Metabolic Acidosis in the Critically Ill

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Important Issues in Metabolic Acidosis

- Recognition of a metabolic acidosis
- Determination of etiology
- Treatment of the cause
Data for Detection of Metabolic Acidosis

- Electrolytes
- Albumin
- Arterial blood gas: pH, $\text{PaCO}_2$
- Compensatory responses
- Clinical correlation
Traditional Method

- Evaluate pH
- Determine primary process (HCO$_3^-$, PCO$_2$)
- If respiratory, acute or chronic?
- If metabolic, determine respiratory compensation
- Calculate anion gap
- Calculate $\Delta$ gap
Limitations of Traditional Method

- Acidosis with “normal” anion gap
  - Hypoalbuminemia
    \[ AG_{\text{corrected}} = AG_{\text{observed}} + 2.5 \times [\text{normal albumin} - \text{measured albumin (g/dL)}] \]
  - Paraproteinemias
- ↑ Anion gap with no acidosis
  - Alkalemia (pH > 7.5)
  - ↑ Albumin concentration
**Base Excess Method**

- Calculated by nomograms/equations
- Standardized for effects of PCO$_2$ and hemoglobin
  - SBE (mEq/L) = $0.9287 \times (\text{HCO}_3^- - 24.4 + 14.83 \times [\text{pH} - 7.4])$
- Negative base excess $\rightarrow$ metabolic acidosis
- Positive base excess $\rightarrow$ metabolic alkalosis
- Significance requires clinical interpretation
Physicochemical Method

Respiratory
- PCO$_2$

pH

Metabolic
- SID
- SID$_{app} = $ Cations - Anions
- A$_{TOT}$
  - Albumin
    - PO$_4$
  - Lactate
  - Ketoacids

Cations
- Na$^+$
- K$^+$
- Ca$^+$
- Mg$^+$

Anions
- Cl$^-$
Etiologies of Metabolic Acidosis

- ↑ Endogenous acid production
- ↓ Renal excretion of acids
- Exogenous acid input
- Loss of bicarbonate
Metabolic Acidoses

- Traditional method
  - Increased anion gap
  - Normal anion gap (hyperchloremia)
- Physicochemical method (↓SID)
  - Free water excess (dilution acidosis)
  - Increase in strong anions (chloride or organic acid)
  - Increase in weak acids (↑$A_{TOT}$)
Anion Gap Acidosis

- Lactic acidosis
  - Type A
  - Type B

- Ketoacidosis
  - Diabetes
  - Ethanol-induced
  - Starvation

- Renal failure
- Toxins
  - Acetaminophen
  - Ethylene glycol
  - Methanol
  - Salicylates
  - Propylene glycol
  - Propofol
Lactic Acidosis in Critical Illness

- Results from anaerobic metabolism due to inadequate $O_2$ delivery/utilization
- Type B lactic acidosis
- Hepatic dysfunction
Type B Lactic Acidosis

- Results from altered cell metabolism with adequate O\textsubscript{2} delivery
- Malignancy—lymphoma, leukemia, myeloma
- \(\beta\)-agonists—epinephrine, dobutamine
- Linezolid
- Metformin
- Propofol
Type B Lactic Acidosis

- Propylene glycol (lorazepam, diazepam, phenobarbital, pentobarbital, phenytoin, etomidate, nitroglycerin)
- Nucleoside reverse transcriptase inhibitors
- Tetracyclines
- Valproic acid
Propofol Infusion Syndrome

- High risk
  - Sepsis
  - Catecholamine use
  - Impaired oxygen delivery
  - Head injury
- ICU patients with prolonged infusion of high doses (>4 mcg/kg/h)
- May occur at lower doses, shorter duration
Propofol Infusion Syndrome

- Lactic acidosis
- Hyperlipemia
- ECG abnormalities
- Myocardial failure
- Arrhythmias
- Hyperkalemia
- Rhabdomyolysis
- Acute renal failure

Early
Propylene Glycol Toxicity

- Usually occurs with >3 dys use of lorazepam
- Anion gap acidosis + osmolar gap
- CNS depression or agitation
- Renal dysfunction/failure
- Seizures
- Cardiac arrhythmias
- Hemolysis

830 mg/ml propylene glycol
Pyroglutamic acidosis (5-Oxoproline)

- Disturbance of γ-glutamyl cycle with ↑production of pyroglutamic acid
- Overproduction
  - Glutathione depletion (acetaminophen, sepsis, malnutrition, liver dysfunction)
- Undersecretion
  - Enzyme inhibition (penicillins, vigabatrin)
Non-Anion Gap Acidosis

- GI loss of $\text{HCO}_3^-$
  - Diarrhea
- Renal loss of $\text{HCO}_3^-$
  - Renal tubular acidosis
  - Tubular injury (ATN)
  - Hypoaldosterone states
- Infusion of chloride-rich solutions
- Pharmacologic intake ($\text{NH}_4\text{Cl}, \text{TPN}$)
**Acid-Base Fluid Issues**

- Normal saline (SID=0, pH 5.5) — lowers SID in large volume resuscitation → acidosis
- Lactated Ringer’s (SID=0, pH 6.5) — L-lactate is weak acid but does not contribute to SID due to rapid metabolism
- Albumin (pH 6.8) — contains weak acids
- Hetastarch (pH 3.5-7) — no weak acids
- Plasmalyte (pH 5.5)
Effects of Acidemia

- Cardiovascular
  - \( \uparrow \) Cardiac output, \( O_2 \) delivery
  - \( \downarrow \) Systemic vascular resistance
  - \( \uparrow \) Pulmonary vascular pressure
  - Coronary vasodilatation
  - Arrhythmias (rare)
  - \( \downarrow \) Response to catecholamines (?)
Effects of Acidemia

- **Respiratory**
  - ↑Minute ventilation

- **Metabolic**
  - ↓Glycolysis, ↑gluconeogenesis, insulin resistance
  - Hyperkalemia, hypercalcemia
  - Protein catabolism
  - Shift of oxyhemoglobin dissociation curve to right
Effects of Acidemia

- Central nervous system
  - ↑Cerebral blood flow
  - Decreased mental status
- Inflammatory mediators
  - Lactate → anti-inflammatory
  - Hyperchloremic → proinflammatory
Management of Metabolic Acidoses

- Determine etiology
- Treat primary pathologic condition
- Anion gap acidoses
  - DKA → insulin, fluids
  - Renal failure → dialysis
  - ↑ Lactate → fluids, inotropes, antidote, discontinue drugs, etc.
Management of Metabolic Acidoses

- Non-anion gap acidoses
  - Replace volume with low chloride, bicarbonate-containing fluid
Buffer Use in Acidosis

- What is the goal pH?
  - pH >7.2-7.25 or >7.15
- Bicarbonate use controversial
  - May improve hemodynamics if pH <7.1
- Buffers do not change outcomes
Potential Adverse Effects of Bicarbonate

- Volume overload
- Intracellular acidosis
- Respiratory acidosis
- Overshoot alkalemia
- Impaired $O_2$ delivery
- Hypokalemia
- Hypocalcemia
- Hypernatremia
- Hyperosmolality

Metabolic Acidoses

- Detection of acidosis
  - Use appropriate corrections
  - Correlate with clinical condition
- Determination of etiology
  - Multiple contributing factors
- Treatment of underlying condition
  - Little benefit of buffers
Thank you for your attention