Understanding the Basics of Clinical Microbiology.

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Disclosures:

- None

Objectives:

1. Describe the utility of laboratory testing/chemistries in the workup of infection.
2. Describe general microbiologic culture and susceptibility methods and their associated time courses.
3. Describe some forms of rapid diagnostic testing (RDTs)

Learning Assessment:

1. T/F – Elevations in inflammatory biomarkers including (ESR, CRP, PCT, and WBC) indicate the presence of an infectious condition.
2. Which of the following is a catalase positive, coagulase positive, latex positive GPC?
   - *Staphylococcus aureus*
   - *Streptococcus pyogenes*
   - *Staphylococcus epidermidis*
   - *Streptococcus pneumoniae*
3. Which susceptibility testing method provides a formal MIC? (circle all that apply)
   - Broth microdilution (BMD)
   - Epsilometer test (E-test)
   - Kirby-Bauer disk diffusion

Start at the Beginning:

- 70 y/o female found down in her assisted living facility (ALF). Nurse at ALF notes patient complaining vaguely of "malaise" and appeared to be slightly more confused for 1-2 days prior to being found down.
  - She is intubated in the ED for hypoxia and inability to protect airway.
- PMH: Diabetes, dementia, CVA, hypertension, hyperlipidemia, COPD, CHF, and history pneumonia (5 months prior).
- Physical exam:
  - Gen: intubated obese white female
  - Neuro: Not responsive to voice or touch, passive movement of all extremities
  - ENMT: NG, Endotracheal tube in place
  - Resp: Lungs with crackles bilaterally
  - CV: Hypotensive (starting norepi), tachycardic, no murmers
  - GI: Distended with present bowel sounds
  - GU: Foley in place
  - Musculo: No edema
  - Skin: open wound to left calf (chronic appearing – venous stasis ulcer) with surrounding erythema

Start at the Beginning:

- Vitals from ED: Temp 101.8, BP 90/55 (non-responsive to 2L NS), Pulse 113, RR 32, O_2 Saturation = 82% on 10 L NC
- Labs: WBC 27 (34% bands), SCr 2.3 (baseline 1.15), H/H 9.5/28.1, plts 225, lactate 5.5, CRP 225, ESR 12, and Procalcitonin 9.1.
  - UA: 4+ Leukocyte esterase, 2+ bacteria, >150 wbc, nitrite positive, 0 RBC, and hazy brown
- Imaging:
  - CXR: Bibasilar infiltrates vs. atelectasis (R>L), cannot exclude pneumonia
- Cultures:
  - Blood (peripheral): Pending
  - Urine (foley): Pending
  - Respiratory (Endotracheal aspirate): Pending

Why do we think she is infected?

- Clinical Presentation!
  1. Constellation of symptoms → Septic Shock
     - Hypotension (not responsive to fluids → vasopressor dependent)
     - Tachycardia
     - Fever
     - Leukocytosis
     - End organ damage: Altered mental status and elevated SCr
  2. Imaging:
     - CXR with ? Pneumonia
  3. Non-specific labs:
     - WBC (bands)
     - Lactate
     - Pro-inflammatory markers: CRP, ESR, Procalcitonin
     - Positive UA?

Non-specific Lab Tests:[1,2]

- There is NO single definitive test for identification of infection!
  - i.e. All have limitations
  - Always should be paired with clinical presentation.
- Examples:
  - White Blood Cell (WBC) Count:
    - Elevate in response to infection
    - Also elevate in response to: Drugs (i.e. steroids), stress, inflammation, etc.
    - Bands = immature neutrophils
      - "Left Shift": >9% bands
  - Lactate:
    - Demonstrates shift to anaerobic metabolism / illustrates tissue hypoperfusion
    - Elevates in response to shock, tissue ischemia, severe liver disease, and some medication (metformin)

Non-specific Lab Tests:[1-3]

- CRP and ESR:
  - C-reactive protein (CRP) and erythrocyte sedimentation rate (ESR:
    - Non-specific acute phase reactant (i.e. non-specific inflammatory marker)
    - Elevate vaguely in response to inflammation
    - Generally CRP reacts faster than ESR
    - Better for trending chronic infections vs. determining if infection present.
  - Erythrocyte sedimentation rate (ESR)
    - Non-specific inflammatory marker
    - Generally reacts slower than CRP
- Procalcitonin:
  - 116 amino acid precursor of calcitonin
  - More sensitive than CRP at detecting bacterial infection
  - Detectable in 2-4 hours / Peak = 8-24 hours / Half-life = 24 hours
  - Rises not impaired by neutropenia or immunosuppression
  - Most useful in community-acquired lower respiratory tract and sepsis

