Fluid and Electrolyte Survey

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Anatomy of Body Fluid Compartments

- Total body water
  - 50 to 70% of total body weight
  - Varies with age, sex and fat content
## Functional Compartments of Body Fluids

### Percent Body Weight

<table>
<thead>
<tr>
<th>Component</th>
<th>Volume (cc)</th>
<th>% Body Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Extracellular Volume</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plasma</td>
<td>3,500</td>
<td>5%</td>
</tr>
<tr>
<td>Interstitial Fluid</td>
<td>10,500</td>
<td>15%</td>
</tr>
<tr>
<td><strong>Total Intracellular Volume</strong></td>
<td></td>
<td>40%</td>
</tr>
<tr>
<td>Intracellular Volume</td>
<td>28,000</td>
<td></td>
</tr>
<tr>
<td><strong>Total Body Water</strong></td>
<td>42,000</td>
<td>60%</td>
</tr>
</tbody>
</table>

**70 kg male**
### Chemical Composition of Body 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>153 mEq/L</td>
</tr>
<tr>
<td>K⁺</td>
<td>4 mEq/L</td>
<td>4 mEq/L</td>
<td>150 mEq/L</td>
</tr>
<tr>
<td>Ca²⁺</td>
<td>5 mEq/L</td>
<td>3 mEq/L</td>
<td>40 mEq/L</td>
</tr>
<tr>
<td>Mg²⁺</td>
<td>3 mEq/L</td>
<td>2 mEq/L</td>
<td>10 mEq/L</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>150 mEq/L</td>
</tr>
<tr>
<td>HCO₃⁻</td>
<td>27 mEq/L</td>
<td>30 mEq/L</td>
<td>10 mEq/L</td>
</tr>
<tr>
<td>SO₄²⁻</td>
<td>150 mEq/L</td>
<td>10 mEq/L</td>
<td>5 mEq/L</td>
</tr>
<tr>
<td>PO₄³⁻</td>
<td>40 mEq/L</td>
<td>40 mEq/L</td>
<td>10 mEq/L</td>
</tr>
<tr>
<td>Organic acids</td>
<td>5 mEq/L</td>
<td>5 mEq/L</td>
<td>5 mEq/L</td>
</tr>
<tr>
<td>Protein</td>
<td>16 mEq/L</td>
<td>1 mEq/L</td>
<td>40 mEq/L</td>
</tr>
</tbody>
</table>

**Note:** The values represent typical concentrations in mEq/L. The table shows the distribution of major cations and anions in different body fluid compartments.
# Volume Deficit

**Most common volume disorder in surgical patients**

<table>
<thead>
<tr>
<th>Measurable Causes</th>
<th>Non-measurable Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood loss</td>
<td>Third spacing / fluid</td>
</tr>
<tr>
<td>sequestration</td>
<td>Traumatized tissues</td>
</tr>
<tr>
<td>Gastrointestinal loss</td>
<td>Inflammatory processes</td>
</tr>
<tr>
<td></td>
<td>Intestinal obstruction</td>
</tr>
<tr>
<td></td>
<td>Burns</td>
</tr>
<tr>
<td>SYMPTOMS</td>
<td>MODERATE</td>
</tr>
<tr>
<td>---------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>Central nervous system</td>
<td>Sleepiness, Apathy, Slow response, Anorexia</td>
</tr>
<tr>
<td>Gastrointestinal</td>
<td>Decrease in food consumption</td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>Tachycardia, Collapsed veins, Collapsing pulse, Orthostatic hypotension</td>
</tr>
<tr>
<td>Tissue signs</td>
<td>Soft small tongue, Decreased turgor</td>
</tr>
<tr>
<td>Metabolism</td>
<td>Temperature decrease, mild</td>
</tr>
<tr>
<td>Renal</td>
<td>Oliguria</td>
</tr>
</tbody>
</table>
Oliguria: Definitions

- Prerenal and how to tell
- Renal and how to tell
- Oliguria vs. Anuria
Oliguria: Things to Monitor

Urine osmolality
Urine sodium
BUN / serum creatinine
Urine and plasma urea
Urine and plasma creatinine
Oliguria: Things to Monitor

- Urine osmolality
- Urine sodium
- BUN / serum creatinine
- Urine and plasma urea
- Urine and plasma creatinine
Fractional excretion of sodium

