



Romney Humphries, PhD D(ABMM)  
Professor, VUMC  
[Romney.Humphries@vumc.org](mailto:Romney.Humphries@vumc.org)

# Microbiology and Stewardship

THE ESSENTIAL ROLE OF CLINICAL MICROBIOLOGY IN  
ANTIMICROBIAL STEWARDSHIP

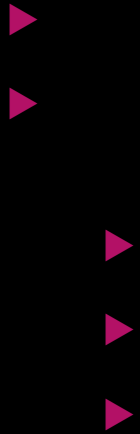
# Disclosures

- ▶ Consultant: Accelerate Diagnostics, ThermoFisher, GI Scientific, QPex
- ▶ Stocks: Accelerate Diagnostics

# Objectives

1. Identify core elements of laboratory testing that promote antimicrobial stewardship
2. Understand MIC-driven therapeutic decisions
3. Describe antimicrobial therapy challenges in critically ill patients

# Vanderbilt Univ. Medical Center



# Case 1.

- ▶ 57 year old man
- ▶ Suboccipital craniectomy for 4<sup>th</sup> ventricular ependymoma
- ▶ Post-surgery, develops altered mental status
- ▶ Febrile, leukocytosis to 29.6
- ▶ CSF: 60 WBC, Gram stain = GNR
- ▶ Meningitis/ventriculitis

## CSF Culture: *Enterobacter (Klebsiella) aerogenes*

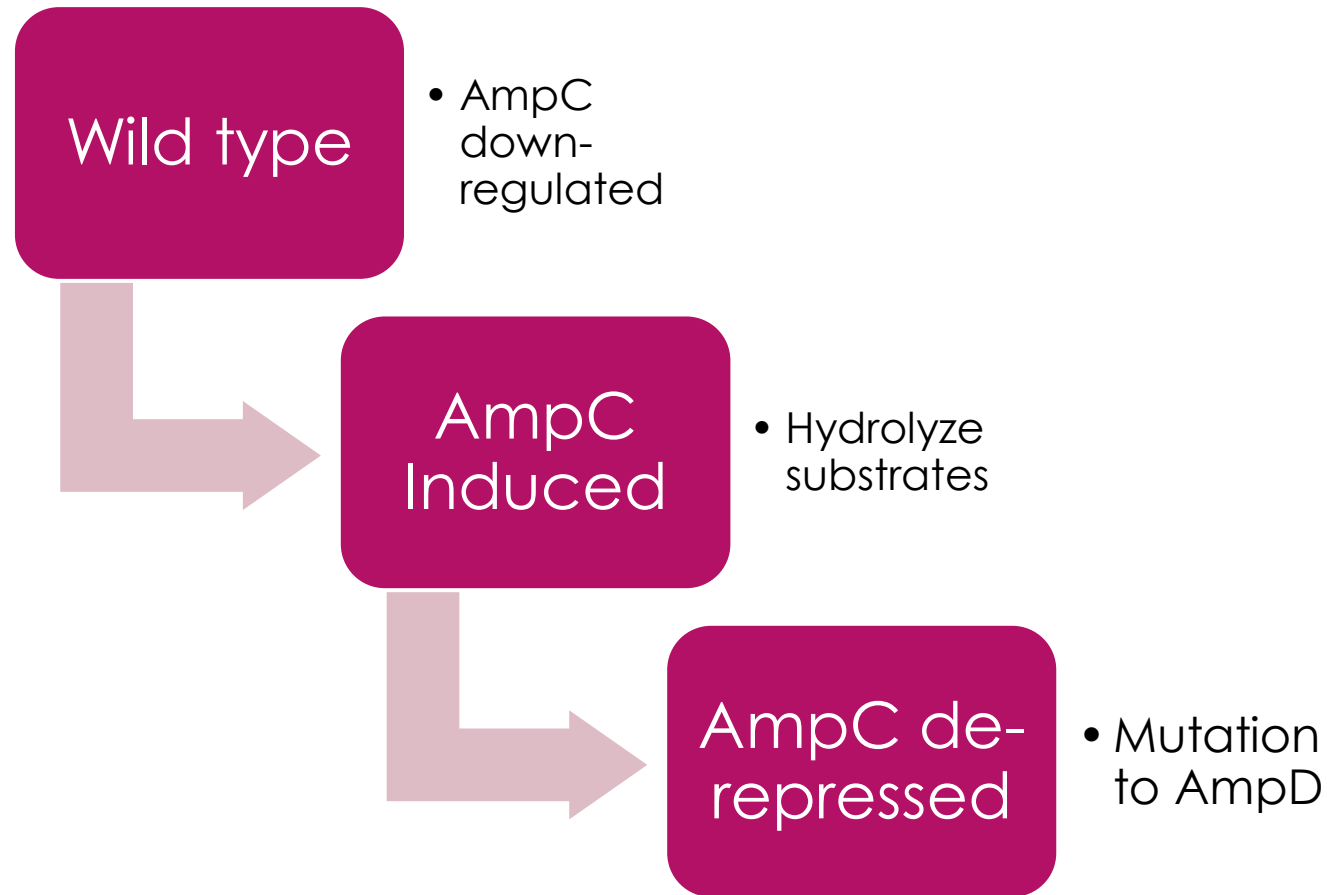
Antimicrobial	MIC (mcg/mL)	
Ampicillin	>16	R
Aztreonam	≤2	S
Cefepime	≤1	S
Ceftriaxone	≤1	S
Pip-tazo	4	S

# Case 1, continued

- ▶ Patient started empirically on cefepime, but changed to ceftriaxone due to seizures (toxicity?)
- ▶ Patient continues to have high WBC in CSF
- ▶ Repeat isolates recovered, but AST not performed
  - ▶ Laboratory policy is to repeat AST only every 5 days
- ▶ Finally, day 6, AST performed: “R” to ceftriaxone

