APPROACH TO METABOLIC ACIDOSIS

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OVERVIEW

- Concepts
- Definition
- Approach

HOMEOSTASIS

- Homeostasis (internal milieu)
- Early living organisms developed an ability to *"carry the ocean with them"* in the form of an internal ocean
- "*The constancy of the internal environment is the condition of a free and independent existence*" - Claude Bernard (1878)
- Organisms must maintain the constancy of this internal ocean despite great fluctuations in diet, fluid intake, and other environmental conditions.

Hoenig MP Clin J Am Soc Nephrol. 2014; 9: 1272–1281.

HOMEOSTASIS

- Physiologic processes that, in aggregate, maintain the constancy of the internal chemistries - Walter Cannon (1939)
- Includes
  - Water balance (defence of volume)
  - Osmolarity
  - **Acid base balance (pH)**
  - Electrolytes

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ACID BASE

- Maintenance of pH is a critical activity
- Essential for normal cellular function
- pH dictates the charged state of proteins
  - Affects conformational shape, enzymatic activity, binding, and cellular transport
  - Allows proteins to perform essential metabolic functions.

WHAT WE MEASURE ROUTINELY

- pH of blood (Normal value 7.35- 7.45)
- Partial pressure of Co2 in blood
- Calculate the bicarbonate extrapolating from equations

WHAT WE DON'T KNOW

- Intracellular pH – where most cellular functions happen
- Actual levels of bicarbonate and other buffers
- Degree of disturbance in the charged state of functional proteins

- Fact- we only skim the surface and know very little about acid base status with our usual blood gas measurements

DEFINITIONS

- Acidemia - refers to serum pH <7.35
  - may be due to respiratory (PCO2) or metabolic disturbance or a combination of both
- Acidosis
  - The process (underlying disturbance) that leads to development of acidemia
  - metabolic acidosis - acid base imbalance with plasma HCO_3 < 20 mmol/L

CLINICAL APPROACH-ESSENTIAL FACTS

Metabolic acidosis can result from

1. Net acid gain
   a. Increased acid production e.g. lactic acidosis, ketoacidosis
   b. Reduced excretion of inorganic acids e.g. renal failure
2. Net loss of alkali (bicarbonate)
3. Dilution of serum bicarbonate by non-balanced fluids e.g. normal saline

CLINICAL APPROACH-ESSENTIAL FACTS

1. Serum electrolytes are important in acid base evaluation
   - closely linked to acid base balance
   - Useful and essential in evaluating acid base disturbances

2. The sum of all anions (negatively charged ions) is same as the sum of all cations (positively charged ions) in the ECF
   - Provided we measure all of them

CLINICAL APPROACH-ESSENTIAL FACTS

3. We don't measure all of them routinely
   - gap between the sum of all routinely measured cations (Na^+ , K^+) and anions (Cl^- and $HCO3^-$) - ***<u>Anion gap</u>***
   - Anion gap: $Na^+ - (Cl^- + HCO3^-)$; Normal value: 12- 16

- All abnormal acids (organic and inorganic) leave behind anions once the H^+ splits from them.
- Hence increase in unmeasured anions is indicative of net gain in acid

STEPS IN ASSESSMENT- STEP 1

Step 1 – Identify metabolic acidosis

- Confirm metabolic acidosis [Acidemia ($pH<7.35$) & $HCO3^{-}$ < 20 mmol/L)]
  - pH, PCo2 and bicarbonate move in same direction (all decrease)
  - PCo2 decreases as a normal compensatory mechanism of the body to bring the pH back to normal

STEPS IN ASSESSMENT- STEP 2

<u>Step 2- Confirm whether there is a mixed acidosis (respiratory and metabolic)</u>

- ❖ Calculate expected PCO_2. (Winter's formula: **$PCO_2 = 1.5 \times HCO_3 + 8 \pm 2$**)

If measured PCO_2 is same as expected – no respiratory acidosis

If measured PCO_2 is higher than expected – associated resp acidosis

If measured PCO_2 is lower than expected – associated resp alkalosis

STEPS IN ASSESSMENT- STEP 3

Step 3 – Identify possible mechanism of metabolic acidosis

- ❖ Calculate anion gap
  - If increased, it is net gain of acid
  - If normal, it is loss of HCO3 or dilution by excess normal saline
  - Sometimes both mechanisms can be present

