

**AHN 347 – Adult Health I**  
**Acid-Base Balance: a critical element**

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**Body pH**

- A result of balance between acids and bases
  - Expressed as pH (presence of Hydrogen Ions)
  - pH can range from 0 (zero) to 15
  - pH above normal range is ALKALOSIS
  - pH below normal range is ACIDOSIS
  - Normal body function requires very narrow range
    - 7.35 – 7.45 (serum pH)
    - Very small changes can produce catastrophic results
    - Most pathologic alterations have potential for acid – base imbalance

**Main Players in pH**

- Acids
  - Substances that produce hydrogen ion ( $H^+$ ) when dissolved
  - By-products of aerobic cellular metabolism
    - Glucose metabolism produces dominant acid
      - Carbon Dioxide produced from Krebs Cycle
        - Combines with  $H_2O$  to make Carbonic Acid
    - Fat metabolism produces significant acids
      - Fatty acids
      - Keto-Acids
    - Protein produces some acid
      - Sulfuric Acid
  - By-products of anaerobic cellular metabolism
    - Glucose produces Lactic Acid
    - Fat produces Keto-Acids
- Bases
  - Almost exclusively Bicarbonate Ion ( $HCO_3^-$ )
    - Ingestion (intestinal absorption)
    - Pancreatic production
    - ICF >>>>> ECF shift
    - Renal Re-absorption

**The Chemistry of pH**

- pH means presence of hydrogen ions ( $H^+$ )
  - SO..... how come more  $H^+$  means less pH?
    - Math of calculating pH involves things like
      - negative logarithm
      - dissociation constant
      - Inverse concentration

- They guys who invented pH (Henderson and Hasslebach) were
  - Really Smart
    - 'cause they figured all this out without a calculator
  - Really Dumb
    - 'cause they figured it would make good sense

Don't sweat it..... Learn it!

- More Acid >>> More H<sup>+</sup> >>> Lower pH  
Less Acid >>> Less H<sup>+</sup> >>> Higher pH
  - Inverse Relationship
    - Which ever way acid goes, pH goes the other way
- More Base (HCO<sub>3</sub>) >>> Higher pH  
Less Base (HCO<sub>3</sub>) >>> Lower pH
  - Direct Relationship
    - Which ever way base goes, pH goes the same way
- An elevated pH (Alkalosis) may be a result of:
  - Increased Base (HCO<sub>3</sub>)  
and/or
  - Decreased Acid (usually CO<sub>2</sub>)
- A depressed pH (Acidosis) may be a result of:
  - Increased Acid (usually CO<sub>2</sub>)  
and/or
  - Decreased Base (HCO<sub>3</sub>)
- The body, if able, will attempt to adjust acid/base balance to move pH toward its normal homeostatic center-point ( 7.40 )
- An initial change in either acid or base will be followed by a compensatory change in the other
- The body will **NEVER overcompensate**

**pH will never pass 7.40 (in either direction) because of a compensatory change**

pH < 7.40 **cannot** be a compensated alkalosis

pH > 7.40 **cannot** be a compensated acidosis

### **Regulation of pH**

- Several systems work in concert
  - Buffer System (1st line)
  - Respiratory System (2nd Line)
  - Renal System (3rd Line)

- Buffer System (1st line)
  - Buffers act like chemical shock absorbers
    - Either absorb or release  $H^+$  if pH changes
      - Slows rate of pH change
    - Primary ECF buffer is Bicarbonate ( $HCO_3^+$ )
    - Primary ICF buffer is Phosphate ( $PO_4^{++}$ )
  - Response is **immediate but limited**
    - Cannot compensate for large or sustained changes
  
- Respiratory System (2nd Line)
  - Central Chemoreceptors
    - Located in Medulla
    - Sensitive to pH ( $[H^+]$ ) in CSF
      - pH of CSF reflects  $PaCO_2$
  - Primary Ventilatory Drive responds to pH ( $PaCO_2$ )
    - $\uparrow PaCO_2 \rightarrow \downarrow pH$ 
      - Respiratory rate increases to “Blow Off”  $CO_2$ 
        - pH increases due to less  $CO_2$
    - $\downarrow PaCO_2 \rightarrow \uparrow pH$ 
      - Respiratory rate decreases (may cease) to retain  $CO_2$ 
        - pH decreases due to retained  $CO_2$
  - Respiratory response to pH is **within minutes**
  
- Renal System (3rd Line)
  - Excretion or Reabsorption of  $HCO_3^+$
  - Excretion or Reabsorption of  $PO_4^{++}$  and Ammonia
    - $H^+$  follows  $PO_4^{++}$  and Ammonia
  - Strongest mechanism regulating pH
  - Renal response to pH is **slowest**
    - May take 24 to 48 hours

### **Acid-Base Imbalance**

- Imbalance may occur with gain or loss of either acid or base components
  - Actual imbalance occurs from gain of one
  - Relative imbalance occurs from loss of other
  
- Gain of acids or bases may occur from:
  - Over-production
  - Under-elimination
- Loss of acids or bases may occur from:
  - Over-elimination
  - Under-production
  
- Imbalances are be categorized by:

