Chapter 25: Fluid, Electrolyte, and Acid/Base Balance

Body Fluids:

1) Water: (universal solvent)

Body water varies based on age, sex, mass, and body composition

- $H_2O \approx 73\%$ body weight
- $H_2O (♂) \approx 60\%$ body weight
- $H_2O (♀) \approx 50\%$ body weight
- $♀ = ▲$ body fat / ▼ muscle mass
- $H_2O \approx 45\%$ body weight

Body Fluids:

1) Total Body Water

- Volume = 40 L (60% body weight)

- Intracellular Fluid (ICF)
  - Volume = 25 L (40% body weight)

- Extracellular Fluid (ECF)
  - Volume = 15 L (20% body weight)

- Interstitial Fluid
  - Volume = 12 L
Body Fluids:
2) Solutes:

A) Non-electrolytes
   (do not dissociate in solution – neutral)
   • Mostly organic molecules
     (e.g., glucose, lipids, urea)

B) Electrolytes
   (dissociate into ions in solution – charged)
   • Inorganic salts
   • Inorganic / organic acids
   • Proteins

Although individual solute are different between compartments, the osmotic concentrations of the ICF and ECF are usually identical...

Body Fluids:
2) Solutes:

What happens to ICF volume if we increase osmolarity of ECF?

IV bags of varying osmolarities allow for manipulation of ECF / ICF levels...

Water Balance:
For proper hydration: Water intake = Water output

<table>
<thead>
<tr>
<th>Water Intake</th>
<th>Water Output</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metabolism (10%)</strong></td>
<td><strong>Feces (2%)</strong></td>
</tr>
<tr>
<td><strong>Solid foods (30%)</strong></td>
<td><strong>Sweat (9%)</strong></td>
</tr>
<tr>
<td><strong>Ingested liquids (60%)</strong></td>
<td><strong>Skin / lungs (30%)</strong></td>
</tr>
<tr>
<td><strong>2500 ml/day</strong></td>
<td><strong>Urine (60%)</strong></td>
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ICF functions as a reservoir

< 0
Osmolarity rises:
• Thirst
• ADH release

> 0
Osmolarity lowers:
• Thirst
• ADH release

= 0
Water Balance: Thirst Mechanism:

(-) \[ \downarrow \text{osmolarity} \]

\[ \downarrow \text{volume of extracellular fluid} \]

Osmoreceptors stimulated (Hypothalamus)

\[ \downarrow \text{saliva secretion} \]

Dry mouth

Sensation of thirst

Drink

\[ \uparrow \text{osmolarity} / \uparrow \text{volume of extracellular fluid} \]

\[ \text{Water Balance:} \]

Water Balance Disorders:

1) Dehydration (long-term water deficiency)
   a) Injury (e.g., burn, hemorrhage)
   b) Exercise (profuse sweating)
   c) Drugs (e.g., diuretic abuse)

2) Hypotonic hydration (water intoxication)

3) Edema (\[ \uparrow \text{fluid in interstitial space} \])

Electrolyte Balance:

Importance:

1) Total [electrolyte] directly affects water balance
2) Individual [electrolyte]s affect cell functions

Uptake into System:
- Across digestive epithelium
- Through metabolic activity

Obtaining electrolytes not a problem...

Pica: Appetite for abnormal substances

Release from System:
- Through digestive tract / kidney
- Through perspiration
- Gastrointestinal disorders

Replenish both fluids and electrolytes...

Cholera: Electrolyte / fluid loss due to bacterial toxin
Chapters 25: Fluid / Electrolyte / Acid-Base Balance

Electrolyte Balance

A) Sodium Balance:

Importance:
1) Contributes to osmotic pressure
2) Maintains neuron / muscle function

Osmoreceptors stimulated
↑ ADH release; ↑ thirst

Osmoreceptors inhibited
↓ ADH release; ↓ thirst

↓ [Na+] in ECF
↓ concentration ECF

Normal [Na+] in ECF
(physiological)

↑ [Na+] in ECF
↓ osmotic pressure

Most abundant cation
in ECF (~ 280 mosm)

• Most common ion associated with electrolyte balance problems
  • Hyponatremia = ↓ [Na+]
  • Hypernatremia = ↑ [Na+]

B) Potassium Balance:

Importance:
1) Maintains neuron / muscle function
2) Assists in maintenance of pH

• As a rule, K+ levels in ECF sufficiently high that K+ needs to be secreted
  • Rate lost at kidney depends on:
    1) Changes in [K+] of ECF (↑ [K+] = ↑ rate of secretion)
    2) Changes in pH (↓ pH = ↑ rate of secretion)
    3) Aldosterone levels (↑ aldosterone = ↑ rate of secretion)

C) Calcium Balance:

Importance:
1) Maintains neuron / muscle function
2) Allows for normal blood clotting

