Disclosures

• None
Objectives

• Introduce a stepwise approach to metabolic acidosis.

• Analyze a variety of clinical scenarios using the tools learnt.

• Reveal helpful and practical clinical pearls.
pH ≈ \frac{\text{HCO}_3}{\text{PaCO}_2}
Initial steps in acid-base interpretation

1. **Look at the pH**
   - pH > 7.4 → alkalemia
   - pH < 7.4 → acidemia

2. **Identify the Primary Acid-Base Disorder**
   - PH & P_a CO_2 change in the same direction → metabolic
   - pH & P_a CO_2 change in the opposite direction → respiratory

3. **Is compensation appropriate?**
   - Yes → disturbance is simple
   - No → disturbance is mixed
Primary Metabolic Acidosis

\[ \downarrow \text{pH} \approx \downarrow \frac{\text{HCO}_3}{\text{P}_a\text{CO}_2} \]

- The lung compensates to bring pH close to normal
- Expected \( \text{P}_a\text{CO}_2 = (1.5 \times \text{HCO}_3) + 8 \pm 2 \)
Primary Metabolic Acidosis

- A sign of an underlying disease process

Mechanisms:
1. Increased production of acids
2. Decreased excretion of acids
3. Loss of bicarbonate

- Prognosis is directly related to the underlying etiology
- May or may not cause acidemia.
Step 1: Calculate the Anion Gap

Anion Gap (AG) = Na\(^+\) – (Cl\(^-\) + HCO\(_3^-\))

Na\(^+\) + unmeasured cations = Cl\(^-\) + HCO\(_3^-\) + unmeasured anions

Na\(^+\) – (Cl\(^-\) + HCO\(_3^-\)) = unmeasured anions – unmeasured cations

Albumin, Phosphate, Mg\(^+\), K\(^+\), Ca\(^+\)
Optimal values: pH 7.40  $P_a\text{CO}_2$ 40  HCO$_3$ 24  AG 12

Case 1

• 52 year-old man with a past medical history of diabetes and alcohol abuse, was admitted for acute diarrhea over the past few days.

• Electrolytes:

Na 142,  K 3.2,  Cl 110,  HCO$_3$ 20,  Glucose 200, BUN 25,  Cr 1.1
Which of the following is more likely causing his metabolic acidosis?

a) Alcoholic Ketoacidosis  
b) Diabetic Ketoacidosis  
c) Diarrhea  
d) Lactic Acidosis
• AG = 142 - (110 + 20) = 12 (normal)

• Normal AG Metabolic Acidosis
DDx of Normal AG Metabolic Acidosis

• Diarrhea
• Renal tubular acidosis
• Medications (Acetazolamide, spironolactone)
• Adrenal insufficiency
• Rapid saline administration

\[ AG = Na^+ - (Cl^- + HCO_3^-) \]
Clinical Pearl

- $[\text{Cl}^-]$ in NS $> [\text{Cl}^-]$ in extracellular fluid
  (154 mEq/L vs. 100 mEq/L, respectively)

NS Infusion raises Cl in extracellular fluid

Increased $\text{HCO}_3^-$ losses in urine to maintain electrical neutrality
Step 2: Compare $\Delta$ AG to $\Delta$ HCO$_3^-$

With AG acidosis each “one added acid" is reflected as “one less HCO$_3^-$”

- $\uparrow$ AG = $\downarrow$ HCO$_3^-$ $\Rightarrow$ No other metabolic processes

- $\uparrow$ AG > $\downarrow$ HCO$_3^-$ $\Rightarrow$ High AG metabolic acidosis & metabolic alkalosis

- $\uparrow$ AG < $\downarrow$ HCO$_3^-$ $\Rightarrow$ High AG metabolic acidosis & normal AG metabolic acidosis
Case 2

A 25-year-old homeless man was admitted for confusion and vague abdominal pain.

Na 128    K 5    Cl 92    HCO₃ 8    BUN 45    Cr 2

pH 7.22    PₐCO₂ 20
Which of the following will be the least helpful in making the specific diagnosis?

a) Serum glucose
b) Urine ketones
c) Serum lactate
d) Urine anion gap
Na 128  K 5  Cl 92  HCO₃ 8  BUN 45  Cr 2
pH 7.22  PₐCO₂ 20

• Step 1: AG = 128 - (92 + 8) = 28 (high)
• Step 2: ∆ AG (28 - 12) = 16 = ∆ HCO₃ (24 - 8)

High AG Metabolic Acidosis
DDx of High AG Metabolic Acidosis

- Ketoacidosis
  - (a) Diabetic
  - (b) Alcoholic
  - (c) Starvation
- Lactic acidosis
- Uremia (sulfate & phosphate accumulation)
- Toxins & drugs
  - (a) Salicylate toxicity
  - (b) Methanol ingestion
  - (c) Ethylene glycol ingestion
MUDPILESERS

- Methanol
- Uremia
- DKA/Alcoholic KA
- Paraldehyde
- Isoniazid
- Lactic Acidosis
- EtOH/Ethylene Glycol
- Rhabdo/Renal Failure
- Salicylates
Case 2 cont.