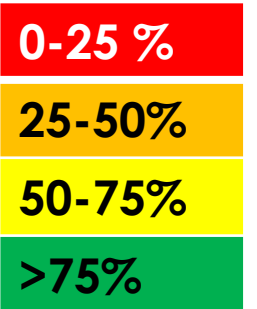
Antimicrobial	Isolate #1 Day 1	Isolate #2 Day 6
Ampicillin	>16, R	>16 R
Aztreonam	≤2, S	16, R
Cefepime	≤1, S	≤1, S
<b>Ceftriaxone</b>	<b>≤1, S</b>	<b>32, R</b>
<b>Pip-tazo</b>	<b>4, S</b>	<b>64, R</b>
Meropenem	S	S

# AmpC Induction Overview



# AmpC de-repressed mutants: Impact on AST results

Species	TZP	CTX	CAZ	FEP
<i>E. cloacae</i>	<5%	0%	0%	35%
<i>E. aerogenes</i>	10%	<5%	0%	98%
<i>C. freundii</i>	29%	0%	0%	80%
<i>P. rettgeri</i>	12%	5%	0%	81%
<i>S. marcescens</i>	55%	0%	75%	88%
<b>Typically</b>	<b>S or R</b>	<b>R</b>	<b>R</b>	<b>S</b>





# Review of AmpC VUMC: *Enterobacter, Citrobacter, Serratia* in Blood

N= 37 patients YTD in 2020

Initial culture results:

81% ceftriaxone – S

89% pip-tazo - S

	Total	%
Patients with repeat testing	28	76%
Repeat + culture grew on repeat testing	8	29%
Median duration of bacteremia	36 h	24-168 h
AST performed on repeat	3	37.5%
Number de-repressed AmpC	2	66.7%

50% of patients treated with ceftriaxone (n=4) suspected of de-repression due to clinical decompensation

## CLSI guidance

*Enterobacter, Klebsiella aerogenes, Citrobacter, and Serratia* may develop resistance during prolonged therapy with 3<sup>rd</sup>-generation cephalosporins as a result of derepression of AmpC beta-lactase. Therefore, isolate that are initially susceptible may become resistant within 3-4 days after initiation of therapy. Testing repeat isolates may be warranted." – M100 S30, page 34

# Opportunities for the lab

1. Provide guidance on frequency of repeating cultures
2. Repeat AST more often than every 5 days
3. “warning” re: use of ceftriaxone for AmpC organisms:
  1. Suppress ceftriaxone / ceftazidime results
  2. Provide a comment re: risk of AmpC de-repression

# Cascade / selective reporting

	Cascade Reporting	Selective reporting
Definition	Reporting broader antimicrobials only if more narrow spectrum agents are "R"	Suppressing select agent results from the laboratory reports based on ASP needs (e.g., formulary, select suppressions etc)
Example	Only report ertapenem if ceftriaxone is "R"	Suppress fluoroquinolone results from urine cultures to support ASP initiative to decrease their use in treatment of cystitis

## Example; cascade & selective reporting

### BLUE = selective

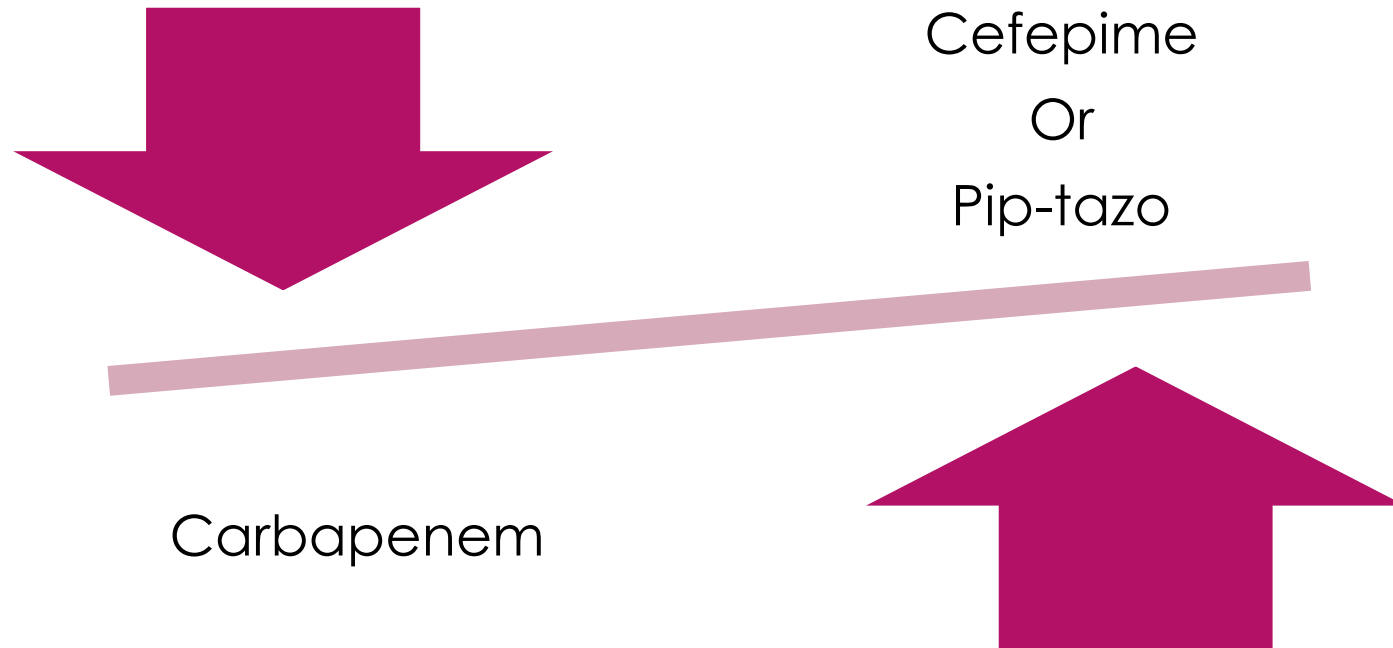
- Drives providers to make the right choice
- Hides 'harmful' choices
- Supports ASP

