Fluids and Electrolytes

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Importance

- Critical aspect in patient management
- Altered in:
  - Major trauma
  - Disease States
  - Operative trauma
Anatomic Distribution

- Total body water = 50-70% weight
  - Higher in men than women
  - Higher in slim than fat
  - Steadily decreases with age

- Example: 70 kg male: 42 liters of water
Total Body Weight

Total Body Water (60%)

Total Body Water = 60% of Body Weight

Body Fluid Compartments

Dry Weight (40%)

Functional (5%)

Blood Volume (5%)

Non-Functional/Transcellular (10%)

Interstitial Fluid (15%)

ECF = 20% Body Wt.

Intracellular Fluid (40%)

Total Body Water = 60% of Body Weight
Osmotic Pressures

Extracellular

\[ \text{Na}^+ \]
\[ \text{Cl}^- \]
\[ \text{HCO}_3^- \]

290-310 Osm

Intracellular

\[ \text{Mg}^+ \]
\[ \text{K}^+ \]
\[ \text{PO}_4^- \]
\[ \text{Proteins}^- \]

290-310 Osm
Definitions

Osmosis

- From the Greek *osmos* (impulse), derived from *otheo* (to push)
- Refers to the tendency, when 2 solutions of differing concentrations are separated by a semipermeable membrane, for the permeable substance to diffuse through the membrane from its higher to its lower concentration until the pressures across the membrane become equal
- In most biologic systems, water is freely permeable across membranes
  - Hence, any change in osmotic pressure will lead to shifts in water distribution (since H$_2$O is usually the only molecule that can move)
Definitions

- Total Osmotic Pressure
  - Sum of all osmotically active particles in the solution
    - NaCl = 2
    - Na$_2$SO$_4$ = 3
    - Glucose = 1
Definitions

- **Oncosis**
  - From the Greek, *onkosis* (swelling), derived from *onkos* (bulk, mass)
  - A condition characterized by the formation of one or more neoplasms, tumors, or other swelling
  - i.e., the term “oncology” derives from the same root

- In common usage, “oncosis” and “oncotic” refer to osmotic properties induced by colloids
Definitions

- Colloid
  - From the Greek *kolla* (glue) + *eidos* (appearance)
  - Aggregates of atoms or molecules in a finely divided state dispersed in a gaseous, liquid, or solid medium, and resisting sedimentation, diffusion, and filtration, thus differing from precipitates
Definitions

- Colloid oncotic pressure (COP)
  - the osmotic pressure exerted by colloids in solution
  - designated as $\pi$. 
Internal Environment

- **Homeostasis** must be preserved for optimal cellular functioning and viability
  - Balance between input and output must be maintained
  - Maintained by
    - Kidneys
    - Brain
    - Lungs
    - Skin
    - GI tract
  - Compromised by major surgical stress
Why do anything?

- Why bother with “ins” and “outs”?
  - That is, if we did nothing, couldn’t we achieve balance by letting it all stay in?

- Answer: No
  - The body produces metabolites that are eliminated in the urine:
    - Urea
    - Creatinine
    - Acid
  - You must excrete 500 - 800 ml of urine a day to excrete products of metabolism
“Ins”

- Normal person: Oral intake
  - 1 to 2.5 liters per day
    - 100 to 1,500 ml liquid
    - 400 - 1000 ml’s
      - extracted from solid food
      - oxidative metabolism (~400 ml/day)
“Outs”

- Urine
  - ~800 - 1500 ml daily
- Stool
  - ~250 ml daily
- Insensible loss
  - 600 ml daily
    - 75% lungs
    - 25% skin
  - Increased due to fever, hyperventilation, hypermetabolism, arid environment, evaporation (i.e., from exposed viscera)
Fundamental Concepts

- Electrolytes are measured in terms of their *concentration* within a fluid, not their content.
# Normal Concentrations of Plasma Electrolytes

<table>
<thead>
<tr>
<th>Electrolyte</th>
<th>Normal plasma concentration (mEq/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na⁺</td>
<td>135 – 145</td>
</tr>
<tr>
<td>K⁺</td>
<td>3.5 – 4.8</td>
</tr>
<tr>
<td>Cl⁻</td>
<td>95 – 106</td>
</tr>
<tr>
<td>HCO₃⁻</td>
<td>22 – 32</td>
</tr>
<tr>
<td>Mg²⁺</td>
<td>1.7 – 2.3</td>
</tr>
</tbody>
</table>
# Normal Volume and Composition of Body Fluids

