Deconstructing Acid Base

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CFPC CoI Templates: Slide 1 – used in Faculty presentation only.

Faculty/Presenter Disclosure

- **Faculty:** Anish Mitra

- **Relationships with financial sponsors:**
  - **None**

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- **<u>Potential for conflict(s) of interest</u>:**
  - None

Mitigating Potential Bias

- Not necessary!

Outline

- Develop an approach to acid base problems
- Understand the purpose of working through acid base problems
- Work through some cases
- Understand the limitations of the approach
- Helpful hints

Approach

- What is the “emia”? – acidemia vs. alkalemia
- What is the “osis”? – respiratory vs. metabolic
- Is there appropriate compensation?
- What is the anion gap?
- What is the delta-delta gap?

Rules

- The body will never over-compensate
- Normal values
  - pH = 7.4
  - pCO_2 = 40
  - HCO_3 = 24
  - Anion gap = 8-12

What is the “emia”?

- Acidemia = pH < 7.4
- Alkalosis = pH > 7.4

- Remember that pH is on a logarithmic scale…so a similar change in pH is less tolerable in acidemia than in alkalosis…
  - [H+] doubles as pH +/- by 0.3 → pH from 7.4 to 7.1 causes [H+] to increase by 40 from 40 nmol/L to 80 nmol/L but pH from 7.4 to 7.7 causes [H+] to decrease by only 20 from 40 nmol/L to 20 nmol/L

What is the “osis”?

- This is the primary disorder that leads to the “emia”

- Metabolic vs. respiratory
  - Acidemia
    - Metabolic acidosis if $HCO_3 < 24$
    - Respiratory acidosis if $pCO_2 > 40$
  - Acidemia
    - Metabolic alkalosis if $HCO_3 > 24$
    - Respiratory alkalosis if $pCO_2 < 40$

Is there adequate compensation?

- Mechanism of compensation:
  - Respiratory for primary metabolic process (fast)
  - Metabolic for primary respiratory process (slow)
- Inadequate compensation may indicate:
  - Incomplete compensation
  - A secondary process

Expected Compensation

- Metabolic acidosis — $\downarrow 1\ HCO_3 : \downarrow 1\ PaCO_2$
- Metabolic alkalosis — $\uparrow 1\ HCO_3 : \uparrow 0.7\ PaCO_2$
- Respiratory acidosis — $\uparrow 1\ PaCO_2 : \uparrow 0.3\ HCO_3$
- Respiratory alkalosis — $\downarrow 1\ PaCO_2 : \downarrow 0.5\ HCO_3$