### RED = cascade

- Drives provider to pick narrow-spectrum
- Supports ASP

Test	Pan "S" E. coli	SPICE organism pan-S	ESBL type E. coli	ESBL type E. coli (urine)
Amikacin				
Gentamicin	Gentamicin	Gentamicin	Gentamicin	Gentamicin
Tobramycin				
Ampicillin	Ampicillin	Ampicillin (R)	Ampicillin (R)	Ampicillin (R)
Cefazolin	Cefazolin	Cefazolin (R)	Cefazolin (R)	urine breakpoints (R)
Aztreonam				
Ceftriaxone	Ceftriaxone		Ceftriaxone (R)	Ceftriaxone (R)
Ceftazidime				
Cefepime		Cefepime		
Ertapenem			Ertapenem	Ertapenem
Meropenem			Meropenem	Meropenem
Imipenem				
Pip-Tazo	Pip-tazo	Pip-tazo	Do not report (MERINO)	Do not report
Amp-sulb				Amp-Sulbactam
SXT	SXT	SXT	SXT	SXT
Nitrofurantoin				Nitrofurantoin
Ciprofloxacin	Ciprofloxacin	Ciprofloxacin	Ciprofloxacin	Ciprofloxacin
Levofloxacin				Levofloxacin
Ceftolo-tazo				
Ceftaz-avi				

# Treatment options

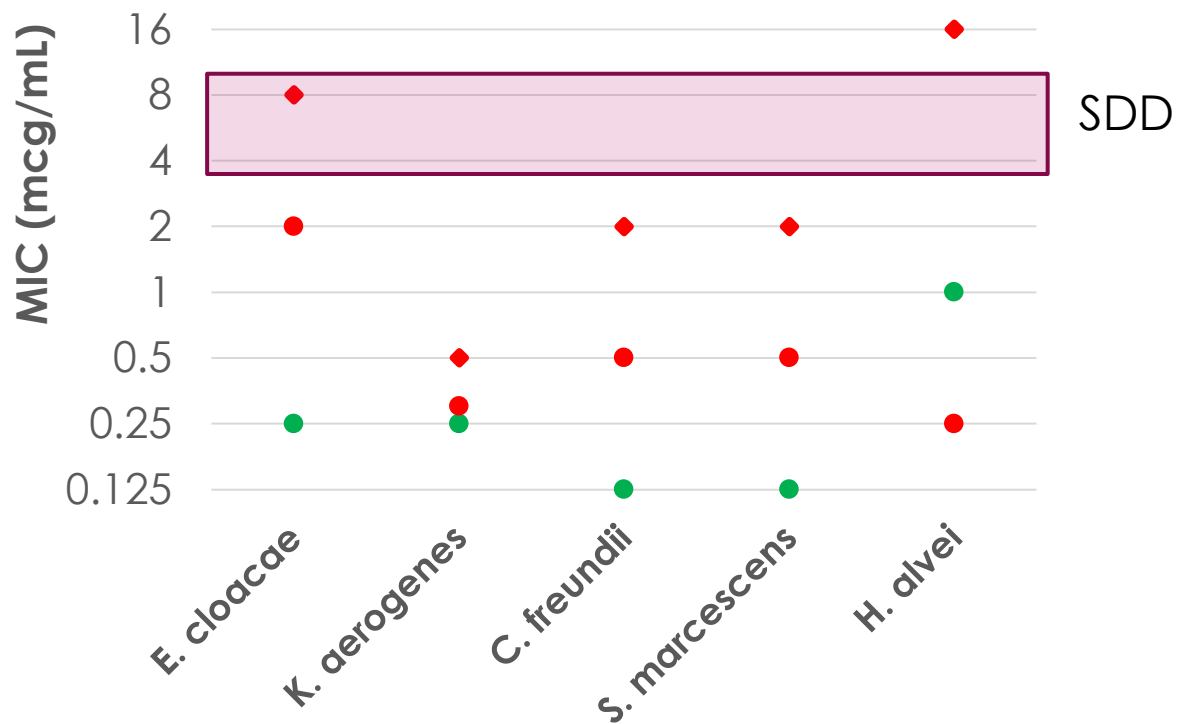


## Very little clinical data!

- Only retrospective studies
- Small "N"
- Significant bias in who gets a carbapenem vs. not (disease severity)
- Nice review by P. Tamma @ IDWeek 2020

# MIC matters

## Cefepime MICs



- MIC 90 uninduced
- MIC50 derepressed
- ◆ MIC90 derepressed

Interpretation	Dose
S	1 g q 12
SDD (4 mcg/mL)	1 g q 8 or 2 g q 12
SDD (8 mcg/mL)	2 g q 8

Combined with source control, disease severity and patient risk

# Case 2: COVID-19 Secondary bacterial pneumonia

- ▶ 65 YO man
- ▶ Diagnosed with COVID-19, late August
- ▶ intubated, high ventilation settings, deep sedation, paralysis
- ▶ Completed dexamethaxone, remdesivir, vancomycin & pip-tazo
  
- ▶ Transferred to VUMC at family's request
- ▶ Arrives septic, sputum produced with deep in-line suctioning





# Blood and respiratory cultures

HEAVY GROWTH OF  
*KLEBSIELLA PNEUMONIAE*

# AST RESULTS

ANTIMICROBIAL	MIC	Interpretation
Ampicillin	>16	R
Amp/sulb	>16	R
Aztreonam	>16	R
Cefepime	>16	R
Ceftriaxone	>32	R
Ertapenem	>4	R
Meropenem	8	R
Ceftaz-avibactam	>16	R
Ceftolozane-tazobactam	>32	R

Rapid blood culture test:

“CTX-M” detected

# Do these make sense?

ANTIMICROBIAL	MIC	Interpretation
Amikacin	≤8	S
Ampicillin	>16	R
Amp/sulb	>16	R
Aztreonam	>16	R
Cefepime	>16	R
Ceftriaxone	>32	R
Ertapenem	>4	R
Meropenem	8	R
Ceftaz-avibactam	16	R
Ceftolozane-tazobactam	>32	R

“CTX-M detected”