<table>
<thead>
<tr>
<th>Source</th>
<th>Daily loss (ml)</th>
<th>[Na(^+)] (mEq/L)</th>
<th>[K(^+)] (mEq/L)</th>
<th>[Cl(^-)] (mEq/L)</th>
<th>[HCO(_3^-)] (mEq/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saliva</td>
<td>~1,000</td>
<td>20-80</td>
<td>10-20</td>
<td>20-40</td>
<td>20-160</td>
</tr>
<tr>
<td>Gastric juice</td>
<td>1,000 – 2,000</td>
<td>20-100</td>
<td>5-10</td>
<td>120-160</td>
<td>0</td>
</tr>
<tr>
<td>Bile</td>
<td>~1,000</td>
<td>150-250</td>
<td>5-10</td>
<td>40-60</td>
<td>20-60</td>
</tr>
<tr>
<td>Pancreatic juice</td>
<td>1,000 – 2,000</td>
<td>120</td>
<td>5-10</td>
<td>10-60</td>
<td>80-120</td>
</tr>
<tr>
<td>Succus entericus</td>
<td>1,000 – 2,000</td>
<td>140</td>
<td>5</td>
<td>Variable</td>
<td>Variable</td>
</tr>
<tr>
<td>Colon</td>
<td>200-1,500</td>
<td>75</td>
<td>30</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td>Sweat</td>
<td>200-1,000</td>
<td>20-70</td>
<td>5-10</td>
<td>40-60</td>
<td>0</td>
</tr>
</tbody>
</table>
Volume Disorders

- Occur due to adding or subtracting an **ISO**tonic fluid
  - Primarily affects extracellular fluid volume
  - No impact on intracellular fluid volume
  - No fluid shifts between compartments
    - (unless volume deficit is so severe than cell membrane pumps fail to maintain transcellular balance)
Causes of Extracellular Volume Deficits

- Loss of both sodium and water
  - not necessarily in the same proportion
- Acute or chronic GI fluid losses
  - Diarrhea
  - Vomiting
  - Fistulae
  - NG suction
- Fluid sequestration ("third spacing")
  - Postinjury
    - Burns
    - Multiple trauma
  - Postsurgical
- Excessive urinary sodium losses
  - Renal disease
  - Adrenal disease
  - Diuretic administration
Extracellular Volume Deficits: Signs and Symptoms

- Orthostatic hypotension
- Narrowed pulse pressure
- Tachycardia
- Evidence of reduced venous filling
- Oliguria
  - Concentrated urine
- Drowsiness
- Mild decrease in body temperature
- Small, soft tongue
- Reduced skin turgor
- More severe volume deficits eventually lead to stupor or coma
  - reduced deep tendon reflexes
  - muscle atony
Extracellular Volume Deficits: Management

- **Replacement with parenteral fluids**
  - Crystalloids
  - Colloids

- **Rapidity of replacement depends upon severity of deficit and underlying general health of the patient**
  - Severe deficits: 500 ml to 1,000 ml boluses
  - Lesser volumes with the elderly and infirm

- **Monitor clinical response**
  - Blood pressure, urine output, correction of other signs that initially signalled volume deficit

- **Set a volume administration threshold**
  - If administered volume is exceeded, a more specific indication of nature and degree of volume status is required
    - Typically a central venous pressure monitor or, more precisely, pulmonary artery catheter
Extracellular Volume Deficits: Maintenance

- **Volume**
  - Determine total quantity of fluid volume loss over 24 hour period
  - Add constant for insensible losses
    - ~ 500 ml at sea level
    - ~ 1,000 ml at elevations, in arid environments
    - Higher insensible losses with fevers, hypermetabolism

- **Concentration**
  - Determine sodium concentration of each fluid
    - Measure concentrations if necessary
  - Divide total by the total fluid volume to arrive at the required sodium concentration
  - Same process can be used for other specific electrolytes when necessary

- **Rate**
  - Divide the total volume by 24 (hours) to calculate the total fluid rate
Example Case #1

- You are providing care for a 32 year-old male who was involved in a motor vehicle collision, sustaining a left pneumothorax, a retroperitoneal hematoma, and a pancreatic transection.