• Levels in ECF regulated primarily by parathyroid hormone:
  1) ↑ PTH = ↑ bone desorption
  2) ↑ PTH = ↑ intestinal Ca++ absorption
  3) ↑ PTH = ↑ renal Ca++ reabsorption

Chvostek's sign

Hypokalemia = ↓ [K+]
Hyperkalemia = ↑ [K+]

Hypocalcemia = ↓ [Ca++]
Hypercalcemia = ↑ [Ca++]

Baroreceptor initiated reflexes also affect [Na+] in body

Marieb & Hoehn – Figure 25.10

Electrolyte Balance

Baroreceptor initiated reflexes also affect [Na+] in body

Marieb & Hoehn – Figure 25.10

Electrolyte Balance

Marieb & Hoehn – Figure 25.10
Acid-Base Balance: Critical for body to maintain pH between 7.35 – 7.45

Problems Encountered:
1) Disruption of cell membrane stability
2) Alteration of protein structure
3) Enzymatic activity change

Acid Types:
1) Volatile Acids: Acids that can leave solution and enter the atmosphere
   \[ \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3 \rightarrow \text{HCO}_3^- + \text{H}^+ \] carbonic acid

2) Fixed Acids: Acids that do not leave solution
   - Result from metabolism (e.g., phosphoric acid / lactic acid / ketone bodies)
   - Can only be eliminated via kidneys

Acid-Base Balance: Chapters 25: Fluid / Electrolyte / Acid-Base Balance

H^+ Gain:
- Across digestive epithelium
- Cell metabolic activities

H^+ Loss:
- Release at lungs
- Secretion into urine

Chemical Buffering Systems:
Dissolved compounds that neutralize H^+ during transport by binding H^+ when pH drops and releasing H^+ when pH rises

1) Bicarbonate Buffer System: (primary ECF buffer)
   \[ \text{H}_2\text{CO}_3 \leftrightarrow \text{HCO}_3^- + \text{H}^+ \]
   - Limitation: Can’t protect system from pH changes resulting from elevated / depressed CO2 levels
   - Respiratory system must be working normally

Acid-Base Balance: Chapters 25: Fluid / Electrolyte / Acid-Base Balance

2) Phosphate Buffer System: (primary ICF buffer)
   \[ \text{H}_2\text{PO}_4^- \leftrightarrow \text{HPO}_4^{2-} + \text{H}^+ \]
   - Also an important buffer in urine

3) Protein Buffer System: (both ECF and ICF buffer)
   If pH rises
   \[ \text{R} – \text{COOH} \rightarrow \text{R} – \text{COO}^- + \text{H}^+ \]
   \[ \text{R} – \text{NH}_2 + \text{H}^+ \rightarrow \text{R} – \text{NH}_3^+ \]
   - Proteins are most plentiful and powerful source of buffers in body

Buffers are a short-term fix to the problem; In the long term, H^+ must be removed from the system...
Chapters 25: Fluid / Electrolyte / Acid-Base Balance

1) Respiratory Regulation:

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

**Bicarbonate buffer system**

If \( \text{H}^+ \) begins to rise in system, respiratory centers excited

\( \text{CO}_2 \) leaves system

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

If \( \text{H}^+ \) begins to fall in system, respiratory centers depressed

\( \text{CO}_2 \) leaves system

Doubling / halving of areolar ventilation can raise / lower blood pH by 0.2 pH units

2) Renal Regulation:

A) Bicarbonate reabsorption:

Kidneys focus on maintaining adequate \( \text{HCO}_3^- \) levels in body

B) Bicarbonate generation:

If high pH \((\text{low} \, [\text{H}^+])\) exists in blood

\( \text{HCO}_3^- \) can be secreted by PCT cells

C) Bicarbonate secretion:

If low pH \((\text{high} \, [\text{H}^+])\) exists in blood

\( \text{HCO}_3^- \) can be secreted by PCT cells
Disturbances of Acid-Base Balance:

1) Respiratory Acid / Base Disorders:
   - A) Respiratory Acidosis:
     - ↑ CO₂ retained in body
     - Causes:
       - Hyperventilation (e.g., emphysema)
     - (Most common acid / base disorder)
   - B) Respiratory Alkalosis:
     - ↓ CO₂, retained in body
     - Causes:
       - Hypoventilation (e.g., stress)
       - (Rarely persist long enough to cause clinical emergency)

2) Metabolic Acid / Base Disorders:
   - A) Metabolic Acidosis:
     - ↑ fixed acids generated in body
     - Causes:
       - Starvation (↑ ketone bodies)
       - Excessive HCO₃⁻ loss (e.g., chronic diarrhea)
       - ↑ Alcohol consumption (↑ acetic acid)
   - B) Metabolic Alkalosis:
     - ↑ HCO₃⁻ generated in body
     - Causes:
       - Repeated vomiting (alkaline tide 'amped')
       - Antacid overdose (Rare in body)

In the short term, respiratory / urinary system will compensate for disorders...