# Gram negative resistance prediction

## Appendix H, Table H4

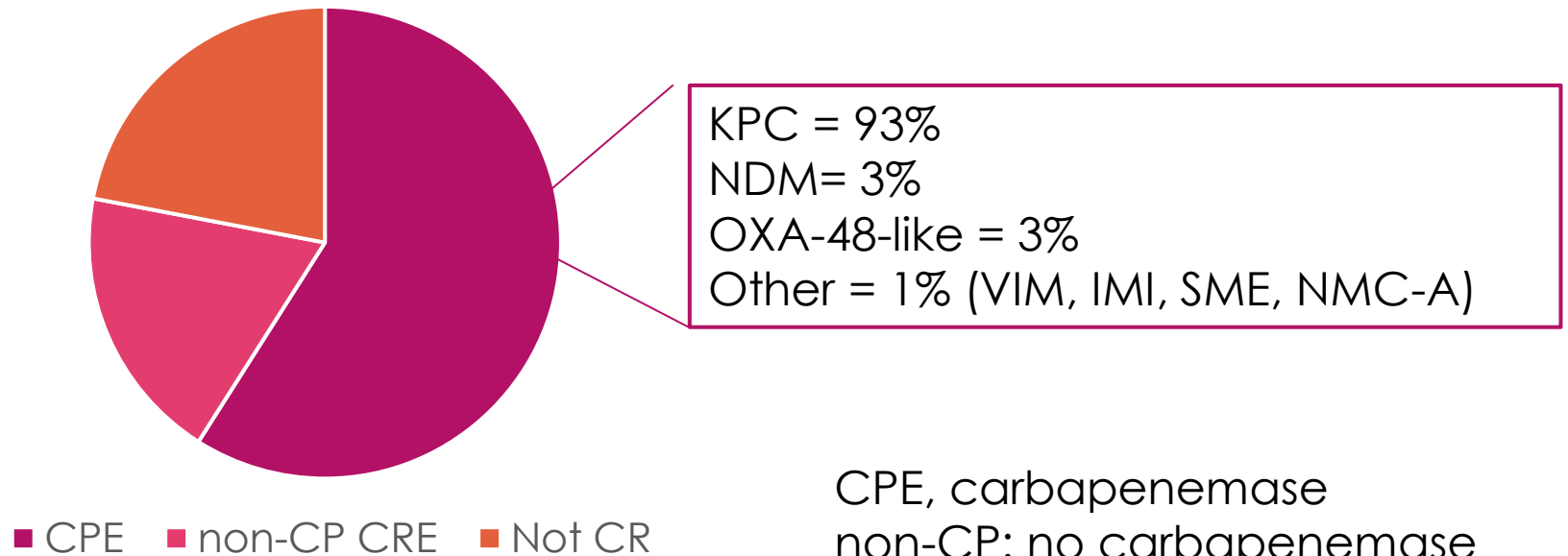
Detection of carbapenem resistance in <b>Enterobacterales</b>	KPC, OXA-48-like, VIM, NDM, or IMP	NAAT, microarray	Colony, blood culture	Detection of any tested carbapenemase target	Resistance to all carbapenems (eg, meropenem R, imipenem R, doripenem R, ertapenem R)	N/A	Report phenotypic results as found (if available); consider reporting presence of molecular target per institutional protocol.	1-4, 12-14
				Detection of any tested carbapenemase target	Susceptible to all carbapenems except ertapenem (variable) (eg, meropenem S, imipenem S, doripenem S, ertapenem R or S)	Repeat molecular and phenotypic tests. If blood culture, check for mixed culture. If mixed, test isolates individually and report phenotypic results as found; consider a phenotypic test for carbapenemase activity (such as CarbaNP or mCIM).	If the discrepancy is not resolved, repeat AST should be performed using a reference method and the conflicting genotypic and phenotypic testing results should both be reported along with a comment advising caution; current clinical and laboratory evidence is insufficient to conclude whether carbapenem monotherapy of carbapenemase-carrying strains with an MIC in the S range will be effective, or whether the molecular assays are completely accurate.	1-4, 12-15

Addresses carbapenems only...  
 Our isolate was "R" to the carbapenems  
 All tests repeat – same results.

So... are we good?

# Incidence of resistance mechanism: carbapenems

Among carbapenem-R Enterobacterales (CRACKLE-2)



CPE, carbapenemase  
non-CP: no carbapenemase  
Not CR: unconfirmed as  
carbapenem-R by central lab

# What about other beta-lactams?

## Enterobacterales

Agent on test system	No carb'ase	With carbapenemase		
		Class A	Class B	Class D
Ceftazidime-avibactam	Green	Green	Red	Green
Cefotolozane-tazobactam	Yellow	Red	Red	Red
Meropenem-vaborbactam	Green	Green	Red	Red
Aztreonam	Red	Red	*	Red
Cefepime	Red	Red	Red	Red

Intrinsic R or %S <30%	%S 30-80%	%S >80%
------------------------	-----------	---------

\* If no ESBL present

Typically expect "S" to ceftazidime avibactam...

- ✓ Always make sure the identification, genotype and phenotype match
- ✓ Troubleshoot discrepancies: re-ID, re-AST, purity plates
- ✓ When in doubt... report more resistant result
- ✓ Keep an eye out for trends & escalate

# Should we perform tests for carbapenemase?



- Best predictor of outcome = MIC
- May be confusing in light of other results
- Extra labor, QC, etc

- Help troubleshoot AST results
- Of value to predict activity of new antimicrobials
- Valuable for epidemiological studies



# Resolution...

- ▶ Performed mCIM test: **negative**
- ▶ Performed PCR for NDM, IMP, VIM, KPC, OXA-48: **negative**
- ▶ Performed Sensititre for ceftazidime-avibactam: **MIC of 16 mcg/mL, resistant**

Reported results as found...