Non-specific Lab Tests:[4,5]

- Urinalysis:
  - Color and Clarity: Non-specific
  - Nitrites:
    - Reductase: Nitrates → Nitrites
    - Weakly sensitive/highly specific for the PRESENCE of bacteria.
  - Leukocyte Esterase:
    - Produced by neutrophils
    - Indicates pyuria
  - WBC: Grades the pyuria
  - Bacteria: May signal contamination, ASB, or infection
  - Squamous Epithelial Cells: May help determine quality of specimen.

COLOR	Amber
CLARITY	Cloudy
Specific Gravity	1.017
PH UA	5.0
GLUCOSE UA	1+
KETONES UA	Trace
PROTEIN UA	2+
BLOOD UA	3+
BILIRUBIN UA	Negative
NITRITE UA	Negative
UROBILINOGEN UA	Normal
ASCORBIC ACID UA	Negative
LEUKOCYTES ESTERASE UA	3+
WBC UA	20 - 50
RBC UA	50 - 100
SQUAMOUS EPITHELIAL UA	5 - 1
BACTERIA UA	1+
HYALINE CASTS UA	>20
GRANULAR CASTS UA	2 - 4
MUCUS UA	Present

Asymptomatic Bacteriuria (ASB):[5]

- No mater what Bear Grylls tells you…
  …urine is not a sterile body fluid.
- A "dirty" UA or "pyuria" in the absence of symptoms is NOT an indication for antimicrobial therapy.
  - Caveats:
    - Pregnancy
    - ASB during procedures which will compromise of urinary mucosa.

Table 2. Prevalence of asymptomatic bacteriuria in selected populations.

Population	Prevalence, %	Reference
Healthy, premenopausal women	1.0–5.0	[31]
Pregnant women	1.9–9.5	[31]
Postmenopausal women aged 50–70 years	2.8–8.6	[31]
Diabetic patients		
Women	9.0–27	[32]
Men	0.7–11	[32]
Elderly persons in the community[a]		
Women	10.8–16	[31]
Men	3.6–19	[31]
Elderly persons in a long-term care facility		
Women	25–50	[27]
Men	15–40	[27]
Patients with spinal cord injuries		
Intermittent catheter use	23–89	[33]
Sphincterotomy and condom catheter in place	57	[34]
Patients undergoing hemodialysis	28	[28]
Patients with indwelling catheter use		
Short-term	9–23	[35]
Long-term	100	[22]

[a] Age, >70 years.

Cultures…the basics:[1,6-9]

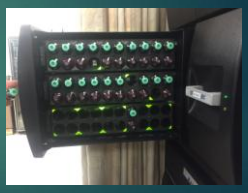
1. Only culture something…if you plan to use the culture to guide therapy.
   - May NOT always be necessary (i.e. uncomplicated CAP or perforated appendicitis)
2. Always culture PRIOR TO administration of antibiotics if possible.
   - Sepsis is the obvious exception
     - 7.6% increase in mortality for every hour antimicrobial therapy is delayed.
3. Take care to avoid contamination with patient's usual flora.
4. Interpret cultures with a critical eye:
   - What source/type of culture was obtained?
   - What was the culture method?
   - What did the gram-stain/grouping show?
   - What grew?
   - Does what grew match the clinical suspicions?
   - What did susceptibilities show?

Culture Source/Type:[1]

- Source:
  - Blood
  - Wound, bone, tissue, abscess
  - CSF
  - Respiratory
  - Stool
  - Urine
  - Body fluid (pleural, ascites, etc.)
- Type:
  - Aerobic
  - Anaerobic
  - Fungal
  - Acid fast bacilli

Culture Source/Type:[1]

- Some variance in microbiology processing:
  - BACTEC alert device
    - Blood
    - Gram-stain negative Body Fluids
  - Required additional processing:
    - Tissue
    - Bone
  - Straight to plate
    - Wound
    - Respiratory
    - Urine
    - Gram-stain positive
    - CSF



Culture Source/Type:[1,8-11]

