MISC	CSF
"Gram negative" Quinolones $-$$ IV/PO ciprofloxacin levofloxacin PO norfloxacin CIDAL -targets DNA gyrase and topoisomerase IV -inhibits DNA synthesis	GNRs including Pseudomonas Levo covers pneumococcus & Stenotrophomonas well "Atypical" pneumonia: Mycoplasma, Chlamydia, Moraxella Some mycobacteria/TB	Cystitis/pyelonephritis *Prostatitis* Intraabdominal infections Endometritis Hospital-associated lung infections Levo best for acute sinusitis/ CAP Norflox: UTI only ***Combo with tetracyclines may be antagonistic.***	IV/PO *IV=PO (bioequivalent)* Dizziness/CNS Diarrhea Hypo-/hyperglycemia Sun sensitivity May exacerbate myasthenia gravis & paralytic agents (inhibits GABA receptors) May prolong QTc (watch for palpitations/syncope; avoid if QTc > 500msec, cardiomyopathy) Rare spontaneous tendon rupture (watch for pain at tendon sites) *Aortic dissection association* C.difficile	YES, HIGH DOSE
"Gram positive or Respiratory" Quinolone $$ PO moxifloxacin CIDAL -targets DNA gyrase and topoisomerase IV -inhibits DNA synthesis	Pneumococcus, Streptococci, Staphylococcus (NOT MRSA) Legionella Gut anaerobes Atypical mycobac/TB	CAP/community-associated respiratory infections Acute sinusitis Intraabdom-inal infections SSTI ***Combo with tetracyclines may be antagonistic.***	IV/PO *IV=PO (bioequivalent)* Above >60% *liver* excretion	UNKNOWN
"Gram positive or Respiratory" Quinolone $$ IV/PO delafloxacin	Streptococci, Staphylococcus *MRSA* Pseudomonas Legionella Gut anaerobes Atypical mycobac/TB	SSTI CAP/community-associated respiratory infections ***Combo with tetracyclines may be antagonistic.***	IV/PO *IV=PO (bioequivalent)* Above	UNKNOWN

CIDAL -targets DNA gyrase and topoisomerase IV -inhibits DNA synthesis				

Nitroimidazole

DRUG	COVERAGE	USES	TOXICITY/MISC	CSF
$$ IV/PO metronidazole CIDAL -degrades DNA by formation of N+-linked free radical -inhibits protein synthesis	Gram – anaerobes incl. Bacteroides fragilis and all Clostridia Entamoeba coli	*"Infections below the diaphragm"* Intraabdominal abscess, peritonitis, diverticulitis, etc Endometritis/ Bacterial vaginosis Clostridium difficile colitis Entamoeba liver abscess/ dysentery NOT to be given alone for lung abscess/ENT infections	IV/PO Disulfiram-like reaction (vomiting) if ethanol consumed within 3 days of therapy Aseptic meningitis/ neuropathies, rare	YES

Tetracyclines (*INTRACELLULAR* ACTIVITY)

DRUG	COVERAGE	USES	TOX-ICITY/MISC	CSF
Tetracyclines $ IV/PO Minocycline Doxycycline STATIC -inhibits protein synthesis -binds 30S ribosome subunit -lipid solubility: mino>doxy>tet	**MRSA**/MSSA Pneumococcus Enterococci (incl VRE. faecalis/faecium) +/- GAS E. coli Legionella N. meningitidis Hemophilus Moraxella Mycoplasma Chlamydia Listeria Brucella Actinomyces Borrelia burgdorferi Rickettsia Vibrio Treponema Anaerobes: Fusobacterium, Cutibacterium, Peptostreptococcus, Clostridium, some Bacteroides fragilis/melanogenicus	Acne/rosacea SSTI CAP, esp under age 40 Dog/cat bite prophy as alternative to amox/clav Tickborne diseases *Prostatitis* ***Combo with PCNs & Quinolones may be antagonistic.*** **Avoid giving PO within 4 hours of food, mineral supplements (reduce absorption)**	IV/PO Discoloration of permanent teeth in children Esophageal ulcer Hepatotoxicity Pseudotumor cerebri, esp minocycline! (watch for headache) Sun sensitivity C.difficile Inhibit lipopolysa-ccharide-induced proinflammatory products	YES (neuroborelliosis, syphilis)
Newer Tetracyclines $$ STATIC -inhibit protein synthesis IV tigecycline >** eravacycline* sarecycline (acne only) -strongly bind 30S ribosome subunit IV/PO omadacycline -binds 70S ribosome subunit	Above, plus Staph. epidermidis Enterococci Corynebacterium N. gonorrhea ESBL + E.coli/Klebs (NOT KPC) Stenotrophomonas Acinetobacter Salmonella B. fragilis/ anaerobes Clostridia incl. C.difficile NOT Pseudomonas, Burkholderia *eravacycline adds ESBL, carbap-R Acinetobacter	SSTI Intraabdo-inal infections CAP/HAP *Prostatitis* Severe C.difficile Y alveolar, soft tissue, bile/gut entry Poor bone/joint, CNS ** Bacteriostatic – be aware of this when empirically treating serious infections. > **Increased mortality** vs. comparators in after-market review of pooled clinical trials, incl in FDA-approved indications.	IV only Above 20% tige, 6.5% erava - nausea, vomiting Inhibit lipopolysaccharide-induced proinflammatory products */** Ampicillin/ Amoxicillin CIDAL-preferred in VRE that is amp-susceptible.	UNKNOWN

