Fluid and Electrolyte Management of the Surgical Patient

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Fluid and electrolyte management are paramount to the care of the surgical patient. Changes in both fluid volume and electrolyte composition occur preoperatively, intraoperatively, and post operatively, as well as in response to trauma and sepsis.
Case 1

- 40 years old male
- SBO
- NGT 1500 ml
- Na 150
- K 2.9
Total Body Water

- 50-60% of total body weight
- Who is having higher proportion of body weight as water? And Why?
  - Males or Females
  - Lean or Obese
  - Young or elderly
Muscle and solid organs have higher water content than fat and bone.

Higher proportion of water in:
- Young
- Lean
- Males
## Fluid Compartments

<table>
<thead>
<tr>
<th>% of Total Body Weight</th>
<th>Volume of TBW</th>
<th>Male (70 kg)</th>
<th>Female (60 kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Extracellular Volume</td>
<td>14,000 mL</td>
<td>10,000 mL</td>
</tr>
<tr>
<td>Plasma 5%</td>
<td>Plasma</td>
<td>3500 mL</td>
<td>2500 mL</td>
</tr>
<tr>
<td></td>
<td>Interstitial</td>
<td>10,500 mL</td>
<td>7500 mL</td>
</tr>
<tr>
<td>Interstitial Fluid 15%</td>
<td>Intracellular volume</td>
<td>28,000 mL</td>
<td>20,000 mL</td>
</tr>
<tr>
<td>Intracellular Volume 40%</td>
<td></td>
<td>42,000 mL</td>
<td>30,000 mL</td>
</tr>
</tbody>
</table>
## Composition of Fluid Compartments

<table>
<thead>
<tr>
<th></th>
<th>Plasma</th>
<th>Interstitial Fluid</th>
<th>Intracellular Fluid</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cations</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Na⁺</td>
<td>142 mEq/L</td>
<td>153 mEq/L</td>
<td>200 mEq/L</td>
</tr>
<tr>
<td>K⁺</td>
<td>4</td>
<td>4</td>
<td>K⁺ 150</td>
</tr>
<tr>
<td>Ca²⁺</td>
<td>5</td>
<td>3</td>
<td>SO₄⁻⁻ 150</td>
</tr>
<tr>
<td>Mg²⁺</td>
<td>3</td>
<td>2</td>
<td>PO₄⁻⁻ 150</td>
</tr>
<tr>
<td><strong>Anions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cl⁻</td>
<td>103 mEq/L</td>
<td>114 mEq/L</td>
<td>HCO₃⁻ 30</td>
</tr>
<tr>
<td>HCO₃⁻</td>
<td>27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SO₄⁻⁻</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PO₄⁻⁻</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein</td>
<td>16</td>
<td></td>
<td>Mg²⁺ 40</td>
</tr>
<tr>
<td>Organic Acids</td>
<td>5</td>
<td></td>
<td>Protein 40</td>
</tr>
<tr>
<td>Organic Acids</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein</td>
<td>1</td>
<td></td>
<td>Na⁺ 10</td>
</tr>
</tbody>
</table>

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**Note:** The values represent the concentration of ions in milliequivalents per liter (mEq/L) for each compartment.
Classification of Body Fluid Changes

- Normal Exchange of Fluid and Electrolytes
- Disturbances in Fluid Balance
- Volume Control
- Concentration Changes
  - Hyponatremia
  - Hypernatremia
- Composition Changes
  - Hyperkalemia
  - Hypokalemia
  - Hypermagnesemia
  - Hypomagnesemia
  - Hypercalcemia
  - Hypocalcemia
  - Hyperphosphatemia
  - Hypophosphatemia
Case 2

- 50 years old female
- Not know to have medical problem
- SBO due to adhesions
- On NGT
- Total intake 2700 ml
- Total output 2800 ml
Normal Exchange

- Normal person consumes 2000ml of H2O
  - 75% oral intake
  - Rest from solid foods
- Daily water losses
  - 1L in Urine
  - 250 ml in stool
  - 600 insensible losses
    - Skin 75%
    - Lungs 25%
Disturbances in Fluid Balance

- Extracellular volume deficit: most common in surgical patients
  - Acute
    - Cardiovascular
    - Central nervous system
  - Chronic
    - Decrease skin turgor
    - Sunken eyes
    - & CVS and CNS
<table>
<thead>
<tr>
<th><strong>System</strong></th>
<th><strong>Volume Deficit</strong></th>
<th><strong>Volume Excess</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Generalized</td>
<td>Weight loss</td>
<td>Weight gain</td>
</tr>
<tr>
<td></td>
<td>Decreased skin turgor</td>
<td>Peripheral edema</td>
</tr>
</tbody>
</table>
| Cardiac | *Tachycardia*  
*Orthostasis/hypotension*  
*collapsed neck veins* | *Increased cardiac output*  
*Increased central venous pressure*  
*Distended neck veins*  
*Murmur* |
| Renal | Oliguria  
Azotemia | |
| Gastrointestinal | Ileus | Bowel edema |
| Pulmonary | | Pulmonary edema |
## Composition of Gastrointestinal Secretions