- He is now 6 days post-injury and has a paralytic ileus and what appears to be an antibiotic-associated enterocolitis
  - He cannot eat and he has diarrhea
Extracellular Volume Deficits: Maintenance

<table>
<thead>
<tr>
<th>Source</th>
<th>Volume (L)</th>
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<tr>
<td>Urine</td>
<td>1.240</td>
</tr>
<tr>
<td>Insensible</td>
<td>0.600</td>
</tr>
<tr>
<td>Diarrhea</td>
<td>0.400</td>
</tr>
<tr>
<td>Chest tube</td>
<td>0.560</td>
</tr>
<tr>
<td>JP drain</td>
<td>0.180</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>2.980</strong></td>
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What happens if these losses continue without replacement?
## Cumulative Fluid Balance without Replacement

<table>
<thead>
<tr>
<th></th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
<th>Day 6</th>
<th>Day 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily fluid losses</td>
<td>2,980</td>
<td>2,980</td>
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</tr>
<tr>
<td>Net balance</td>
<td>-2,980</td>
<td>-5,960</td>
<td>-8,940</td>
<td>-11,920</td>
<td>-14,900</td>
<td>-17,880</td>
<td>-20,860</td>
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Average $[\text{Na}^+]$ (mEq/L) = 209/2.98 = 70
# Electrolyte Content of Parenteral Fluids (mEq/L)

<table>
<thead>
<tr>
<th>Solution</th>
<th>Cations</th>
<th>Anions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Na⁺</td>
<td>K⁺</td>
</tr>
<tr>
<td>Extracellular fluid</td>
<td>142</td>
<td>4</td>
</tr>
<tr>
<td>Lactated Ringer’s solution</td>
<td>130</td>
<td>4</td>
</tr>
<tr>
<td>0.9% sodium chloride (saline)</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>M/6 sodium lactate</td>
<td>167</td>
<td></td>
</tr>
<tr>
<td>M (molar) sodium lactate</td>
<td>1,000</td>
<td></td>
</tr>
<tr>
<td>3% sodium chloride</td>
<td>513</td>
<td></td>
</tr>
<tr>
<td>5% sodium chloride</td>
<td>855</td>
<td></td>
</tr>
<tr>
<td>0.9% ammonium chloride</td>
<td></td>
<td></td>
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*Present in solution as lactate, which is converted to bicarbonate.*
Extracellular Volume Deficits: Maintenance

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Average [Na⁺] (mEq/L) = 209/2.98 = **70**

= D₅¹/₂ NS at 2,980 ml/24 hours
= D₅¹/₂ NS at 125 ml/hr
Example Case #2

- You are caring for a patient on his 2\textsuperscript{nd} day following an open cholecystectomy and a common bile duct exploration for acute suppurative cholangitis.

- He has a nasogastric tube and a Jackson-Pratt drain in place.
Extracellular Volume Deficits: Maintenance

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<tbody>
<tr>
<td>Urine</td>
<td>2.3</td>
<td>30</td>
<td>69</td>
</tr>
<tr>
<td>NG losses</td>
<td>0.400</td>
<td>60</td>
<td>24</td>
</tr>
<tr>
<td>Insensible</td>
<td>0.200</td>
<td>140</td>
<td>28</td>
</tr>
<tr>
<td>JP drain</td>
<td>0.180</td>
<td>140</td>
<td>25</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3.080</strong></td>
<td></td>
<td><strong>146</strong></td>
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Extracellular Volume Deficits: Maintenance

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General Rule: Replace no more than 1,500 ml of daily urine output—or you’ll be chasing your own volume infusions as the urine output cumulatively increases.