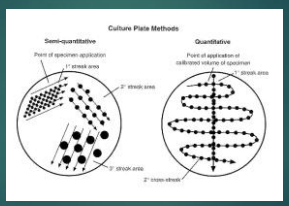
- Anticipate pathogen based on location of infection.
  - Skin and Soft Tissue Source:
    - Skin flora (Staphylococcus/Streptococcus)
  - Respiratory Source: *S. pneumoniae, M. catarrhalis, L. pneumophila, M. Pneumoniae, C. pneumoniae, H. influenzae.*
    - Hospital-acquired: MDRO gram-negative rods (including *P. aeruginosa*) and *S. aureus*
  - GI Source: *E. coli, Klebsiella spp., B. fragilis, S. anginosus, Enterococcus spp.*

Culture Method:[10-14]

- How was it collected?
- Is it a good specimen?
- Could it be contaminated?
- General features:
  - Look for presence of WBC
  - Look for absence of squamous epithelial cells
- Respiratory:
  - Sputum (expectorated) vs. sputum (suction)
  - Endotracheal aspirate vs. Bronchoalveolar lavage (BAL) vs. mini-BAL
- Wounds:
  - Purulent vs. Non-purulent
  - Superficial swab vs. tissue/biopsy
  - Chronic ulcer vs. acute wound
- Blood:
  - ? Contaminant
    - How many bottles of how many draws?
    - How long did it take to grow?

Culture Method:[15]

- Semi-quantitative:
  - Attempts to ESTIMATE the quantity of organisms in a given culture.
  - Cultures plated in one quadrant on plate
  - Growth in primary quadrant = 1+
  - Extension characterized as 2+, 3+, and 4+



http://intranet.tdmu.edu.ua/data/cd/disk2/ch010.htm

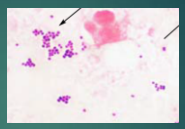
- Quantitative:
  - Provides more robust estimate of number of organisms in a given culture.
  - Requires fluid specimen.
  - One mL of specimen is plate in plated and depending on growth on streak estimate made.
  - i.e. >100,000 cfu/mL

Gram Stains:[1]

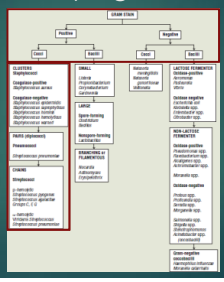
- Specimen applied to slide
- Crystal violet stain applied followed by iodine.
- Alcohol decolorizing solution applied
- Counterstain with safranin
- Gram-negative: Red/Pink
- Gram-positive: Purple in appearance

Gram Stains:[16]

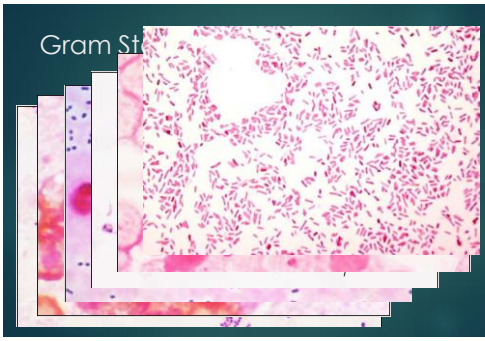
- Grouping:
- More relevant in gram positive cocci (GPC):
  - Staphylococcus spp. → GPC pairs, tetrads, and clusters
  - Streptococcus spp. / Enterococcus spp. :
    - Generally: GPC in chains
      - LONG chains → Beta-hemolytic strep or *S. viridans*
      - Diplococci and chains → *S. pneumonia*
- What about… GPC pairs?



Gram Stains/Grouping:[1]



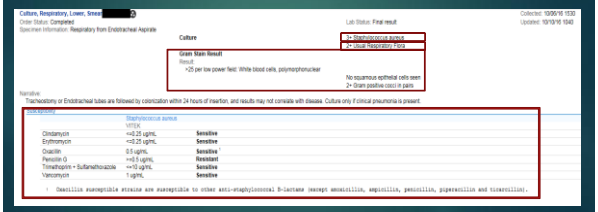
Gram St



Gram Stains x 2:

- Specimen received
- Initial gram stain (1-6 hours)
- Plated and grown (24-48 hours)
- Growth gram stain
- Organism identification (0-24 hours)
- Susceptibilities (18-24 hours)

Gram Stains → Plate Growth:


Culture, Respiratory, Lower, Sputum

Culture

Gram Stain Result

Result:
>25 per low power field: White blood cells, polymorphonuclear

No squamous epithelial cells seen
2+ Gram positive cocci in pairs

Narrative:
Tracheostomy or Endotracheal tubes are followed by colonization within 24 hours of insertion, and results may not correlate with disease. Culture only if clinical pneumonia is present.