<table>
<thead>
<tr>
<th>Type of Secretion</th>
<th>Volume mL/24 h</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>Stomach</td>
<td>2000-1000</td>
<td>90-60</td>
<td>30-10</td>
<td>130-100</td>
<td>0</td>
</tr>
<tr>
<td>Small intestine</td>
<td>3000-2000</td>
<td>140-120</td>
<td>10-5</td>
<td>120-90</td>
<td>40-30</td>
</tr>
<tr>
<td>Colon</td>
<td>60</td>
<td>30</td>
<td>40</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Pancreas</td>
<td>800-600</td>
<td>145-135</td>
<td>10-5</td>
<td>90-70</td>
<td>115-95</td>
</tr>
<tr>
<td>Bile</td>
<td>800-300</td>
<td>145-135</td>
<td>10-5</td>
<td>110-90</td>
<td>40-30</td>
</tr>
</tbody>
</table>
Case 3

- 78 years old male
- Not know to have any medical problem
- Had sigmoid colectomy for Ca
- 2nd day post op
- Na 130
Hyponatremia

- Causes
  - Sodium depletion
  - Sodium dilution
Sodium depletion

- Decrease intake
  - Low Na diet
  - Enteral feeds

- Increase loss
  - Gastrointestinal Losses
    - Vomiting
    - Prolonged NGT suctioning
    - Diarrhea
  - Renal Losses
    - Diuretics
    - Primary renal disease

- Depletional hyponatremia is often accompanied by extracellular volume deficit
Sodium dilution

- Due to excess extracellular water
  - Intentional: excessive oral intake
  - Iatrogenic: Intravenous
- Increase ADH
  - Increase reabsorption of water from the kidneys
- Drugs
  - Antipsychotics
  - Tricyclic antidepressants
  - Angiotensin-converting enzyme inhibitors
- Physical signs: usually absent
- Lap: hemodilution
- Hyperosmolar
  - Mannitol
  - Hyperglycemia

- Pseudohyponatremia
  - Plasma lipids
  - Plasma proteins
<table>
<thead>
<tr>
<th>Body System</th>
<th>Hyponatremia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central nervous system</td>
<td>Headache, confusion, hyper- or hypoactive deep tendon reflexes, seizures, coma, increased intracranial pressure</td>
</tr>
<tr>
<td>Musculoskeletal</td>
<td>Weakness, fatigue, muscle cramps/twitching</td>
</tr>
<tr>
<td>Gastrointestinal</td>
<td>Anorexia, nausea, vomiting, watery diarrhea</td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>Hypertension and bradycardia if significant increases in intracranial pressure</td>
</tr>
<tr>
<td>Tissue</td>
<td>Lacrimation, salivation</td>
</tr>
<tr>
<td>Renal</td>
<td>Oliguria</td>
</tr>
</tbody>
</table>
Serum Osmolality

Isotonic (280–290 mOsm)

- Measure Blood Glucose, Lipid, Protein

  Isotonic Hyponatremia
  1. Pseudohyponatremia
     a. Hyperlipidemia
     b. Hyperproteinemina
  2. Isotonic infusions
     a. Glucose
     b. Mannitol
     c. Glycine
  3. TURP

  Hypovolemic
  Hypotonic Hyponatremia
  1. GI losses
  2. Skin losses
  3. Lung losses
  4. Third-space losses
  5. Renal losses

Hypertonic (>290 mOsm)

- Hypotonic (<280 mOsm)

  Clinically Assess ECF Volume

  Hypertonic Hyponatremia
  1. Hyperglycemia
  2. Hypertonic infusions
     a. Glucose
     b. Mannitol
     c. Glycine
  3. TURP

  Hypervolemic
  Hypotonic Hyponatremia
  1. CHF
  2. Cirrhosis
  3. TURP

  Isovolemic
  Hypotonic Hyponatremia
  1. Water intoxication
  2. K⁺ losses
  3. Reset osmostat
  4. SIADH
  5. Drugs
     a. Sulfonylureas
     b. Carbamazepine
     c. Phenothiazines
     d. Antidepressants
Management of Hyponatremia

- Exclude Hyperosmolar causes
- Depletion versus dilution
- Dehydration or over hydrated
- Normal volume >> evaluate ADH
- Na losses
  - Urine Na <20 mEq/L = extrarenal
  - Urine Na >20 mEq/L = Renal
- Free water restriction
- If severe administration Na
- If neuralgic symptoms are present
  - 3% N.S
  - No more than 1 mEq/L per hour
  - Until reaches 130 mEq/L or neurological symptoms improve
- If asymptomatic
  - 0.5 mEq/L per hour maximum 12 mEq/L per day
Hypernatremia