Further labs are ordered:
Glucose: 360
Lactate: -ve
Urine ketones: -ve
Serum beta-hydroxybutyrate: 6 (elevated)
Now what is the most likely diagnosis?

a) Alcoholic Ketoacidosis
b) Diabetic Ketoacidosis
c) Starvation Ketoacidosis
d) Lactic Acidosis
DKA diagnostic pearls

- Biochemical triad of:
  - Hyperglycemia (Glucose > 250 mg/dL)
  - Ketonemia
  - Metabolic acidosis (pH ≤ 7.3, HCO₃ ≤ 18)

- Beta-hydroxybutyrate is the strongest and most prevalent acid in DKA

- The dipstick test (nitroprusside ketone reaction) can detect acetoacetate but not beta-hydroxybutyrate
Case 2 cont.

Na 128    K 5    Cl 92    HCO$_3$ 8    BUN 45    Cr 2    
pH 7.22    P$_a$CO$_2$ 20

You start IV normal saline & insulin drip per DKA protocol, he starts to feel better with good urine output.
What should you administer now?

a) Potassium
b) Sodium bicarbonate
c) Both a) and b)
d) Neither a) or b)
Few hours later you repeat his labs and notice that $\text{HCO}_3$ has not changed (8) and urine ketones are now positive. What would you do?

a) Start sodium bicarbonate  
b) Intubate the patient  
c) Both a) and b)  
d) Neither a) or b)
DKA management pearls

- No bicarbonate is necessary if pH is >7.0

- Start K replacement for K < 5.3 mEq/l, assuming adequate urine output at 50 ml/h

- Look for a normal gap acidosis which can follow successful treatment

*Diabetes Care. 2006 Dec;29(12):2739-48.*
• Monitoring HCO$_3$ alone will create a false impression that ketoacids are not being cleared

• During therapy, β-OHB is converted to acetoacetic acid, which may lead you to believe that ketosis has worsened

• Assessment of ketone levels by the nitroprusside method should not be used as an indicator of response to therapy
Case 3

- A 61 year old man with a history of alcohol abuse, presents to the hospital with poor PO intake, nausea and vomiting. Claims he had no alcohol over the past few days.

- pH 7.4, $P_aCO_2$ 40, $HCO_3$ 24
- Na 135, K 3.5, Cl 91, $HCO_3$ 24, BUN 30, Cr 1.2
- Blood alcohol level: 0
What does this patient have?

a) Metabolic acidosis
b) Metabolic alkalosis
c) Both a) and b)
d) Neither a) or b)
Na 135, K 3.5, Cl 91, HCO₃ 24, BUN 30, Cr 1.2, pH 7.4, PₐCO₂ 40

• Step 1: AG = 135 - (91 + 24) = 20 (high)
• Step 2: ∆ AG (20 - 12) > ∆ HCO₃ (24 - 24)

High AG Metabolic Acidosis (AKA) and Metabolic Alkalosis (vomiting)
Clinical pearls

- AKA usually appears 1 - 3 days after a period of heavy binge drinking

- Metabolic acidosis & metabolic alkalosis can co-exist, and the patient may end up with a normal $\text{HCO}_3$$_3$

- A normal ABG does not exclude the presence of an acid-base abnormality
Case 4

• An 82 year-old SNF resident was transferred to the hospital for a reported fever, diarrhea, and change in mental status.

• Na 132, K 3.5, Cl 106, HCO$_3$ 14, Albumin 2

• pH 7.31, P$_a$CO$_2$ 29
What does this patient have?

a) High AG Metabolic acidosis
b) Normal AG Metabolic acidosis
c) Both a) and b)
d) Neither a) or b)
Clinical pearl

- Hypoalbuminemia lowers the anion gap, which can mask a significant gap acidosis

\[ \text{AG} = \text{unmeasured anions} - \text{unmeasured cations} \]

- Corrected AG = AG + 0.25 \times (4 - \text{albumin})
Na 132, K 3.5, Cl 106, HCO₃ 14, Alb 2
pH 7.31, PₐCO₂ 29

• Step 1: AG = 132 - (106 + 14) = 12 (normal)
  Corrected AG = 12 + 2.5 × (4 - 2) = 17 (high)
• Step 2: Δ AG (17-12) < Δ HCO₃ (24-14)

AG Metabolic Acidosis & non-AG Metabolic Acidosis
Case 4 cont.

- You order lactate on this patient and it comes back elevated at 8
- She becomes hemodynamically unstable despite medical management and is transferred to the ICU
- IVF and broad spectrum Abx were administered.
- She is now requiring moderate dose of Norepinephrine drip to maintain her BP.
What would you do next?

a) Start IV sodium bicarbonate
b) Start IV THAM
c) Both a) and b)
d) Neither a) or b)
IV sodium bicarbonate

- Inexpensive and simple to use

- Can cause volume overload (50-mL bolus of sodium bicarbonate has physiologic results similar to 325 mL of NS or 385 mL of LR)

- Increases CO$_2$ generation which might exacerbate intracellular acidosis
THAM (*tris*-hydroxymethyl-amino-methane)

- Buffers acidosis without increasing serum Na or generating more CO$_2$

- Requires intact renal function or dialysis

- Despite these attributes, THAM has not been documented clinically to be more efficacious than sodium bicarbonate.

- May induce respiratory depression and hypoglycemia
We recommend against the use of sodium bicarbonate therapy for the purpose of improving hemodynamics or reducing vasopressor requirements in patients with hypoperfusion-induced lactic acidemia with pH ≥ 7.15 (grade 2B)

Questions?

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