Staphylococcus aureus
VITEK

Clindamycin	<=0.25 ug/mL	Sensitive
Erythromycin	<=0.25 ug/mL	Sensitive
Oxacillin	0.5 ug/mL	Sensitive
Penicillin G	>=0.5 ug/mL	Resistant
Trimethoprim + Sulfamethoxazole	<=10 ug/mL	Sensitive
Vancomycin	1 ug/mL	Sensitive

† Oxacillin susceptible strains are susceptible to other anti-staphylococcal B-lactams (except amoxicillin, ampicillin, penicillin, piperacillin and ticarcillin).

Plate Growth:

- Identification…
  …what is taking so long?
  - Pure plates vs. mixed plates
    - "re-isolating for more information"
  - Poor vs. no plate growth plates
  - Oddly behaving organisms

Plate Growth (GNR):[1]

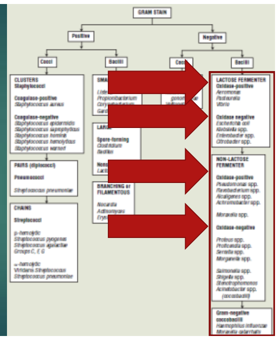


Plate Growth (GNR):[17]

- Gram Negatives:
  - Lactose fermentation:
    - Helps to distinguish between GNRs prior to formal ID.
      - Pseudomonas vs. other
    - MacConkey agar:
      - Inhibits gram-positive growth
      - Lactose Fermenting:
        - Lowers pH → red agar
      - Non-lactose fermenting:
        - Ammonia production raises pH → Clear/opaque agar

https://en.wikipedia.org/wiki/MacConkey_agar#/media/File:MacConkey_agar_with_LF_and_LF_colonies.jpg

Plate Growth (GNR):[17]

- Oxidase:
  - Assesses for presence of cytochrome oxidase
  - Not produced by Enterobacteriaceae
    - Produced by pseudomonas
  - Positive test = Purple stain
    - i.e. agent is oxidized
  - Negative test = Colorless
    - i.e. agent remains reduced

http://www.medical-labs.net/oxidase-test-1291/

Plate Growth (GPC):[1]

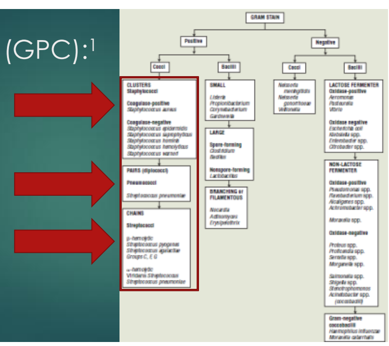
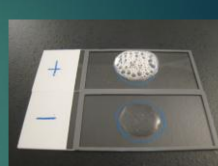


Plate Growth (GPC):[17]

- Catalase:
  - $2H_2O_2 \rightarrow O_2 + H_2O$
    - O_2 released as gas = bubbles
  - Differentiates staphylococcus from streptococcus
    - Staphylococcus = catalase positive
    - Streptococcus = catalase negative



http://4.bp.blogspot.com/-pGWy_YzoaD4/UZXnPopWsUI/AAAAAAAAAH0/nmpu-kKutg/s1600/slide+catalase+test+results.jpg

Plate Growth (GPC):[17]

- Catalase positive:
  - Latex agglutination:
    - Antibody for *S. aureus on latex beads*
      - Latex positive = *S. aureus*
      - Latex negative = CoNS
  - Coagulase:
    - Converts fibrinogen to fibrin clot with help of plasma factors
    - *S. aureus* = positive
    - *S. epidermidis* and other CoNS = negative
- Catalase negative:
  - Hemolysis:
    - Does it growth cause hemolysis of blood agar
      - Alpha = green = partial hemolysis
        - *S. viridans*
        - *S. pneumonia*
        - Maybe *S. anginosus*
      - Beta = clear = full hemolysis
        - "Typeable" streptococcus
          - Group A, B, C, G
      - Gamma = red = no hemolysis
        - Enterococcus spp. (PYR)
        - Maybe *S. anginosus*

Organism Identification:

- Specimen received
- Initial gram stain (1-6 hours)
- Plated and grown (24-48 hours)
- Growth gram stain
- Organism identification (0-24 hours)
- Susceptibilities (18-24 hours)

Organism Identification:

- VITEK vs. Microscan vs. Phoenix
- PAMC = VITEK2
  - Performs both:
    - Organism identification
    - Susceptibilities
      - Automated broth microdilution (BMD)
        - We will come back to this!