- Source of Imbalance
  - Respiratory
    - Gain or loss of CO<sub>2</sub>
  - Metabolic
    - Gain or Loss of HCO<sub>3</sub><sup>-</sup>
- Direction of Imbalance
  - Acidosis
    - Decreased pH
  - Alkalosis
    - Increased pH
- Respiratory Imbalance
  - Acidosis ( pH < 7.35 )
    - PaCO<sub>2</sub> > normal (35-45)
      - Under-elimination
        - Decreased Respiratory Rate/Depth
        - Airway Obstruction
        - Alveolar-Capillary Diffusion Defect
  - Alkalosis ( pH > 7.45 )
    - PaCO<sub>2</sub> < normal (35-45)
      - Over-elimination
        - Hyperventilation
- Metabolic Imbalance
  - Acidosis ( pH < 7.35 )
    - HCO<sub>3</sub><sup>-</sup> < normal (22-27)
      - Over-production of H<sup>+</sup>
        - Hyper-metabolism
        - Anaerobic Metabolism (Lactic Acidosis)
        - Keto-acidosis
      - Under-production of HCO<sub>3</sub><sup>-</sup>
        - Renal Failure
        - Hepatic Failure
        - Pancreatic Failure
    - Over-elimination of HCO<sub>3</sub><sup>-</sup>
      - Diarrhea
- Metabolic Imbalance
  - Alkalosis ( pH > 7.45 )
    - HCO<sub>3</sub><sup>-</sup> > normal (22-27)
      - Excess Base (actual)
        - Usually over-ingestion
        - Rapid/massive blood transfusions
      - Acid Deficit (relative)
        - Vomiting or NG Suction
        - Drugs

- Physical Assessment
  - Acidosis ( pH <7.35 )
    - Neuro-Muscular Depression
      - Lethargy, Confusion, Stupor, Coma
      - Decreased Muscle Tone and DTR's
      - Initial Cardiovascular Compensation
        - HR, BP increased
      - Subsequent Cardiovascular Collapse
        - HR, BP decreased
    - Increased Respiratory Rate if Metabolic Source
  - Alkalosis ( pH > 7.45 )
    - Neuro-Muscular Stimulation
      - Lightheaded, Agitation, Confusion
      - Increased Muscle Tone and DTR's
        - Twitching
        - Tetany
    - Cardiovascular Irritability
      - Palpitations
      - ↑HR, ↓BP
    - Subsequent Cardiovascular Collapse
      - HR, BP decreased
    - Decreased Respiratory Rate if Metabolic Source

- Lab Assessment
  - Electrolytes
    - Acidosis
      - High K+
      - Low CO2\*
    - Alkalosis
      - Low Cl-
      - High CO2\*

\*Note: the CO2 which is part of an electrolyte panel is actually a measurement of the serum bicarbonate (HCO<sub>3</sub><sup>-</sup>).

In other words: the CO2 on the Lytes Panel is the same as the HCO<sub>3</sub> on the ABGs

DON'T ASK ME WHY

■ Lab Assessment

■ Arterial Blood Gas (ABG) Interpretation

You **MUST** know normal values:

$$\text{pH} = 7.35 - 7.45$$

$$\text{pCO}_2 = 35 - 45$$

$$\text{HCO}_3^- = 22 - 27$$

You **MUST** understand how a deviation from normal, of any component, will influence pH

■ **Step 1 - Is anything abnormal?**

- No abnormalities = no acid/base imbalance
- If any abnormal, go to Step 2

■ **Step 2 - Which side of 7.40 is pH?**

- $< 7.40$  = Acidosis
- $> 7.40$  = Alkalosis

■ **Step 3 - Which abnormal would push pH in direction noted in Step 2?**

- If Acidosis, only  $\uparrow \text{CO}_2$  =(respiratory) or  $\downarrow \text{HCO}_3^-$  =(metabolic) could be responsible
- If Alkalosis, only  $\downarrow \text{CO}_2$  =(respiratory) or  $\uparrow \text{HCO}_3^-$  =(metabolic) could be responsible

■ **Step 4 - Is there an abnormal which would not push pH in the direction noted in Step 2?**

- If “NO”, then imbalance is “Uncompensated”
- If “YES”, then there has been some compensation for imbalance

■ **Step 5 - Is pH within normal range?**

- If “NO”, then imbalance is “Partially Compensated”
- If “YES”, then imbalance is “Fully Compensated”

■ ABG Examples

■ pH = 7.25

■ CO<sub>2</sub> = 55

■ HCO<sub>3</sub> = 24

■ pH = 7.28

■ CO<sub>2</sub> = 25

■ HCO<sub>3</sub> = 18

■ pH = 7.31

■ CO<sub>2</sub> = 50

■  $\text{HCO}_3 = 29$

### **Acid-Base Management**

- General Interventions
  - Anticipate/Recognize Physical and Diagnostic changes
    - Maintain Ongoing Physical assessment
    - Monitor Lab
      - Electrolytes
      - ABGs
  - Promote conditions supporting acid-base balance and prevention of complications
  
- Acidosis (Review Text, Chart 16-4, p. 229)
  - Respiratory
    - Promote excretion of  $\text{CO}_2$ 
      - Maintain Ventilation
  - Metabolic
    - Inhibit production of Acids
      - Maintain Perfusion
      - Maintain Oxygenation
    - Promote retention of  $\text{HCO}_3$ 
      - Inhibit diarrhea
  
- Alkalosis (Review Text, Chart 16-6, p. 232)
  - Respiratory
    - Promote retention of  $\text{CO}_2$ 
      - Inhibit Hyperventilation
  - Metabolic
    - Inhibit loss of Acids
      - Inhibit Emesis
    - Promote retention of  $\text{HCO}_3$ 
      - Maintain Renal Function
      - Inhibit diarrhea