Glycopeptides, lipoglycopeptides

DRUG	COVERAGE	USES	TOXICITY/ MISC	CSF
$-$$$ IV/PO vancomycin CIDAL, except *STATIC for Enterococci* -Inhibits peptidoglycan cross-linking	Gram + cocci except VRE/VRSA *Most* Gram + rods (but see below) Corynebacterium Listeria C.diff (only PO) Increasing vancomycin MICs > 1 assoc with treatment failures ("MIC creep") **Instrinsic resistance in:** Leuconostoc Lactobacillus Propionobacterium Pediococcus Erysipelothrix Clostridia(non-diff.)	SSTI due to MRSA HAP/CAP due to MRSA Infections due to VRE	Vanc IV≠PO – PO not absorbed from gut Vanc requires a **central IV line**, due to phlebitis (which may cause fevers, unnecessary antibiotics/cultures/increased lengths of stay…) "Red man syndrome" with vanc (histamine release) if infused too rapidly—infuse over 1-2 hours Leukopenia Thrombocytopenia Rare interstitial necrosis Ototoxicity (abrupt, irreversible, usually elderly) Rarely, DRESS	YES
$$$ IV dalbavancin CIDAL -binds D-ala-D-ala, preventing cross-linking of cell wall precursor	MSSA, MRSA, VSEnterococcus, *not* VRSA/vanA-VRE, Group A, B streptococci, Strep anginosus group Inhibits peptidoglycan cross-linking	SSTI, osteomyelitis/prosthetic joint infection, endocarditis, bloodstream infection **346-hour half-life:** 1500mg IV x1 OR 1000mg IV then 500mg in 7 days, or even additional dosing at 28 days (Some variation in dosing exists due to very long half-life; adjust for GFR<30mL/min)	Nausea, headache, diarrhea Hepatotoxicity "Red man syndrome" with vanc (histamine release) if infused too rapidly—infuse over 1-2 hours	
$$$ IV televancin CIDAL -Inhibits peptidoglycan cross-linking + binds to	MSSA, MRSA/VISA/VRSA, Group A, B streptococci, Strep anginosus group, VSEnterococcus	SSTI HAPneumonia due to MRSA/VISA	N/V, foamy urine Nephrotoxicity QTc prolongation Mortality > with mod/sev renal impairment compared with vanco Possibly teratogenic—avoid in pregnancy	

peptide bridging in the cell wall.			unless maternal benefit exceeds fetal risk “Red man syndrome” with vanc (histamine release) if infused too rapidly—infuse over 1-2 hours Interferes with coag tests but not coagulation	
$$$ IV oritavancin CIDAL including *Enterococci* -Inhibits peptidoglycan cross-linking + binds to peptide bridging in the cell wall.	MSSA, MRSA, Group A, B, C streptococcus, Streptococcus anginosus group, VSEnterococcus	SSTI ****FAILED for osteomyelitis**** **245-hour half-life:** 1200mg IV x1, over 3 hr	Headache, N/V “Red man syndrome” with vanc (histamine release) if infused too rapidly—infuse over 1-2 hours Hepatotoxicity Artificially prolong PT/INR for up to 12 hr (5.1); aPTT for up to 120 hours, and may prolong PT and INR for up to 12 hr and ACT for up to 24 hr—Use Factor Xa assay for coagulation testing Coadministration with warfarin may result in higher exposure of warfarin and increase risk for bleeding; monitor frequently for signs of bleeding	

Cyclic Lipopeptides

DRUG	COVERAGE	USES	TOXICITY/ MISC	CSF
$$$$ IV daptomycin CIDAL -Inhibits peptidoglycan cross-linking	All Gram + cocci incl. Vanc-/Amp-resistant* Enterococcus MRSA/VRSA	SSTI Bacteremia Osteomyelitis, Joint infections May be active in biofilms (which usually inactivate antibiotics)	IV only False Prothrombin Time prolongation Nausea/vomiting Rhabdomyolysis & associated renal insufficiency (weekly creatinine, CPK) Rare asthmatic pulmonary eosinophilia NOT for primary pneumonia because it is inactivated in alveolar fluid BUT seems effective in embolic lung infection/septic emboli due to Gram +s, since the infection is more parenchymal. *ampicillin/ amoxicillin (CIDAL) preferred in VRE that is amp susceptible.	UNKNOWN