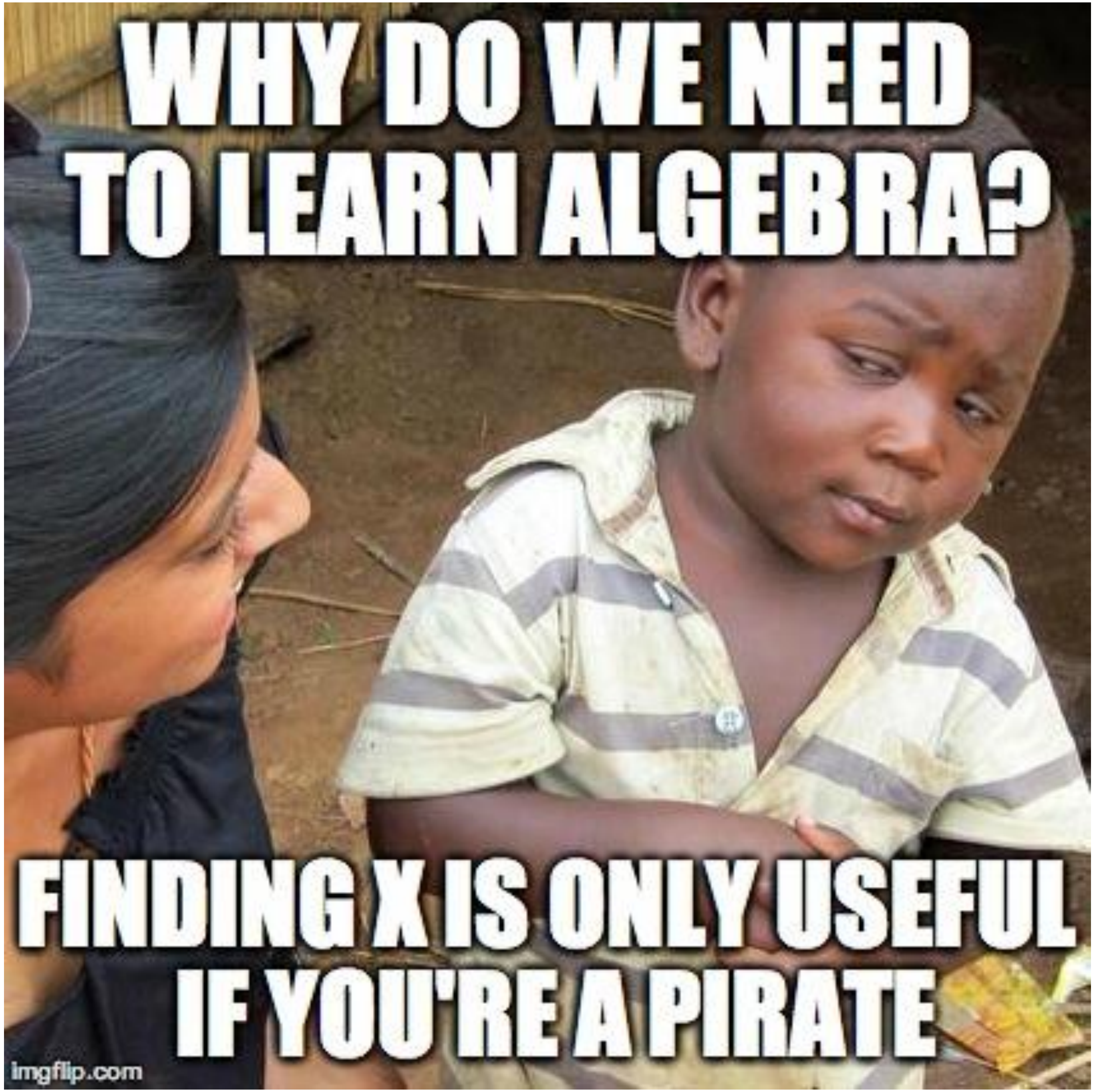
- Mnemonic: *17 is half of 35*

What is the anion gap?

- Anion gap = Na – (Cl + HCO_3)
- Anion gap exists because some anions and cations are not regularly measured in the blood
- Blood is neutral
- Anion gap indirectly attempts to estimate presence of unexpected anions
- Normal anion gap is 8-12
    - Correction factor for albumin: ↓ albumin by 10 → ↓ expected anion gap range by 3

What is the delta-delta gap?

- Only necessary if there is an anion gap
- Delta-delta gap: Δ anion gap / Δ HCO_3
  - (calculated anion gap – normal anion gap (12)) / (normal HCO_3 (24) – measured HCO_3)
- Delta-delta gap = 1-2 → pure anion gap metabolic acidosis
- Delta-delta gap > 2 → concurrent metabolic alkalosis
  - Measured serum HCO_3 is higher than expected
- Delta-delta gap < 1 → concurrent non-anion gap metabolic acidosis
  - Measured serum HCO3 is lower than expected