STEPS IN ASSESSMENT- STEP 3

- Anion gap
  - **Na^{+} - (Cl^{-} + $HCO3^{-}$)**
  - **Normal value: 12- 16**
  - **Correction of serum albumin**
    - for every 1 gm decrease in albumin below 4g/dL, add 2.5 to anion gap
    - Corrected anion gap = calculated AG + 2.5 (4 - serum albumin)

STEPS IN ASSESSMENT- STEP 3

Step 3 – Identify possible mechanism of metabolic acidosis

- Calculate anion gap
  - If **increased**, it is net **gain of acid**
  - If **normal**, it is **loss of HCO_3** or dilution by excess normal saline
  - Sometimes both mechanisms can be present
    - Decrease in HCO_3 will be more

STEPS IN ASSESSMENT- STEP 3

- **Delta ratio**
  - Attempt to see if the entire change in anion gap can be explained by change (decrease) in bicarbonate itself
  - Ratio of change in anion gap to change in bicarbonate

$$\frac{\text{measured anion gap} - 12}{24 - HCO_3}$$

  - **If delta ratio is 1 - 2 – simple net acid gain is the mechanism**
  - **If delta ratio < 1 - Loss of HCO_3 is also present**
  - **If delta ratio >2 - Associated metabolic alkalosis**

STEPS IN ASSESSMENT- STEP 4

Step 4- Identify possible etiology

- Usually obvious by clinical setting (History and physical exam)
- Additional clues

If net gain of acid (increased anion gap) is the mechanism

- Is ECF volume low? (dehydrated) - DKA , lactic acidosis
- Is GFR low (high serum creatinine)? – AKI / CKD
- High plasma osmolal gap – methanol, ethylene glycol
- Sepsis / shock – Lactic acidosis

STEPS IN ASSESSMENT- STEP 4

If loss of HCO_3 is the mechanism (normal anion gap)

- HCO_3 loss can happen either through kidney or GI tract
- Urinary anion gap is helpful
- Urine anion Gap : **$Na^+ + K^+ - Cl^-$**

Negative urinary anion gap – GI loss of bicarbonate

Positive urinary anion gap - Renal loss of bicarbonate

SUMMARY

Step 1	Step 2	Step 3	Step 4
Step 1 • Identify metabolic acidosis ⇩ pH ⇩ PCO2 ⇩ HCO3	**Step 2** • Confirm whether there is a mixed acidosis –Winter's formula	**Step 3** • Identify possible mechanism – Anion gap and delta ratio	**Step 4** • Identify possible etiology

MANAGEMENT PRINCIPLES

Issues about correction of metabolic acidemia

1. Do we know intracellular pH where all metabolism happen?
   - 7.00 ± 0.06 (skeletal muscle)
2. Intracellular pH has more robust buffer mechanisms
3. During intense exercise
   - Interstitial pH - 7.04 (6.93–7.12) in one study

Most harmful effects are due to the basic abnormality causing acidosis rather than pH itself.

So correction of pH alone may not have any effect beyond better numbers on paper / screen

MANAGEMENT PRINCIPLES

Complications of HCO_3 therapy

- Hypernatremia
- Hyperosmolality
- Hypercapnia
- Paradoxical Intracellular acidosis (CO_2)
- CSF acidosis
- Hypocalcemia
- Hypokalemia
- Impaired oxygen delivery

TREAT THE BASIC CAUSE

- Is ECF volume low? (dehydrated) - **<u>Correct volume status</u>**
- Is GFR low (high serum creatinine)? – AKI / CKD - **<u>RRT</u>**
- High plasma osmolal gap – methanol, ethylene glycol - **<u>Dialysis</u>**
- Sepsis / shock – Lactic acidosis – **<u>Resuscitate to stable hemodynamics</u>**
- Is HCO_3 lost in urine ? (RTA) - **<u>HCO_3 supplementation</u>**

THANK YOU

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