Discussed case with team, agreed to investigate cefiderocol

Whole genome sequencing = plasmid AmpC in this isolate



# Clinical Evolution of AmpC-Mediated Ceftazidime-Avibactam and Cefiderocol Resistance in *Enterobacter cloacae* Complex Following Exposure to Cefepime

Ryan K Shields, Alina Iovleva, Ellen G Kline, Akito Kawai, Christi L McElheny, Yohei Doi ✉

*Clinical Infectious Diseases*, ciaa355, <https://doi.org/10.1093/cid/ciaa355>

**Published:** 01 April 2020    **Article history** ▼

“2-amino acid deletion in the R2 loop of AmpC beta-lactamase, which caused resistance to ceftazidime-avibactam, and reduced susceptibility to cefiderocol”

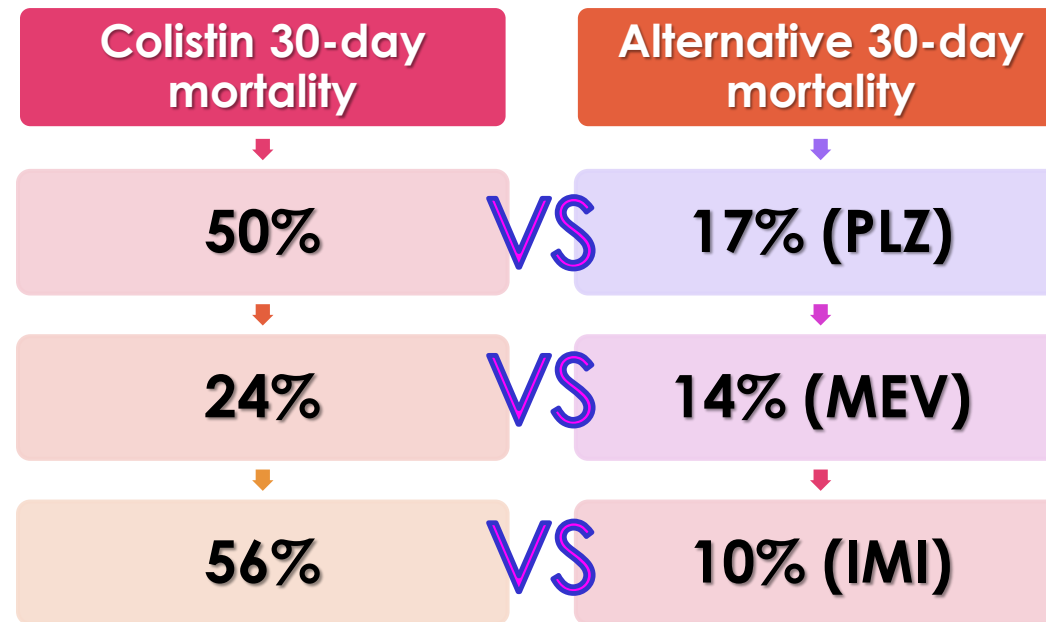
# Testing newer agents: GNRs

Agent	Test			
	Disk	Gradient strip	Automated Systems	Manual MIC
Ceftazidime-avibactam	✓	✓	✓	✓
Cefotolozane-tazobactam	✓	✓	✓	✓
Imipenem-relebactam	Hardy	Etest, MTS	Sensititre, Vitek 2	Sensititre
Meropenem-vaborbactam	✓	✓	✓	✓
Cefiderocol	Hardy	-	Sensititre	Sensititre
Eravacycline	Hardy	Etest, MTS	Mscan, Sensititre, Vitek 2	Sensititre
Plazomicin	Hardy	Etest, MTS	Sensititre	Sensititre
Colistin	No	No	RUO on some	RUO on some

✓ Available on most platforms

# A note about colistin...

**More patients die 30 days after therapy with colistin than with comparator agents**



Randomized controlled trials comparing colistin + 2nd drug (eg, imipenem) to newer agents for treatment of CRE.

Abbreviations: PLZ, plazomicin; MEV, meropenem-vaborbactam; IMI, imipenem-relebactam

# Infectious Diseases Society of America Guidance on the Treatment of Antimicrobial Resistant Gram-Negative Infections

Published by IDSA, 9/8/2020

A Focus on Extended-Spectrum  $\beta$ -lactamase Producing Enterobacterales (ESBL-E), Carbapenem-Resistant Enterobacterales (CRE), and *Pseudomonas aeruginosa* with Difficult-to-Treat Resistance (DTR-*P. aeruginosa*)

Pranita D. Tamma\*, Samuel L. Aitken, Robert A. Bonomo, Amy J. Mathers, David van Duin, Cornelius J. Clancy

*\*Corresponding Author*

# IDSA guidance: CRE\* treatment

If carbapenemase test not done or negative

Ertapenem	Meropenem	Preferred treatment	Alternative
R	S	Extended infusion meropenem	Ceftazidime-avibactam
R	R	Ceftazidime-avibactam Meropenem-vaborbactam Imipenem-relebactam	Cefiderocol Tigecycline, eravacycline

\* CDC definition: "R" to any of ertapenem, doripenem, meropenem or imipenem

Review > Expert Rev Anti Infect Ther. 2019 Oct;17(10):819–827.

doi: 10.1080/14787210.2019.1673731. Epub 2019 Oct 8.

## Use of meropenem in treating carbapenem-resistant Enterobacteriaceae infections

Renato Pascale<sup>1</sup>, Maddalena Giannella<sup>1</sup>, Michele Bartoletti<sup>1</sup>, Pierluigi Viale<sup>1</sup>, Federico Pea<sup>2 3</sup>

Affiliations + expand

PMID: 31559876 DOI: 10.1080/14787210.2019.1673731

### Abstract

**Introduction:** The epidemiology of carbapenem-resistant Enterobacterales (CRE) is increasingly worldwide. Production of carbapenemases is the most common and efficient mechanism of carbapenem resistance, and could theoretically be overcome by optimizing the pharmacokinetic/pharmacodynamic (PK/PD) behavior of meropenem. **Areas covered:** This article overviews the available literature concerning the potential role that meropenem may still have in the treatment carbapenem-resistant Enterobacteriaceae infections. Clinical studies published in English language until June 2019 were searched on PubMed database. **Expert commentary:** High-dose continuous infusion meropenem-based combination regimens could still represent a valuable option for treating CRE infections in specific circumstances. Knowledge of the local prevalent mechanisms of carbapenem resistance, of patient clinical severity, of the site of infection, of an accurate minimum inhibitory concentration (MIC) value, coupled with the possibility of carrying-out a real-time therapeutic drug monitoring (TDM)-based PK/PD optimization of drug exposure must all be considered as fundamental for properly pursuing this goal.