WHY DO WE NEED TO LEARN ALGEBRA?
FINDING X IS ONLY USEFUL IF YOU'RE A PIRATE
imgflip.com

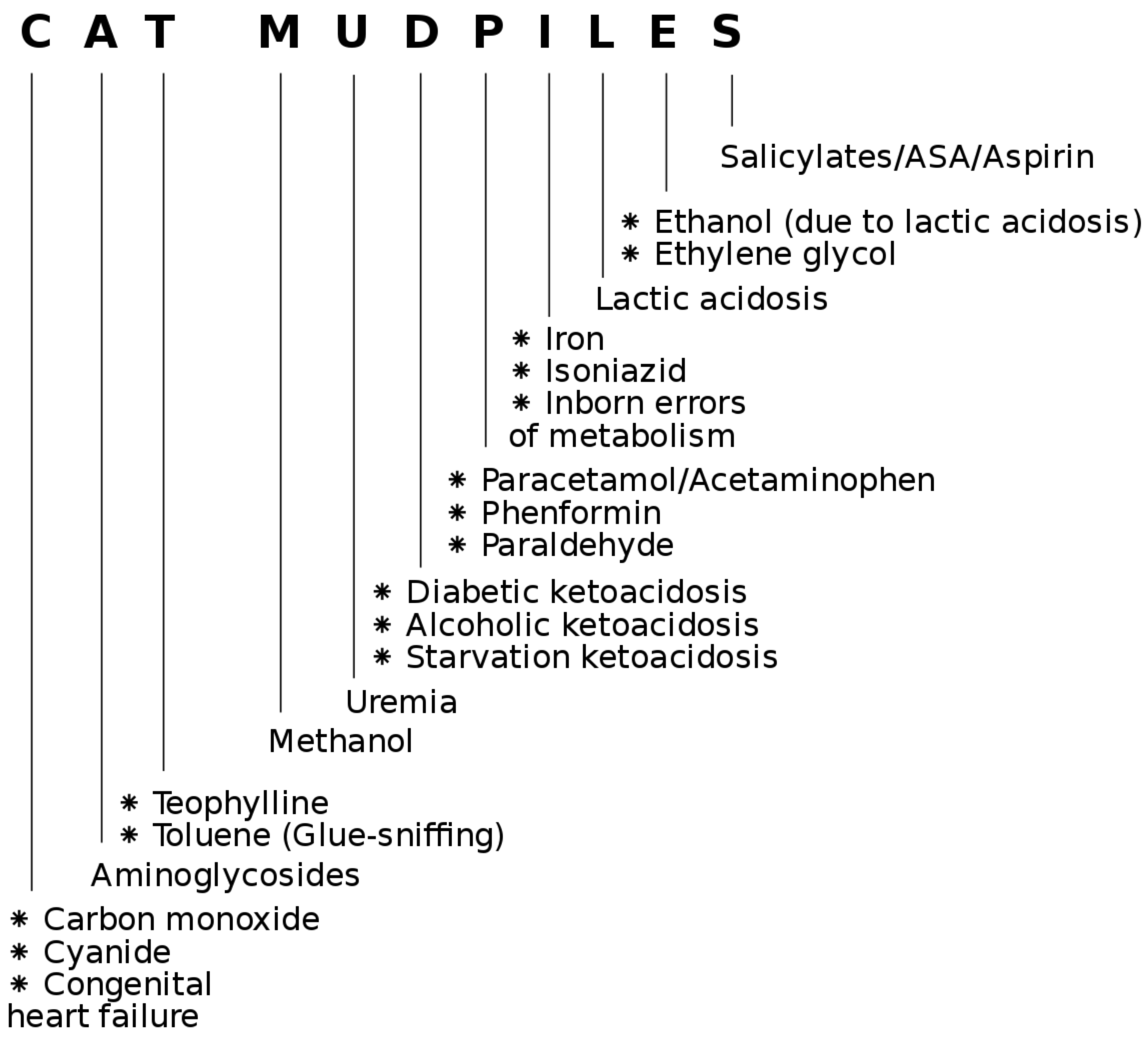
What is the value of this approach?

- Understanding the “emia” and the “osis” allows you to understand the patient’s primary problem and begin a differential diagnosis.
- Assessing for appropriate compensation allows you to determine if there is a secondary problem.
- Looking for an anion gap allows you to find the most common severe acid base problem
- Calculating the delta-delta gap allows you to impress nephrologists…

Metabolic acidosis

- Anion gap metabolic acidosis
  - KULT
    - Ketones, uremia, lactate, toxins (look it up)

Causes of high anion-gap metabolic acidosis



Metabolic acidosis

- Anion gap metabolic acidosis
  - KULT
    - Ketones, uremia, lactate, toxins (look it up)
  - MUDPILES
  - GOLDMARK
    - Glycols (ethylene and propylene), oxoproline, L-lactate, D-lactate, methanol, aspirin, renal failure, ketoacidosis
- Note that toxic alcohols contribute to the osmolar gap…
  - Osmolar gap = measured serum osmoles – calculated serum osmoles
    - Calculated serum osmoles = 2*Na+glucose+BUN
    - Normal osmolar gap < 10

