ACID/BASE BALANCE

REVIEW

From Chapter 3, Part 1
• Acid-base balance is a dynamic relationship that reflects the relative concentration of hydrogen ions in the body.
• Hydrogen ions are acidic and the concentration of those in the body must be maintained within fairly strict limits.
• Any deviation adversely affects the body
• Changes from second to second
The pH Scale

• pH=potential of Hydrogen
• The pH scale is inversely related to hydrogen ion concentration
• The greater the hydrogen concentration, the lower the pH
• The pH scale ranges from 1 to 14
• Normal body pH is 7.35 to 7.45
• pH below 7.35=Acidosis
• pH above 7.45=Alkalosis
• Variance of 0.4 can be lethal
Regulation of Acid-Base Balance

• The body is constantly producing hydrogen ions (acids) through metabolism and other biochemical processes
• To maintain the correct acid-base balance, these hydrogen ions must be eliminated
3 Mechanisms to Remove Hydrogen

- Buffer system (bicarbonate buffer system)
- Respirations
- Kidney function
Buffer System
(Bicarbonate Buffer System)

• The fastest mechanism.
• Two components of this system are bicarbonate ion \((\text{HCO}_3^-)\) and carbonic acid \((\text{H}_2\text{CO}_3)\) and are normally in equilibrium with hydrogen \((\text{H}^+)\).
Hydrogen may combine with bicarbonate to produce carbonic acid.

In other circumstances carbonic acid will dissociate into bicarbonate and hydrogen.

Normally, for every molecule of carbonic acid, there are 20 molecules of bicarbonate ion. (Ratio of 20:1)
\[ H^+ + HCO_3^- \leftrightarrow H_2CO_3 \]

- An increase in hydrogen ion (acidosis) is corrected as the excess hydrogen ions combine with bicarbonate ions to form carbonic acid
  - Increase in hydrogen ion leads to an increase in carbonic acid
- A decrease in hydrogen ions (alkalosis) will cause carbonic acid to dissociate into bicarbonate ion and hydrogen ion
$\text{H}^+ + \text{HCO}_3^- \leftrightarrow \text{H}_2\text{CO}_3$

- Increased Acid: $\uparrow \text{H}^+ + \text{HCO}_3^- \rightarrow \uparrow \text{H}_2\text{CO}_3$
- Decreased Acid: $\downarrow \text{H}^+ + \text{HCO}_3^- \rightarrow \downarrow \text{H}_2\text{CO}_3$
Acid-base Relations Relevant to pH

Ratio

20:1
(Normal pH)

20:4
(respiratory acidosis)

15:1
(Metabolic acidosis)
Respiratory and Kidney Mechanisms

• Increased respirations cause increased elimination of CO$_2$ which causes a decrease in hydrogen ions and an increase in pH.
• The kidneys regulate the pH by altering the concentration of bicarbonate ions in the blood.
Acid Base Balance Disorders

- Respiratory Acidosis
- Respiratory Alkalosis
- Metabolic Acidosis
- Metabolic Alkalosis
The Respiratory Component of Acid-Base Balance

- Decreased ventilations lead to increased PaCO$_2$ and carbonic acid which lowers the pH
  \[ \downarrow \text{ventilations} = \uparrow \text{PaCO}_2 + \uparrow \text{H}_2\text{CO}_3 = \text{Respiratory acidosis} \]

- Increased ventilations lead to decreased PaCO$_2$ and carbonic acid which increases the pH
  \[ \uparrow \text{ventilations} = \downarrow \text{PaCO}_2 + \downarrow \text{H}_2\text{CO}_3 = \text{Respiratory alkalosis} \]
The Respiratory Component of Acid-Base Balance
Respiratory Acidosis

- \( \uparrow \text{CO}_2 + \text{H}_2\text{O} \Leftrightarrow \uparrow \text{H}_2\text{CO}_3 \Leftrightarrow \uparrow \text{H}^+ + \text{HCO}_3^- \)

- Simplified: \( \uparrow \text{CO}_2 \Leftrightarrow \uparrow \text{H}^+ \)

- As \( \text{CO}_2 \) increases, pH should decrease producing acidosis

- Commonly seen on patients in respiratory arrest or breathing very slowly
Respiratory Alkalosis

• $\downarrow \text{CO}_2 + \text{H}_2\text{O} \Leftrightarrow \downarrow \text{H}_2\text{CO}_3 \Leftrightarrow \downarrow \text{H}^+ + \text{HCO}_3$

• Simplified: $\downarrow \text{CO}_2 \Leftrightarrow \downarrow \text{H}^+$

• As CO$_2$ decreases, pH should increase producing alkalosis

• Caused by hyperventilation
Normal Values

- pH: 7.35 to 7.45
- $\text{PaCO}_2$: 35 – 45 torr
- $\text{PO}_2$: 80-100 torr
Abnormal Values

- Respiratory Acidosis: $\downarrow \text{pH}$ and $\uparrow \text{CO}_2$
- Respiratory Alkalosis: $\uparrow \text{pH}$ and $\downarrow \text{CO}_2$
Example:

• pH = 7.25
• PaCO$_2$ = 60
• What is the acid/base imbalance?