Total Volume: 3.163

Average [Na⁺] (mEq/L) = \[
\frac{146}{3.08} = 47
\]
Extracellular Volume Deficits: Maintenance

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<td><strong>146</strong></td>
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Average [Na⁺] (mEq/L) = 146/3.08 = **47**
### Extracellular Volume Deficits: Maintenance

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<tr>
<th>Source</th>
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<th>[(\text{Na}^+)] (mEq/L)</th>
<th>Total Na(^+) lost (mEq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urine</td>
<td>1.5</td>
<td>30</td>
<td>45</td>
</tr>
<tr>
<td>NG losses</td>
<td>8</td>
<td>180</td>
<td>45</td>
</tr>
<tr>
<td>Insert</td>
<td>3.2</td>
<td>450</td>
<td>14</td>
</tr>
<tr>
<td>JP drain</td>
<td>0.180</td>
<td>140</td>
<td>25</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2.280</strong></td>
<td><strong>140</strong></td>
<td><strong>122</strong></td>
</tr>
</tbody>
</table>

Average [\(\text{Na}^+\)] (mEq/L) = \(\frac{146}{3.08}\) = **54**

\[= D_{5}^{1/3} \text{ NS at 2,280 ml/24 hours}\]

\[= D_{5}^{1/3} \text{ NS at 100 ml/hr}\]
Volume Excess

Causes:

- Iatrogenic
- Renal Insufficiency
- Cirrhosis
- CHF
Fluid & Electrolyte Abnormalities

- Hypernatremia (ICD-9 code 276.0)
- Hyponatremia (ICD-9 code 276.1)
- Hyperkalemia (ICD-9 code 276.7)
- Hypokalemia (ICD-9 code 276.8)
- Hypercalcemia (ICD-9 code 275.42)
- Hypocalcemia (ICD-9 code 275.41)
- Hyper/hypomagnesemia (ICD-9 code 275.2)
- Hyper/hypophosphatemia (ICD-9 code 275.3)
- Hypervolemia (ICD-9 code 276.6)
- Hypovolemia (ICD-9 code 276.5)
Sodium Concentration Abnormalities

Hypernatremia = Dehydration

Hyponatremia = Overhydration

Dehydration ≠ Hypovolemia

Overhydration ≠ Hypervolemia
Concentration Changes

Overhydration

Normal hydration

Dehydration

H₂O

H₂O

H₂O

Na⁺

Na⁺

Na⁺

Hyponatremia

Eunatremia

Hypernatremia
Concentration Changes

Overhydration

Normal hydration

Dehydration

Hyponatremia

Eunatremia

Hypernatremia
Body water

- **Decreased**
  - Hypovolemic hypernatremia
  - Hyponatremia

- **Normal**
  - Hypernatremia
  - Normal (Eunatremia, normovolemia)

- **Increased**
  - Hypervolemic hypernatremia
  - Hyponatremia

- **Volume status**
  - Decreased
  - Normal
  - Increased
Hypernatremia & hyponatremia

- Abnormalities of sodium concentration most commonly result primarily from alterations in water balance.
- Hypernatremia typically results from loss of water, not from excess sodium content of the body.
- Hyponatremia most commonly results from overhydration (i.e., excess water), not from inadequate salt content.
Hyponatremia

- **Symptoms:**
  - Mental obtundation
  - Seizures

- **Differential diagnosis:**
  - Total body water excess
  - Factitious (i.e., hyperglycemia)
    - $[\text{Na}^+]$ is reduced by 1.6 mEq/L for every 100 mg/dl (5.5 mmol/L) rise in glucose above normal
  - SIADH
  - Sepsis
  - Renal Failure
    - Associated with increased total body sodium content
    - Pitting edema
Management of Hyponatremia

- **Assessment of volume status**
  - **Hypervolemia**
    - Seen with excess free water intake or SIADH
    - Treated with fluid/free water restriction
  - **Euvolemia**
    - May be factitious
    - Free water restriction usually helpful
  - **Hypovolemia**
    - Hypotension & oliguria must be treated promptly to avert acute renal failure
  - **Severe hyponatremia: < 120 mEq/L**
    - Calculate sodium deficit & replace accordingly
Treatment of Severe Hyponatremia

Normal Na⁺ (mEq/L) – actual Na⁺ (mEq/L) = Na⁺ deficit (mEq/L)
Example: 140 – 110 = 30

0.6 x body wt. (kg) = Total body water (L)
Example: 0.6 x 60 = 36

TBW (L) x Na⁺ deficit (mEq/L) = estimated Na⁺ deficit (mEq)
Example: 36 x 30 = 1,080