Metabolic Acidosis

- Non-anion gap metabolic acidosis
    - Renal
        - Acute tubular necrosis
        - Renal tubular acidosis
        - Drug induced
            - Acetazolamide, amphotericin
    - GI
        - Diarrhea
        - Short bowel syndrome
    - Rapid saline administration

Non-anion gap metabolic acidosis

- Urine anion gap
  - Urine anion gap = urine Na + urine K – urine Cl
    - Normally 0 or slightly positive
    - In presence of non-anion gap metabolic acidosis → urine anion gap should be negative if kidneys are functioning properly
      - Kidneys should be excreting acid
    - Positive urine anion gap in non-anion gap metabolic acidosis → Renal problem
    - Negative urine anion gap in non-anion gap metabolic acidosis → GI or other problem

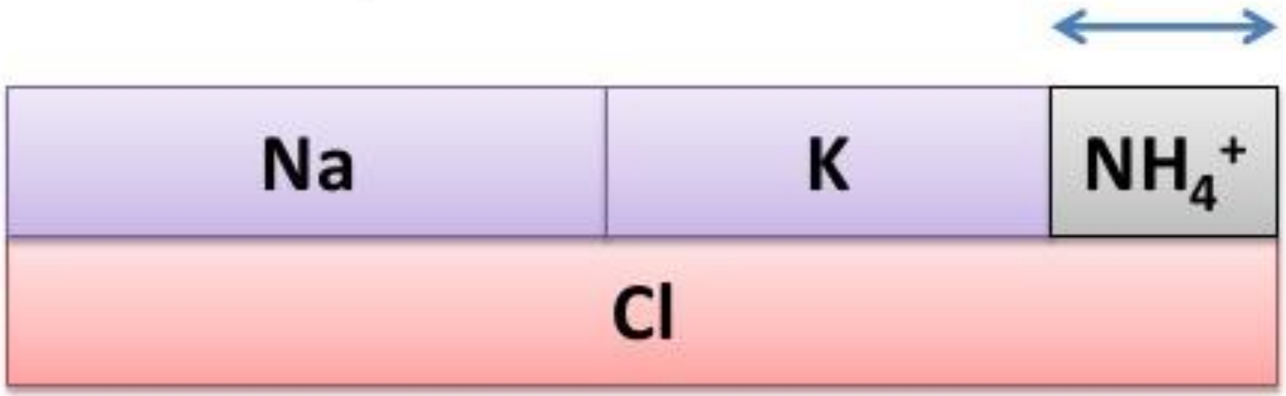
URINE ANION GAP

$U_{Na+} + U_{K+}$ + Unmeasured cations = U_{Cl-} + Unmeasured anions

Or, Unmeasured anions – Unmeasured cations = $(U_{Na+} + U_{K+}) - U_{Cl-}$

Urine Anion Gap (UAG) = $(U_{Na+} + U_{K+}) - U_{Cl-}$

- **NH_4^+** is the primary unmeasured cation which is not balanced by anions.
- **UAG as indirect assay for renal NH4+ excretion**



By Dr. Jagjit Khosla

Metabolic Alkalosis

- Volume contraction (kidneys retain sodium in exchange for hydrogen)
  - Vomiting
  - Diuresis
- Hyperaldosteronism
- Post-hypercapnea

Respiratory Acidosis

- CNS
  - Brainstem stroke, respiratory depressing drugs
- Spinal cord
  - Spinal cord injury, ALS
- Peripheral nerves
  - Guillaine-Barre syndrome
- Neuromuscular junction
  - Myasthenia gravis, Lambert-Eaton syndrome, botulism
- Muscles
  - Dermatomyositis, muscular dystrophy
- Chest wall
  - Kyphoscoliosis, ankylosing spondylitis
- Obstructive lung disease
  - COPD, asthma
- Restrictive lung disease
  - ILD, obesity

Respiratory Alkalosis

- Hypoxia
- Neuropsychiatric
  - Delirium
  - Anxiety
  - Pain
- Pregnancy/Cirrhosis
  - Secondary to progesterone and estradiol
- ASA overdose
- Gram – sepsis
  - Endotoxin stimulation or respiratory centers

Case 1

- 40 yo M w/ PMHx of EtOH abuse brought to ED in a coma. No focal neurological deficits.
- pH 7.3/$PaCO_2$ = 30/PaO_2 = 90

- Na 135, K 4.0, Cl 99, HCO_3 14, BUN 6, Glucose 10, EtOH 80, serum osmoles 366

Case 2

- 30 you M with one week history of diarrhea after a trip to Mexico presents to ED. He is volume deplete on exam and has decreased dark urine output.