**Keywords:** CRE treatment; Combination therapy; Meropenem; PK/PD optimization; continuous infusion; therapeutic drug monitoring.

#### Knowledge of:

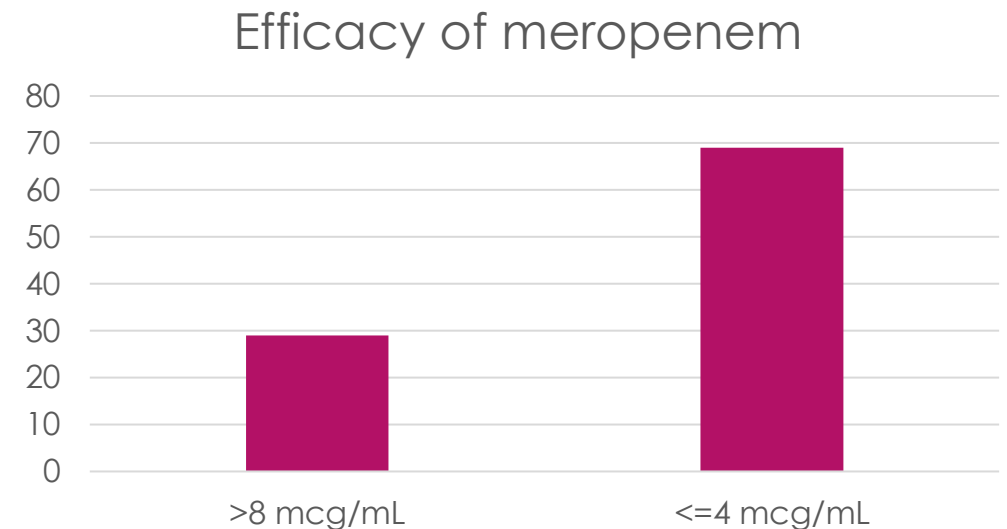
- Local resistance mechanisms
- Clinical severity
- **Accurate MIC**

# How does the MIC come into play?

- ▶ Meropenem, 2g q8 h by prolonged infusion, is recommended by some to treat isolates with MICs of 2- 8 mcg/mL.

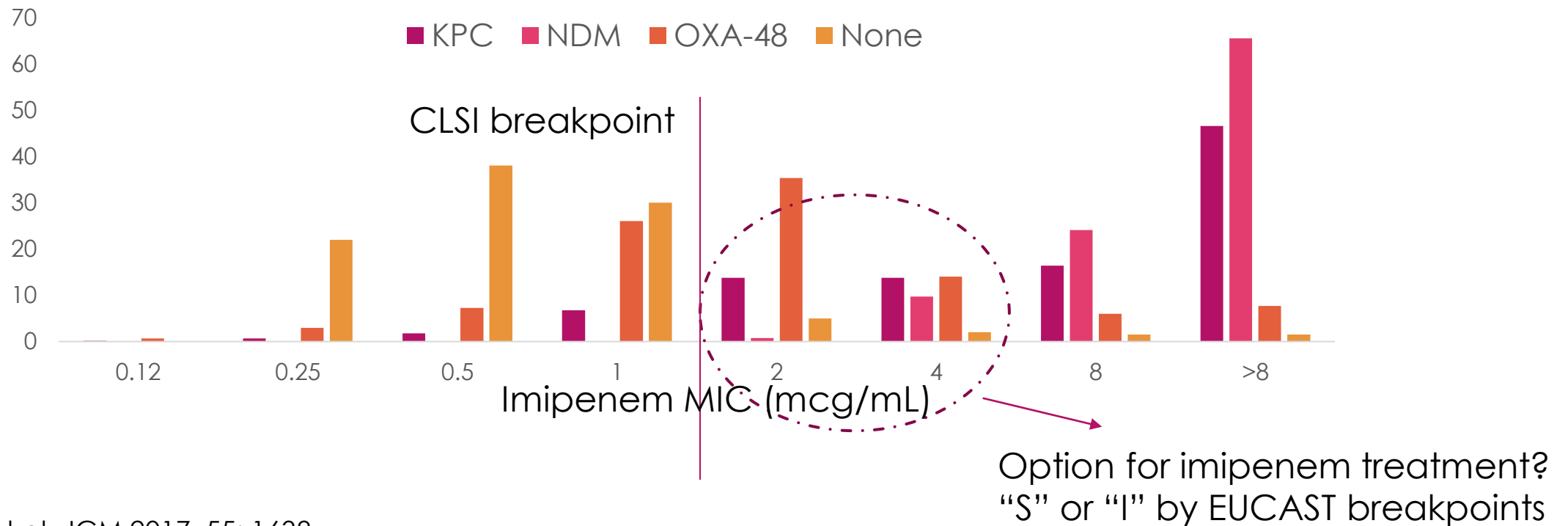
Carbapenem	EUCAST		CLSI	
	S	R	S	R
Ertapenem	≤0.5	>0.5	≤0.5	>1
Meropenem	≤2	>8	≤1	>2
Imipenem	≤2	>4	≤1	>2

EUCAST: MIC OF 4 (mero/imi) or 8 (mero) can be treated with elevated exposures (dose, frequency etc)



# Imipenem MIC by carbapenemase type

IMIPENEM MICs AMONG ERTAPENEM-R ISOLATES





# IDSA Guidance: CPE

Carbapenemase	Preferred	Alternative
KPC	Ceftazidime-avibactam Meropenem-vaborbactam Imipenem-relebactam	Cefiderocol, Tigecycline, Eravacycline
NDM, VIM, IMP	Ceftazidime-avibactam + Aztreonam Cefiderocol	Tigecycline, Eravacycline
OXA-48-like	Ceftazidime-avibactam	Cefiderocol Tigecycline Eravacycline