Organism ID vs. Clinical Suspicion:

- Culture Source
- Method of Collection
- Suspicion for Contamination
- Gram stains

vs.

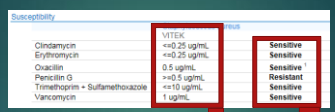
- Growth
- Organism ID

- Presence of Usual flora?
- Odd organism for culture source?
- Growth that doesn't match the initial gram stain?
- Initial gram stain that doesn't match the growth?

Susceptibilities:

- Specimen received
- Initial gram stain (1-6 hours)
- Plated and grown (24-48 hours)
- Growth gram stain
- Organism identification (0-24 hours)
- Susceptibilities (18-24 hours)

Susceptibilities:[1]



Qualitative Results:
- Driven by MIC
- Actual determinant behind quantitative results
- Multiple methods (BMD vs. KB vs. E-test)

Valuable…but sometimes hard to interpret.

Quantitative Results:
- Susceptible
- Intermediate
- Resistant

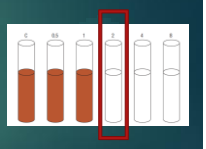
User friendly…but perhaps oversimplified.

"Semi" -Qualitative Susceptibilities:[1]

- Disk diffusion test (i.e. Kirby Bauer)
  - Grow bug → Drop Disk → Measure zone of inhibition
  - Susceptibility of organism is determined by "zone of inhibition"
    - Determined by CLSI standards
    - Varies depending on organism
    - Varies depending on drug
  - Generally:
    - Bigger zone of inhibition = more susceptible bug
    - Can perform multiple tests (up to 12) on same plate
    - Able to choose specific agents to test
  - Pros: Reliable, flexible, cheap, and simple
  - Cons: May be impacted by incubation temp or bacterial inoculum

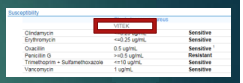
Qualitative Susceptibilities:[1]

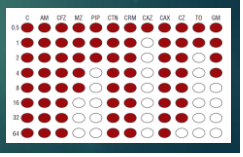
- Minimum Inhibitory Concentration:
  - "The lowest antimicrobial concentration that prevents visible growth of an organism after ~24 hours of incubation in a specified growth medium"
  - Susceptibility breakpoints determined by CLSI
  - Traditionally
    - Macrotube dilution method vs. Solid agar
    - Labor intensive!
  - Present day:
    - Automated
      - VITEK2 vs. Microscan (turbidity) vs. Phoenix
    - Epsilometer Test (i.e. E-test)
  - Tells us the level of susceptibility of an organism rather than just the interpretation of that level.
    - E. coli: Piperacillin/tazobactam </= 4 vs. 32 mcg/mL
    - MRSA: Vancomycin <0.5 vs. 2 mcg/mL



Qualitative Susceptibilities:[1]

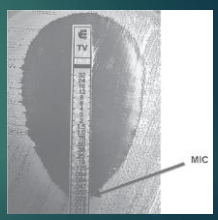
- Automated Broth Microdilution (BMD):
  - Inoculate card → Put in machine → Wait
  - Tests organism to multiple concentrations of multiple drugs
    - Drugs in card determined by manufacturer or card selected.
  - Determines organism MIC to multiple agents in single test
    - Run time = 18-24 hours
  - Pros: Easy, reliable, provides formal MIC
  - Cons: Requires machine ($$$) and lacks flexibility in agent selection.





Qualitative Susceptibilities:[1,18]

- Epsilometer test (i.e. E-test)
  - Grow bug → Drop strip → look for ellipse/strip intersection.
  - E-Strip:
    - Single agent
    - Increasing concentrations
  - One strip per plate.
    - Has been at times to be more accurate than automated broth microdilution
  - Pros: Easy to perform, ? Easy to read, cheap
  - Cons: One per plate, ? Easy to read



Susceptibilities:

- Summary:

1. Do you have qualitative, quantitative, or both?
2. If qualitative, was it performed via BMD, E-test, or Kirby-Bauer?
3. If BMD or E-test, just how susceptible was the organism (i.e. what was the MIC)?