- pH = 7.3/$PaCO_2$ = 35/PaO_2 = 100

- Na 129, K 2.9, Cl 100, HCO_3 19

Case 3

- 80 yo F with PMHx of COPD presents with worsening SOB over several weeks

- pH = 7.3/$PaCO_2$ = 50/PaO_2 = 80

- Na 130, K 2.7, Cl 80, HCO_3 27

Case 4

- 32 yo M with peptic ulcer disease presents with gastric outlet obstruction and 2 weeks of persistent vomiting. He is volume deplete exam.

- pH 7.5/$PaCO_2$ = 50/PaO_2 = 95

- Na 130, K 2.7, Cl 80, HCO_3 38

Case 5

- 56 yo M admitted for severe pneumonia requiring mechanical ventilation. Currently intubated, on PSV 15/5, FiO2 30%, RR15 while on propofol infusion at 50 mcg/kg/min. Does not tolerate weaning ventilatory support while sedated as he desaturates when pressure support is lowered. He becomes tachypneic and clearly delirious whenever sedation is reduced. When sedation is off and patient is on PSV 5/5, FiO2 30%, RR is 45 and ABG is:
- pH 7.50/$PaCO_2$ = 22/PaO_2 = 100
- Na 139, K 4.2, Cl 113, HCO_3 15

Case 6

- 68 yo F presents with leg edema and dyspnea on exertion, reports “heart problems” on history. Initially stable vitals, normal ECG, normal CXR, ↑ BNP at 985. Diagnosed with heart failure and despite aggressive diuresis became progressively more short of breath (RR 35), started on O2 at 4 LPM → ICU called.