3.0% hypertonic saline solution contains 0.5 mEq/ml
Therefore, replacement is calculated:
(Estimated Na⁺ deficit [mEq])/0.5 = volume of 3% saline (ml)
Example: 1,080/0.5 = 2,160
Treatment of Severe Hyponatremia

- To avoid neurologic complications, $[\text{Na}^+]$ should not be raised by more than 12 mEq/L during the first 24 hours.
- Once $[\text{Na}^+] \geq 120$ mEq/L or symptoms have resolved, further aggressive correction generally is not required.
Hypernatremia

Causes

- Inadequate free water intake
  - Elderly, debilitated
- Excessive free water losses
  - Gastrointestinal (diarrhea, vomiting), sweating (without water replenishment)
- Inadequate postoperative fluid replacement
- Diabetes insipidus
  - Central
  - Nephrogenic
- Sodium overload
  - Intake of hypertonic sodium solutions
Causes of Diabetes Insipidus

- **Central**
  - Idiopathic
  - Traumatic
  - Neurosurgical
  - CNS neoplasms
  - Alcohol
  - Diphenylhydantoin
  - Eosinophilic granuloma
  - Sarcoidosis

- **Nephrogenic**
  - Congenital (usually sex-linked dominant)
  - Lithium
  - Demeclocycline
  - Amphotericin
  - Methoxyflurane
  - Propoxyphene overdose
Treatment of Hypernatremia

- Overly rapid correction can produce cerebral edema, seizures, permanent neurologic damage, or death
- No sequelae observed when $[\text{Na}^+]$ lowered at rate of 0.5 mEq/L/hr or less
  - Thus, 14 mEq/L concentration excess should be lowered over 28 hours or more
  - $4.8\text{L}/28\text{ hours} = 170\text{ ml/hour D}_5\text{W}$
  - *Don’t forget to keep up with ongoing losses in addition to replacing this deficit*
Diabetes Insipidus Management

- Ideally, hypernatremia can be corrected by supplementing with free water
- In cases where water alone is inadequate, dDAVP (a 2-AA substitute of ADH) can be used
  - usual dose 5 to 20 mg QD-BID
  - nasal spray
  - no vasopressor activity
- Disadvantages
  - Long duration of action → water retention & hyponatremia
  - Can be a problem in acute head injury with cycling between SIADH & DI
  - Expensive
Case #3

- A 28-year-old 72 kg male sustained a severe intracerebral hemorrhage following a motorcycle crash 4 hours ago. He underwent arteriography to embolize a bleeding splenic vessel. He has received 3,500 ml of crystalloid resuscitation. He is now producing 600-1,200 ml of urine per hour.

- What are the possible causes of his high urine output?
  A. SIADH
  B. Contrast load
  C. Diabetes insipidus
  D. Diuretic administration
Case #3

Which of the following tests would most quickly distinguish between IV contrast load and diabetes insipidus?

A. Serum chloride and urine osmolality
B. Serum sodium and urine specific gravity [Correct]
C. Serum and urine osmolality
D. BUN and urine osmolality
Distinction between Specific Gravity and Osmolality

- **Specific gravity**
  - Density of a solution relative to the density of water
    - Water’s density is set arbitrarily at 1
  - Density is defined as mass/volume
  - Therefore, SpG is related to the *weight* a substance provides

- **Osmolality**
  - Relates to the number of particles exerting an osmolar effect that are in solution
  - Therefore, Osm depends upon a molecular *concentration*
Case #3

- The patient’s serum sodium is 154 mEq/L and his urine specific gravity is 1.006.
- His urine concentration & volume are:
  - A. Physiologically appropriate
  - B. Physiologically inappropriate
Case #3

- The patient’s serum sodium is 154 mEq/L and his urine specific gravity is 1.006.
- His urine concentration & volume is:
  - A. Physiologically appropriate
  - B. Physiologically inappropriate
- He has:
  - A. Diabetes insipidus
  - B. Contrast load