- Select a therapy!

1. What is the narrowest spectrum agent that treats all presently identified organisms?

Rapid Diagnostic Testing:[17]

Sensitivity vs. Specificity

Varies depending on testing method and specific test

- Sensitivity:
  - If a person HAS the disease how often will the test be positive?
    - I.e.
      - 10 influenza patients present and are swabbed for EIA
      - Rapid flu swab (EIA) detects 5/10.
      - Sensitivity = 50%
  - Rate of true positive vs. false negative.
- Specificity:
  - If a person does NOT HAVE the disease how often will the test be negative.
    - I.e.
      - 10 patients WITHOUT influenza present and are swabbed for EIA
      - Rapid flu swab (EIA) detects 2/10
      - Specificity = 80%
  - Rate of true negative vs. false positive.

Rapid Diagnostic Testing (RDT):[17]

- Antibody testing:
  - Agglutination testing:
    - Antibodies (polyclonal or monoclonal) attached to latex beads and specimen introduced.
      - If lattice structure forms then antigen is present (antibody-antigen complexes)
    - Typically tested from growth (not generally from direct specimen)
    - Ex: *S. aureus* from plate growth
  - Enzyme immunoassay (EIA)/Enzyme-linked immunosorbent assay (ELISA):
    - Antibody coated wells/trays → Specimen (antigen) introduced → Well washed out → Second antibody introduced → well washed out → coloring agent added.
      - Wells that change color = positive for antigen.
    - Typically tested direct from specimen
    - Ex: Influenza A and B, Ag EIA (i.e. rapid flu swab)

Rapid Diagnostic Testing (RDT):[1,17]

- Polymerase Chain Reaction (PCR / NAAT):
  - Testing done directly from collection specimen
  - Target amplification system
    - Amplifies SMALL sections of DNA using DNA polymerase and short oligonucleotide primers for detection.
      - If more than one primer used = improved sensitivity (multiplex PCR)
  - Ex: Respiratory viral pathogen panel (Biofire™)
    - Blood Culture Identification Panel (BCID)
    - GI Panel
    - Meningitis/Encephalitis Panel
    - C. diff. NAAT
- 16S rRNA:
  - Looks for specific section of ribosomal RNA that helps to identify specific organisms in a specimen.
    - Draws on LARGE bank of known sequencing vs. specific testing on specific platform
    - Testing of direct specimen

Rapid Diagnostic Testing (RDT):[17]

- Mass Spectrometry:
  - Matrix-assisted laser desorption ionization time-of-flight (MALDI-TOF)
    - Thin smear on metallic slide
    - Hit with pulses of laser
    - Desorbed and deionized particles then accelerated through electrostatic field and drifted through vacuum tube
    - Contact mass spectrometers detector
    - Different particles fly at different speeds which indicates the presence of components of specific organisms
    - Typically run off of organism growth

Rapid Diagnostic Testing (RDT):[19]

- Accelerate Diagnostics – Pheno™
  - Gel electro-filtration (GEF)
    - Sample loaded into gel well that contains pores smaller than bacterial cells
    - Electric current applied which removes cellular debris to isolate/concentrate bacterial cells
  - Electro-kinetic concentration (EKC)
    - Cells are drawn to surface where analysis will take place by exposure to mild electric charge.
  - FISH (Fluorescence in-site hybridization)
    - Cells exposed to probes with fluorescent tags looking for specific nucleic acid sequences.
  - Fast phenotypic susceptibility testing
    - Cell exposed to single concentration of agent and time lapse imaging correlates growth patterns to MICs.