Respiratory Acidosis!
Example:

• A patient is found unconscious and breathing 6 times per minute

• Should the \( \text{PaCO}_2 \) be high or low?
  • High

• Should the pH be high or low?
  • Low

• What is the respiratory pH imbalance?
  • Respiratory acidosis
Example:

• A patient is found hyperventilating and breathing 46 times per minute

• Should the PaCO$_2$ be high or low?
  • Low

• Should the pH be high or low?
  • High

• What is the respiratory pH imbalance?
  • Respiratory alkalosis
Example:

- $\text{pH} = 7.60$
- $\text{PaCO}_2 = 20$
- What is the acid/base imbalance?

Respiratory Alkalosis!
Simplifying Acid/Base Imbalances

- Look at the pH
  - If it is below 7.35 then it is acidosis
  - If it is above 7.45 then it is alkalosis

- Look at the PaCO$_2$
  - If it is below 35 torr or above 45 torr, then it is respiratory
  - If the PaCO$_2$ is within 35-45 torr, then the imbalance is metabolic
Simplifying Acid/Base Imbalances

- There can be combination of metabolic and respiratory imbalances
- Respiratory problems will normally affect metabolic changes
- Metabolic problems will normally affect respiratory changes
- Metabolic imbalances will be discussed later
ACID/BASE BALANCE

REVIEW

From Chapter 4, Part 1
Respiratory Acidosis

Caused by abnormal retention of CO₂ from impaired ventilation due to problems occurring in the lungs or respiratory center of the brain.

• Increased CO₂ = lowered pH

\[ \downarrow \text{Respirations} = \uparrow \text{CO}_2 + \text{H}_2\text{O} \rightarrow \uparrow \text{H}_2\text{CO}_3 \rightarrow \uparrow \text{H}^+ + \text{HCO}_3^- \]

• Treatment is to improve or assist ventilations
Respiratory Alkalosis

Caused by increased respiration and excessive elimination of CO₂. The CO₂ level is decreased and the pH is increased.

Decreased CO₂ = Increased pH

\[
\text{\textup{\textasciitilde}Respirations=\downarrow CO_2 + H_2O \rightarrow \downarrow H_2CO_3 \rightarrow \downarrow H^+ + HCO_3^-}
\]

- Treatment, if required, is to increase CO₂ level
Metabolic Acidosis

Results from the production of metabolic acids such as lactic acid due to anaerobic metabolism. These acids consume bicarbonate ions.

• Can be the result of dehydration, diabetes, or medication usage.

• pH is decreased, CO$_2$ is normal

\[ \uparrow H^+ + HCO_3^- \rightarrow \uparrow H_2CO_3 \rightarrow H_2O + \uparrow CO_2 \]
Metabolic Acidosis

• Treatment is to treat underlying cause, and:
  • Ventilations to eliminate excess CO$_2$ and subsequently Hydrogen ion
  • Could require Sodium Bicarbonate
Compensation for metabolic acidosis begins with an increase in respirations.
Metabolic Alkalosis

• It is usually caused by administration of diuretics, loss of chloride ions associated with prolonged vomiting, and overzealous administration of sodium bicarbonate.

• The pH is increased and the CO\textsubscript{2} level is normal.

\[
\downarrow \text{H}^+ + \text{HCO}_3^- \rightarrow \downarrow \text{H}_2\text{CO}_3 \rightarrow \text{H}_2\text{O} + \downarrow \text{CO}_2
\]

• Treatment is to correct underlying problem
Acid Base Imbalances

• Normally, both a respiratory and metabolic component are present in an acid-base imbalance.
• Actual determination requires arterial blood gas studies (ABGs)
• ABGs include pH, PaCO2, PaO2, bicarbonate concentration, and O2 sats
Determining Acid/Base Imbalances

• 1) Look at pH
  – Low = acidosis
  – High = alkalosis

• 2) Look at CO2
  – Normal = metabolic
  – High or low = Respiratory

• Most are a combination
  – Ex: Respiratory acidosis with slight metabolic acidosis
Acid Base Example 1

• Lab values:
  – pH is 7.30
  – PaCO2 is 38
  – PaO2 is 90
• Is this acidosis, normal, or alkalosis?
  • Acidosis
• Is CO2 high, low, or normal?
  • Normal
• What is the acid/base imbalance?
  • Metabolic Acidosis
Acid Base Example 2

• Lab values:
  – pH is 7.58
  – PaCO2 is 44
  – PaO2 is 90

• Is this acidosis, normal, or alkalosis?
  • Alkalosis

• Is CO2 high, low, or normal?
  • Normal

• What is the acid/base imbalance?
  • Metabolic Alkalosis
Acid Base Example 3

• Lab values:
  – pH is 7.64
  – PaCO2 is 34
  – PaO2 is 88

• Is this acidosis, normal, or alkalosis?
  • Alkalosis

• Is CO2 high, low, or normal?
  • Slightly low

• What is the acid/base imbalance?
  • Metabolic Alkalosis with slight Respiratory Alkalosis
Acid Base Example 4

• Lab values:
  – pH is 7.20
  – PaCO2 is 49
  – PaO2 is 88
• Is this acidosis, normal, or alkalosis?
• Acidosis
• Is CO2 high, low, or normal?
• Slightly high
• What is the acid/base imbalance?
• Respiratory Acidosis