- Na 150, K 4.0, Cl 114 , HCO_3 12

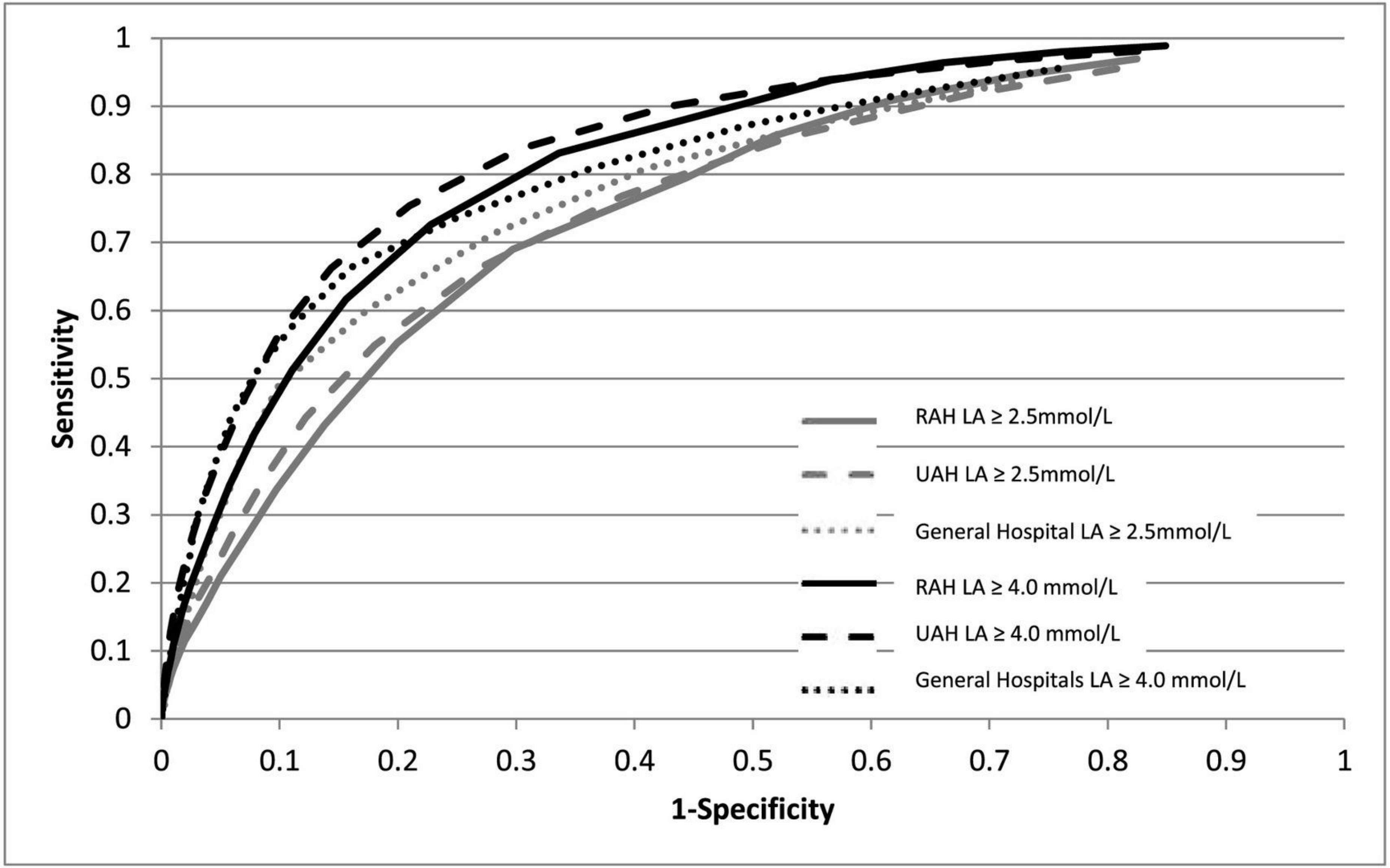

KNOWING YOUR LIMITATIONS
JUST BECAUSE YOU CAN HOLD YOUR BREATH UNDERWATER DOESN'T MEAN THAT YOU CAN LIVE THERE.

Limitations

- This approach is a gross simplification of a very complex metabolic system involving multiple organs
  - We are using single values instead of ranges for pH, $PaCO_2$, and HCO_3
  - Our expected compensations are also single values instead of ranges
    - E.g. expected $PaCO_2$ in a metabolic acidosis should be calculated using Winter's formula
      - $PaCO_2 = (1.5 \times HCO_3) + 8 +/- 2$
  - These simplifications make acid/base analysis easier and more efficient and likely provide enough information for clinical decision making most of the time…