# IDSA Rx Options: carbapenemase producers

Agent	Drug class	IDSA indication	Resistance?
Ceftaz-avib	Beta-lactam combo	KPC OXA-48	Mutation to KPC gene
Mero-vabor	Beta-lactam combo	KPC	? Porin loss/efflux (rare)
Imi-relebactam	Beta-lactam combo	KPC	? Not documented
Cefiderocol	Siderophore cephalosporin	MBL 2 <sup>nd</sup> line, KPC, OXA-48	~20% are "R", due to modest enzymatic activity vs. cefiderocol
Eravacycline	Fluorocycline	2 <sup>nd</sup> line, any	Often R, must test
Tigecycline	Glycylcycline	2 <sup>nd</sup> line, any	May be R, must test

Mushtaq et al. AAC. 2020 In press; Simner and Patel. JCM2020 in press.  
 Livermore et al. AAC 2020. in press

# Case 3: Surgical infection

- ▶ 48 YO man
- ▶ Crush injury to hand
- ▶ Amputation to 2 fingers: small finger and ring finger
- ▶ Postoperatively given cephalexin
- ▶ Returns to ED 1 week later due to pain, foul odor
- ▶ Surgical revision, irrigation and debridement, infection of flexor tendon sheath of small finger



# Culture results

<i>K. pneumoniae</i>	MIC (mcg/mL)	
Amox-clav	>16	R
Amp-sulbactam	8	S
Aztreonam	≤2	S
Cefoxitin	≤4	S
Cefepime	4	SDD
Ceftazidime	≤2	S
Ceftriaxone	>32	R
Ciprofloxacin	≤0.25	S
SXT	≤0.5	S

“ESBL detected”

Laboratory:  
“Should we trust these results?”

# Back to M100 Appendix H

**Table H3. Reporting Results From Extended-Spectrum  $\beta$ -Lactamase Resistance and Carbapenemase Molecular Tests for Enterobacterales**

Indication	Target(s)	Method	Specimen Type	Results		Suggestions for Resolution	Report as:	Comments <sup>a</sup>
				Molecular Target Results	Observed Phenotype (if tested)			
Detection of ESBL resistance in <b>Enterobacterales</b> (in an isolate susceptible to all carbapenems)	ESBL type CTX-M, SHV, TEM	NAAT, microarray	Colony, blood culture	Detection of any ESBL target	R to all 3rd- and 4th-generation cephalosporins tested (eg, ceftriaxone R, cefotaxime R, ceftazidime R, cefepime R)	N/A	Report phenotypic results as found (if available); consider reporting molecular institution	1-12
				Detection of any ESBL target	S to all 3rd- and 4th-generation cephalosporins tested (eg, ceftriaxone S, cefotaxime S, ceftazidime S, cefepime S)	Repeat molecular and phenotypic tests. If blood culture, check for mixed culture. If mixed, test isolates individually and report phenotypic results as found.	If the disc resolved, should be using a reference method, a conflicting phenotypic results should be reported.	
				Detection of CTX-M ESBL target	Variable resistance to 3rd- and 4th-generation cephalosporins (eg, ceftriaxone R, cefotaxime R, ceftazidime R or S, cefepime R or S)	Expected phenotype for some CTX-M strains. Check cefepime using a reference method if S.	Report phenotypic results as found, including reference cefepime result; consider reporting presence of molecular target per institutional protocol.	
				Detection of TEM or SHV ESBL target	Variable resistance to 3rd- and 4th-generation cephalosporins (eg, ceftriaxone R or S, cefotaxime R or S, ceftazidime R or S, cefepime R or S).	Expected phenotype for some TEM/SHV strains. Check cefepime using a reference method if S.	Report phenotypic results as found, including reference cefepime result; consider reporting presence of molecular target per institutional protocol.	1-12

Variable resistance to 3<sup>rd</sup> and 4<sup>th</sup>- generation cephalosporins

Expected phenotype

Report phenotype as found

# Types of ESBLs in the US (common)

	Prevalence	Observed susceptibility (2020 breakpoints)			
		Ceftriaxone	Ceftazidime	Cefepime	Pip-tazo
SHV type	~25%	>90% R	>90% R	>75% R	<10% R
TEM type	<5%	>75% R	>75% R	~50% R	<10% R
CMT	Low	>75% R	>75% R	>75% R	>75% R
CTX-M-14	~10%	>90% R	~50% R	~50% R	<10% R
CTX-M-15	~43%	>90% R	>90% R	>90% R	<10% R