Oxazolidinone (*INTRACELLULAR* ACTIVITY)

DRUG	COVER-AGE	USES	TOXICITY/ MISC	CSF
$$$$ IV/PO linezolid STATIC except CIDAL for strepto-cocci -Binds 23S rRNA-blocks formation of 50s/70s ribosomal initiation complex	All Gram + cocci incl. ** vanc-/amp-resistant* Entero-coccus MRSA/VRSA TB/Atypical mycobacteria	SSTI MRSA HAP/CAP due to MRSA Osteomyelitis/ Joint infections (good bone penetration) **NOT for bacteremia without a well-defined and removal or draining focus, NOT for endovascular infections	*IV=PO (bioequivalent)* Nausea/ vomiting/ diarrhea Temporary tooth staining Headache Thrombocytopenia/ Neutropenia after 7 days Peripheral/ Optic neuropathies with extended use Lactic acidosis (nausea, fatigue) **Serotonin syndrome:** Avoid high tyramine food/drink, SSRIs (> 100mg tyramine per meal). E.g. aged cheeses, dried/processed meats, ethanol, sauerkraut, soy sauce, or yeast extract/supplements, ferments */**ampicillin/amoxicillin (CIDAL) preferred in VRE that is amp-susceptible. **Associated **with treatment failure in bacteremia**, incl line & endovascular infections.	GOOD Myrianthefs et al. Serum and CSF concentrations of linezolid in neurosurgery patients. AAC 2016. 50(12): 3971-6.

$$$$ IV/PO tedizolid STATIC -inhibits protein synthesis -binds 50S ribosomal subunit	All Gram + cocci incl. ** VRE, Amp-resistant* Enterococcus, MRSA/VRSA	SSTI	*IV=PO (bioequivalent)* 6 days tedizolid Qdaily = 10 days linezolid BID = higher lipid solubility/higher tissue levels Nausea/headache/diarrhea Lower thrombocytopenia than linezolid; similar neuropathic events; no longer term data **Serotonin syndrome:** Avoid high tyramine food/drink (> 100mg tyramine per meal). E.g. aged cheeses, dried/processed meats, ethanol, sauerkraut, soy sauce, or yeast extract/supplements, ferments	NO DATA – suspect similar to linezolid

Polymixins

DRUG	COVERAGE	USES	TOXICITY/MISC	CSF
$$$ IV colistin polymixin B colistimethate CIDAL -membrane disruption, binds lipopolysaccharide (LPS)/ Gram neg endotoxin	**Reserved for multi-drug resistant organisms (MDRO)** Gram - including Pseudomonas, Acinetobacter	Intraabdominal infections UTI/GU infections Pneumonia/ Hospital-associated respiratory infections Potent anti-LPS binding/ neutralizing activity	IV/Aerosol 30% Nephrotoxicity! Peripheral/ Optic neuropathies Neuromuscular blockade (may exacerbate myasthenia gravis & paralytic agents)	YES

Triazaacenaphthylene

DRUG	COVERAGE	USES	TOXICITY/MISC	CSF
$$$ IV gepotidacin CIDAL -inhibits DNA replication – blocks 2 essential topoisomerase enzymes	MSSA/MRSA Enterococcus faecalis Neisseria gonorrhea	Uncomplicated UTI Urogenital gonorrhea		NO

Rifamycins

DRUG	COVERAGE	USES	TOXICITY/MISC	CSF
$-$$ IV/PO rifampin PO rifabutin Only rifampin is discussed here, in context of use outside of mycobacterial infections CIDAL -Inhibits DNA-dependent RNA polymerase	Very broad, incl GPC/GNR, mycobacteria; use is *condition*-specific RAPID RESISTANCE if given alone – *Use in combinations*	*Only* used alone as prophylaxis against Neisseria meningitidis (2 days), Hemophilus influenza b (4 days) in contacts/nasal carriage Combination treatment in serious S. aureus, Streptococcal infections Combination treatment of Legionella, Anthrax, Brucella, Bartonella, Anaplasma, Ehrlichia Combination treatment of tuberculous and non-tuberculous Mycobacteria	IV/PO Red urine, sweat, tears, saliva – hold soft contact use Nausea, abd pain Hepatotoxicity (avoid ethanol & hepatotoxins), hyper-bilirubinemia Type I & Flu-like hypersensitivity Autoimmune reactions Many drug interactions – always check an updated reference	YES

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Acknowledgment:

Gratitude for support of my teaching efforts is owed to my alma mater, the University of South Florida Morsani College of Medicine Division of Infectious Diseases and International Medicine, and my distinguished professors there. I remain honored and very humbled to call them my colleagues these several years. I strive always to measure up to their high standards.

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Thank YOU, dear Colleague, for your dedication to the Art and Science of Medicine.
I hope that you find this tool of help in your care of the VIP at the center of our efforts:

The Patient.

Dr. G