Limitations

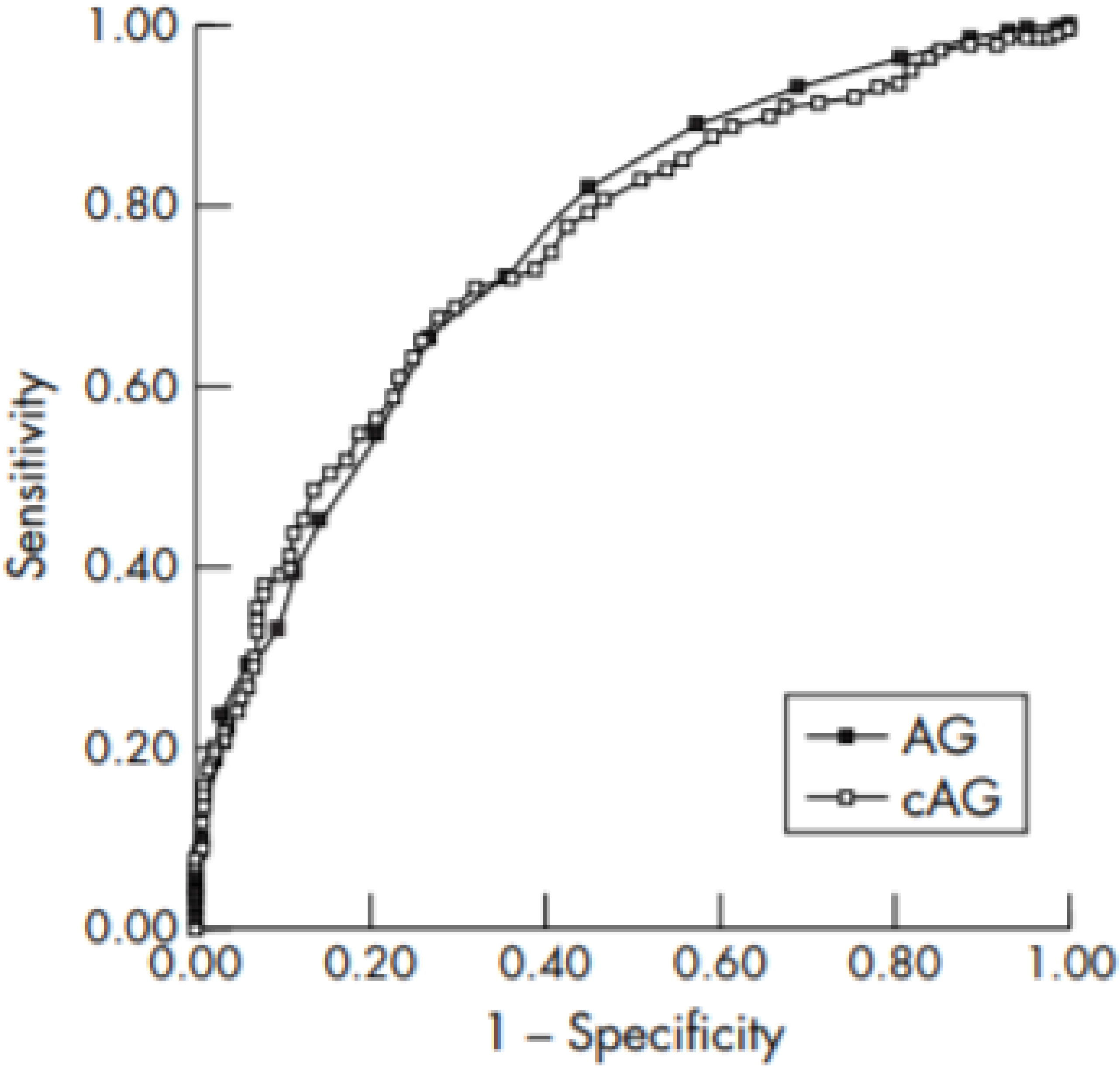
- Anion gap is not an ideal test for lactic acidosis



Xu Q, et al. Low sensitivity of anion gap to detect clinically significant lactic acidosis in the emergency department. Clin Biochem. 2017;50(18):1164–1167.

Limitations

- Anion gap is not an ideal test for lactic acidosis
  - Sensitivity 61% (AG ≥ 12 to detect lactate ≥ 2.5 mmol/L)
- Anion gap using albumin correction is not much better



Dinh CH, Ng R, Grandinetti A, Joffe A, Chow DC. Correcting the anion gap for hypoalbuminaemia does not improve detection of hyperlactataemia. Emergency Medicine Journal : EMJ. 2006;23(8):627-629. doi:10.1136/emj.2005.031898.

Limitations

- Anion gap is not an ideal test for lactic acidosis
  - Sensitivity 61% (AG ≥ 12 to detect lactate ≥ 2.5 mmol/L
- Anion gap using albumin correction is not much better
  - Sensitivity 75% (cAG ≥ 12 to detect lactate ≥ 2.5 mmol/L)
  - Formula
    - cAG (mmol/l) = anion gap + 0.25 × (normal albumin − measured albumin) (albumin is measured in g/l)

Acid-Base Tips

- Every hospitalized patient gets an electrolyte panel → it behooves you to look at the HCO_3
  - If it is ↑ investigate..
  - If it is ↓ investigate and worry…
- Get an ABG on every *sick* patient with a respiratory problem, an abnormal HCO3, or who you are worried about
  - Remember to interpret this statement through the lens of an intensivist
- Every patient with a metabolic acidosis should have labs sent for ketones, renal failure (uremia), lactate, and serum osmoles

Summary

- Develop an approach to acid base problems
- Understand the purpose of working through acid base problems
- Work through some cases
- Understand the limitations of the approach
- Helpful hints

"I don't have any answers. I'm a non-prophet."