Paterson and Bonomo. 2005. CMR. 18:657

Wang et al. JCM. 2011. 49:3127

Castanheira et al. 2014. AAC. 58:838

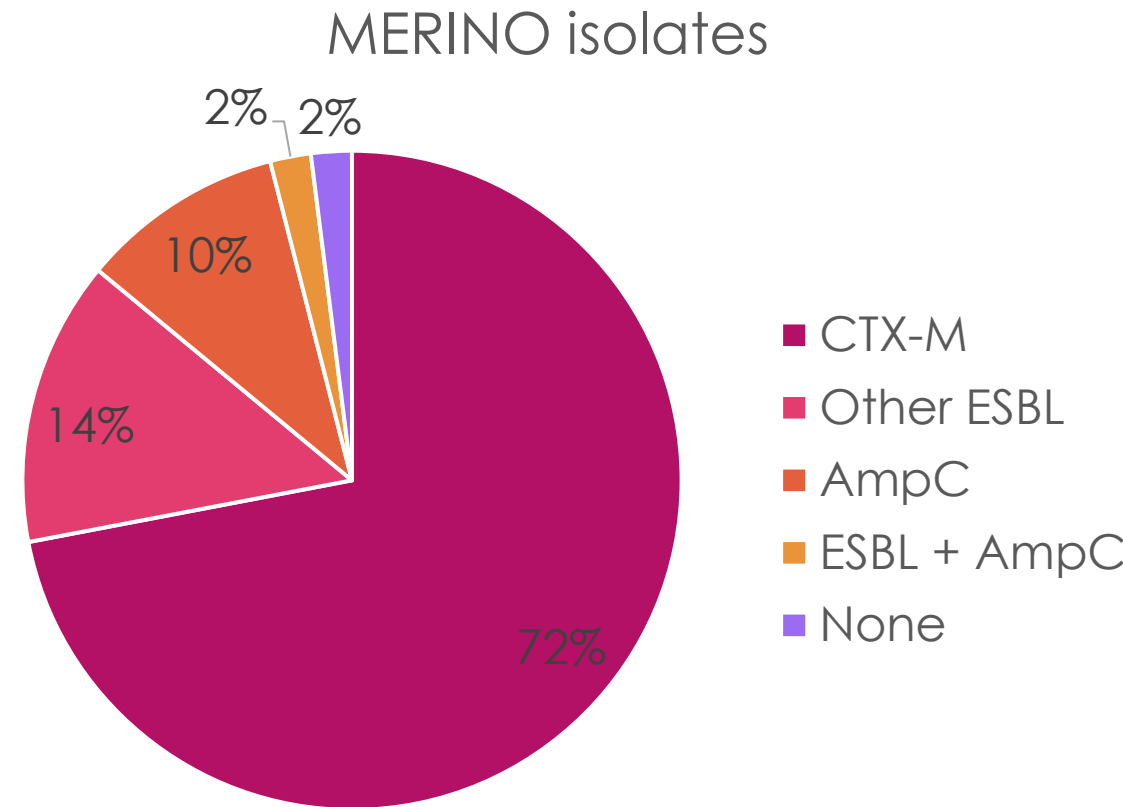
# MERINO Trial



- Study of “ceftriaxone not susceptible” isolates
- Patient with bacteremia treated

with:

	<u>Mortality</u>
- Pip-tazo	12.3%
- Meropenem	3.7%



# Should we do ESBL testing again?

- ▶ MERINO was trial of ceftriaxone I or R, not ESBL (many did not have ESBL)
  - ▶ Ceftriaxone NS can be due to: hyperexpression of TEM/SHV, AmpC, porin mutations, etc
- ▶ CLSI (and commercial tests) vary in ability to detect ESBL:

CLSI double disk <sup>1</sup>	<i>E. coli</i>	<i>K. pneumoniae</i>
PPV	97.6%	81.8%
NPV	75.9%	95.2%

- ▶ “Ceftriaxone not- susceptible *E. coli* and *Klebsiella* spp (I or R) are associated with an increased risk for treatment failure with piperacillin-tazobactam. Meropenem therapy preferred.”



# IDSA Guidelines: ESBL treatment

Infection	First-line	Second-line
Uncomplicated UTI	Nitrofurantoin Trim-sulfamethoxazole	Amox-clavulanate Aminoglycoside Oral Fosfomycin
Complicated UTI	Carbapenem Fluoroquinolone SXT	-
Other	Carbapenem	Oral step-down: - Fluoroquinolone - Trimeth-sulfa

“Piperacillin-tazobactam should be avoided, even if “S”.  
If started empirically for uUTI, and clinically improving, no need to change.

Example:  
Ceftriaxone-R  
*E. coli*

Typical GN AST panel

Antimicrobial	Result	Report?
Ampicillin	R	Yes
Amox-clavulanate	S	If urine
Aztreonam	R	Yes
Cefazolin	R	Yes
Ceftriaxone	R	Yes
<b>Cefepime</b>	<b>SDD</b>	<b>No</b>
<b>Pip-Tazo</b>	<b>S</b>	<b>No</b>
Ertapenem	S	Yes
Meropenem	S	Yes
Trim-sulfa	S	Yes
<b>Amikacin</b>	<b>S</b>	<b>No</b>
<b>Tobramycin</b>	<b>S</b>	<b>No</b>
Gentamicin	S	Yes
<b>Tetracycline</b>	<b>S</b>	<b>No</b>
Ciprofloxacin	R	Yes
Levofloxacin	R	Yes
Nitrofurantoin	S	If urine

# Final reports: urine

Antimicrobial	Result
Ampicillin	R
Amox-clavulanate	S
Aztreonam	R
Cefazolin	R
Ceftriaxone	R
Ertapenem	S
Meropenem	S
Trim-sulfa	S
Gentamicin	S
Ciprofloxacin	R
Levofloxacin	R
Nitrofurantoin	S

## Optional comments:

- ▶ Ceftriaxone resistance is consistent with the presence of an ESBL in this isolate
- ▶ Nitrofurantoin or trimethoprim-sulfamethoxazole are preferred options for uncomplicated cystitis, if tolerated
- ▶ Nitrofurantoin should not be used in patients with renal insufficiency
- ▶ Nitrofurantoin should not be used for cases of complicated UTI, including pyelonephritis.

# Final reports: not urine

Antimicrobial	Result
Ampicillin	R
Aztreonam	R
Cefazolin	R
Ceftriaxone	R
Ertapenem	S
Meropenem	S
Trim-sulfa	S
Gentamicin	S
Ciprofloxacin	R
Levofloxacin	R

- ▶ Ceftriaxone resistance is consistent with the presence of an ESBL in this isolate
- ▶ Carbapenems are preferred therapy of infections outside of the urinary tract

# ESBL: options

- ✓ Check cephalosporin vs. ESBL call (or CTX-M detection from molecular test)
- ✓ Aware ceftazidime may be S or R, expect ceftriaxone and cefepime are R
- ✓ If ceftriaxone I or R, do not report pip-tazo (regardless of MIC). Report meropenem

# Summary

- ▶ Genotype: phenotype interpretations can be complex
- ▶ Maximize value of AST testing by doing both, but only if:
  - ▶ Laboratory has protocols for how to compare genotype with phenotype
  - ▶ Laboratory has protocols for troubleshooting results
- ▶ Knowing the MIC can be of value: troubleshooting and also for treatment
- ▶ Lots of new drug options! But... must test most.

# Thank you!

- ▶ Question?
- ▶ Email me: [romney.humphries@vumc.org](mailto:romney.humphries@vumc.org)