- Loss of free water
- Gain sodium in excess
<table>
<thead>
<tr>
<th>Body System</th>
<th>Hypernatremia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central nervous system</td>
<td>Restlessness, lethargy, ataxia, irritability, tonic spasms, delirium, seizures, coma</td>
</tr>
<tr>
<td>Musculoskeletal</td>
<td>Weakness</td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>Tachycardia, hypotension, syncope</td>
</tr>
<tr>
<td>Tissue</td>
<td>Dry sticky mucous membranes, red swollen tongue, decreased saliva and tears</td>
</tr>
<tr>
<td>Renal</td>
<td>Oliguria</td>
</tr>
<tr>
<td>Metabolic</td>
<td>Fever</td>
</tr>
</tbody>
</table>
Clinically Assess ECF Volume

- Depleted
  - Hypovolemic Hypernatremia
    - Loss of Water and Sodium
      - Renal
      - Diuretics
      - Glycosuria
      - Urea Diuresis
      - Acute or chronic renal failure
      - Partial obstruction
      - GI losses (diarrhea)
      - Respiratory losses
      - Skin losses (burns)
      - Adrenal insufficiency
  - Diabetes insipidus
  - Reset osmostat
  - Skin losses
  - Iatrogenic
- Expanded
  - Normal
  - Isovolemic Hypernatremia
    - Loss of Water
      - Renal
      - Diuretics
      - Glycosuria
      - Urea Diuresis
      - Acute or chronic renal failure
      - Partial obstruction
      - GI losses (diarrhea)
      - Respiratory losses
      - Skin losses (burns)
      - Adrenal insufficiency
  - Hypervolemic Hypernatremia
    - Gain of Water and Sodium
      - Iatrogenic
      - Mineralocorticoid excess
Treatment

- In hypovolemic patients, volume should be restored.
- Water deficit is replaced using a hypotonic fluid
  - Water deficit (L) = (serum sodium - 140 / 140) * TBW
  - TBW = 50% for lean men and 40% for women
- No more than 1 mEq/h and 12 mEq/d for acute.
Case 4

- 40 years old male
- Polytrauma
- # Rt femur and blunt abdominal injury
- K 2.9
- Oliguria
- And on going blood transfusion
Case 5

- 40 year old male
- Case of crohn's with entero-cutaneous fistula
- On TPN
- K 6.5
Potassium

- Average intake of potassium 50-100 mEq/d
- 2% of total body potassium is located within extracellular compartment
- Normal range 3.5-5.0 mEq/L
Hyperkalemia

- Excessive potassium intake
  - Oral
  - Intravenous
  - Blood transfusions
- Increased release of potassium from cells
  - Hemolysis
  - Rhabdomolysis
  - Crush injuries
  - Gastrointestinal hemorrhage
  - Acidosis
  - Rapid increase of extracellular osmolality
- Impaired excretion by the kidneys
  - Potassium sparing diuretics
  - Angiotensin-Converting enzyme inhibitors
  - Nonsteroidal antiinflammatories
  - Renal insufficiency and renal failure
Symptoms
  • Gastrointestinal
    ■ Nausea
    ■ Vomiting
    ■ Intestinal colic
    ■ Diarrhea
  • Neuromuscular
    ■ Weakness
    ■ Ascending paralysis to respiratory failure
  • Cardiovascular
    ■ ECG changes
      ○ Peaked T waves
      ○ Flattened P wave
      ○ Prolonged PR interval
      ○ Widened QRS complex
      ○ Ventricular fibrillation
    ■ Cardiac arrhythmias
    ■ Arrest
- Discontinue exogenous potassium
- Cation-exchange resin, Kayexalate
- Glucose
- Insulin
- Calcium chloride or calcium gluconate
- All the above measures are temporary lasting from 1 to 4 hours
- Dialysis should be considered
Hypokalemia

- More common in surgical patient
- Inadequate intake
  - Dietary
  - Potassium free IV fluids
  - Total parenteral nutrition with inadequate potassium replacement
- Excessive renal excretion
  - Hyperaldosteronism
  - Medications
- Loss in gastrointestinal secretions
  - Vomiting
  - High NGT output
- Intracellular shift
  - Metabolic alkalosis
  - Insulin therapy
- Drugs induce magnesium depletion
  - Amphotericin
  - Aminoglycosides
  - Foscarnet
  - Cisplatin
  - ifosfamide
Symptoms
- Gastrointestinal
  - ileus
  - Constipation
- Neuromuscular
  - Weakness
  - Fatigue
  - Diminished tendon reflexes
  - Paralysis
- Cardiac
  - Cardiac arrest
  - ECG changes
    - U waves
    - T wave flattening
    - ST segment changes
    - Arrhythmias
- Potassium repletion
- Orally or intravenous
- In IV no more than 10 to 20 mEq/h
- 40 mEq/h when ECG monitoring
- Caution with oliguria or impaired renal function