What is the patient’s free water deficit?
Case #3

Free $H_2O$ deficit (L) = \[
\frac{[Na^+] - 140}{140} \times \frac{2}{3} \times \text{Wt. (kg)}
\]

\[
= \frac{154 - 140}{140} \times \frac{2}{3} \times 72 \text{ kg}
\]

\[
= \frac{14}{140} \times \frac{2}{3} \times 72 \text{ kg}
\]

\[
= 0.1 \times \frac{2}{3} \times 72 \text{ kg}
\]

\[
= 4.8 \text{ L}
\]
Acid-Base Metabolism

- **Intracellular**
  - Renal excretion of inorganic acids anions with NH$_4^+$
  - Metabolism of organic acid anions

- **Extracellular**
  - HCl + NaHCO$_3$ → NaCl + H$_2$CO$_3$
Buffer Systems

- **Intracellular**
  - Proteins
  - Phosphates

- **Extracellular**
  - Bicarbonate/Carbonic Acid system
  - (proteins)
  - (hemoglobin)
Differentiation of Acid-Base Status

<table>
<thead>
<tr>
<th></th>
<th>Metabolic</th>
<th>Respiratory</th>
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</thead>
<tbody>
<tr>
<td><strong>Acidosis</strong></td>
<td>↓ Base excess</td>
<td>↑ $P_{CO_2}$</td>
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</tbody>
</table>
Respiratory Acidosis

- Defined as hypoventilation
- More common in medical patients
  - COPD (chronic compensation)
  - “50-50” club
- Seen with oversedation, poor pulmonary toilet
  - Can cause agitation
  - Needs to be evaluated before sedating patient
Respiratory Alkalosis

- More common than previously thought
- Secondary to hyperventilation
  - pain
  - apprehension
  - hypoxia
  - CHI
- Tachypnea ≠ hyperventilation
- Associated with hypokalemia → arrhythmias
Metabolic Acidosis

- **Anaerobic metabolism from**
  - Inadequate circulation
    - Volume depletion
    - Poor cardiac function
    - Sepsis
- **Excessive alkali loss**
  - Diarrhea, fistulae
- **Diabetic Ketoacidosis**
- **Renal failure**
Metabolic Alkalosis

- Excessive alkali intake
- Loss of acid
  - High gastric output
    - NG tubes, vomiting, pyloric obstruction
    - “Paradoxical aciduria”
Paradoxical Aciduria in Metabolic Alkalosis from High Gastric Losses

Volume loss

↑ Aldosterone secretion

↑ K+/H+ exchange for Na+ absorption

Aciduria
Hypokalemia

■ Symptoms:
  ◆ Weakness
  ◆ Flattened T-waves on EKG

■ Differential diagnosis:
  ◆ Metabolic alkalosis causing shift of K+ in exchange for H+
  ◆ Renal losses from diuretic use
  ◆ GI losses
    ✦ NG
    ✦ Diarrhea
  ◆ Inadequate supplementation
Hypokalemia

Treatment

- No accurate calculation of potassium deficit
  - Decrease of 2 mEq/L = 200 mEq deficit
  - Decrease of 3 mEq/L = 400-500 mEq deficit

- Preferable to replace by enteral route (40-60 mEq p.o./day)

- IV route no more that 20 mEq/hr
Hyperkalemia

- **Symptoms:**
  - Nausea, vomiting, abdominal pain
  - Cardiac arrhythmias
  - Peaked T-waves, wide QRS, ST depression

- **Differential diagnosis:**
  - Renal failure
  - Iatrogenic potassium administration
Hyperkalemia Treatment

- **Counteract cardiac toxicity**
  - Administer Ca\(^{++}\) gluconate or CaCl
- **Drive K\(^+\) into the cells**
  - Administer Na\(^+\) Bicarbonate - raises pH
  - Administer Insulin 25U IV and D50
  - Administer Albuterol
    - for resistant hyperkalemia
    - increases plasma insulin concentration
    - lowers K\(^+\) level by 0.5-1.5 mEq/L
    - Beneficial in patients when fluid overload is concern (i.e., renal failure)
- **Bind K\(^+\)**
  - K\(^+\) binding resins - Kayexalate (25 - 50g)
- **Dialysis**
  - True last resort
Summary

- The surgical patient can manifest a variety of fluid and electrolyte disorders in a variety of settings.
- A thorough understanding of basic physiology coupled with clinical acumen is the physician’s toolkit for managing these disorders.