Patient Case: (HD1)

- Blood:
  - Drawn vial peripheral draw
  - Aerobic and anaerobic bottles drawn from 2 separate sites
  - In BACTEC and pending
- Urine:
  - Collected from foley
  - No gram-stain ordered
  - Plated and pending
- Respiratory:
  - Collected as endotracheal aspirate
  - Gram stain: 1+ usual respiratory flora (<10 WBC / 0 epithelial)
  - Plated and pending

Patient Case: (later on HD1)

- Blood:
  - 1/2 draws positive for gram-negative rods at 8 hours → plated
  - Collected from peripheral draw x 2 (aerobic and anaerobic on each)
- Urine:
  - Cultures currently pending
  - Collected from foley catheter
- Respiratory:
  - Cultures currently pending
  - Collected from ETA with initial gram stain (1+ URF, <10 WBC, 0 epithelial)

Patient Case: (HD2)

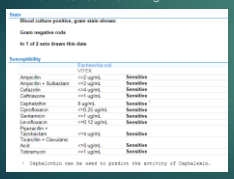
- Blood:
  - Growth of GNR on plates at 24 hours (lactose fermenter / oxidase negative)
  - Collected from peripheral draw x 2 (aerobic and anaerobic on each)
- Urine:
  - 40,000 cfu gram negative rods on plates at 24 hrs (lactose fermenter / oxidase negative)
  - Collected from foley (initial plate growth = >100,000 cfu GNR)
- Respiratory:
  - Plates growing 1+ usual respiratory flora (at 24 hours)
  - Collected from ETA with initial gram stain (1+ URF, <10 WBC, 0 epithelial)

Patient Case: (HD3)

- Blood:
  - E. coli identified as organism
- Urine:
  - E. coli identified as organism
- Respiratory:
  - Cultures "finaled" as 1+ "usual respiratory flora"
  - Collected from ETA with initial gram stain (1+ URF, <10 WBC, 0 epithelial)

Patient Case: (HD4)

- Blood:
  - E. coli identified as organism
- Urine:
  - E. coli identified as organism



Blood culture positive, gram stain shown:

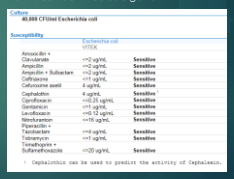
Gram negative rods

In 1 of 2 sets drawn this date

Susceptibility

	Escherichia coli VITEK	
Ampicillin	<=2 ug/mL	Sensitive
Ampicillin + Sulbactam	<=2 ug/mL	Sensitive
Cefazolin	<=4 ug/mL	Sensitive
Ceftriaxone	<=1 ug/mL	Sensitive
Cephalothin	8 ug/mL	Sensitive †
Ciprofloxacin	<=0.25 ug/mL	Sensitive
Gentamicin	<=1 ug/mL	Sensitive
Levofloxacin	<=0.12 ug/mL	Sensitive
Piperacillin + Tazobactam	<=16 ug/mL	Sensitive
Ticarcillin + Clavulanic Acid	<=8 ug/mL	Sensitive
Tobramycin	<=1 ug/mL	Sensitive

† Cephalothin can be used to predict the activity of Cephalexin.



Cultures

40,000 CFU/ml Escherichia coli

Susceptibility

	Escherichia coli VITEK	
Amoxicillin + Clavulanate	<=2 ug/mL	Sensitive
Ampicillin	<=2 ug/mL	Sensitive
Ampicillin + Sulbactam	<=2 ug/mL	Sensitive
Ceftriaxone	<=1 ug/mL	Sensitive
Cefuroxime axetil	4 ug/mL	Sensitive
Cephalothin	8 ug/mL	Sensitive †
Ciprofloxacin	<=0.25 ug/mL	Sensitive
Gentamicin	<=1 ug/mL	Sensitive
Levofloxacin	<=0.12 ug/mL	Sensitive
Nitrofurantoin	<=16 ug/mL	Sensitive
Piperacillin + Tazobactam	<=4 ug/mL	Sensitive
Tobramycin	<=1 ug/mL	Sensitive
Trimethoprim + Sulfamethoxazole	<=20 ug/mL	Sensitive

† Cephalothin can be used to predict the activity of Cephalexin.

Learning Assessment:

1. T/**F** – Elevations in inflammatory biomarkers including (ESR, CRP, PCT, and WBC) indicate the presence of an infectious condition.
2. Which of the following is a catalase positive, coagulase positive, latex positive GPC?
   - ***Staphylococcus aureus***
   - *Streptococcus pyogenes*
   - *Staphylococcus epidermidis*
   - *Streptococcus pneumoniae*
3. Which susceptibility testing method provides a formal MIC? (circle all that apply)
   - **Broth microdilution (BMD)**
   - **Epsilometer test (E-test)**
   - Kirby-Bauer disk diffusion

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