Can tell you if the kidney is functioning properly…

\[ \text{FENa} = \frac{\text{Urine}}{\text{Plasma Na}} \times 100 \]

\[ \text{Urine} / \text{Plasma Creatinine} \]
Treatment of Volume Deficits

1. Estimate the deficit

**Maintenance:**
- $1^{st}$ 10 kg body weight $\rightarrow$ 100 cc / kg / day
- $2^{nd}$ 10 kg body weight $\rightarrow$ 50 cc / kg / day
- $> 20$ kg body weight $\rightarrow$ 20 cc / kg / day

**Measurable losses**
- Blood loss, GI loss
- Insensible losses
Treatment of Volume Deficits

2. Replace Volume Intravenously
   Crystalloid
   Colloid
   Blood
Treatment of Volume Deficits

3. Assess results
   - Vital signs
   - Urine Output
   - Central venous pressure
   - Swan-Ganz measurements
# Electrolyte Content of Fluids

<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</td>
<td>130</td>
<td>4</td>
</tr>
<tr>
<td>0.9% NaCl</td>
<td>154</td>
<td></td>
</tr>
<tr>
<td>M/6 Sodium lactate</td>
<td>167</td>
<td></td>
</tr>
<tr>
<td>M Sodium lactate</td>
<td>1,000</td>
<td></td>
</tr>
<tr>
<td>3% NaCl</td>
<td>513</td>
<td></td>
</tr>
<tr>
<td>5% NaCl</td>
<td>855</td>
<td></td>
</tr>
<tr>
<td>0.9% Ammonium Cl</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Using different fluids

- Advantages and Disadvantages of:
  - Lactated Ringer’s
  - NS
  - Hypertonic Solution
  - Hypotonic solution
Volume excess

- Most common in the elderly and patients with heart disease
- Often iatrogenic from over-resuscitation
- Acute renal failure can be a cause
Symptoms of Volume Excess

- Nervous System
  - Rarely symptoms

- Gastrointestinal
  - At operation, edema of stomach, colon, omentum and small bowel mesentery
Cardiovascular Symptoms of Volume Excess

- **Moderate**
  - ↑ venous pressure
  - Distension of veins
  - ↑ cardiac output
  - Murmurs
  - ↑ pulse pressure

- **Severe**
  - Pulmonary edema
Tissue Symptoms of Volume Excess

- Moderate
  - Pitting edema
  - Basilar rales

- Severe
  - Anasarca
  - Vomiting
  - Diarrhea
  - Rales
Symptoms of Volume Excess

- Metabolic
  - None

- Renal
  - Moderate: None
  - Severe: None
Treatment of Volume Excess

- Decrease fluid intake
- Diuretics
- Inotropic agents
- Vasodilators
- Hemodialysis
Concentration Abnormalities

- Serum Sodium and Osmolality
- Cell membrane permeability
Sodium

- Plays a major role in water balance and muscle contraction
- Draws water through permeable membranes in the body thereby distributing fluid throughout the body
Hyponatremia

- Causes
  - Almost always due to free water
  - Often iatrogenic (fluid replacement)
  - Oliguria
  - Endogenous water release (cell catabolism)
  - Intracellular shifts (sepsis)
  - SIADH
Central Nervous System Signs of Hyponatremia

- **Moderate**
  - Muscle twitching
  - ↑ tendon reflexes
  - ↑ intracranial pressure

- **Severe**
  - Convulsions
  - Loss of reflexes
  - ↑ intracranial pressure
Signs and Symptoms of Hyponatremia

- **Cardiovascular**
  - Changes in blood pressure and pulse related to ↑ ICP

- **Tissues**
  - Increased salivation
  - Diarrhea

- **Renal**
  - Oliguria progressing to anuria
Treatment of Hyponatremia

- Calculate sodium deficit
  - Total body weight $\times$ (140 mEq – Serum Na)
- Replace slowly
  - < 12 mEq / L / 24 hours
  - Dangers of central pontine myelinosis
- Isotonic vs. Hypertonic solutions
Causes of Hypernatremia

- Excessive extrarenal water loss
  - Fever
  - Tracheostomy
  - Burns
Causes of Hypernatremia

- Renal water loss
  - High output renal failure
  - Diabetes insipidus
Causes of Hypernatremia

☐ Solute loading
  ■ ↑ protein intake
  ■ Osmotic diuretics
CNS Signs of Hypernatremia

- Moderate
  - Restlessness
  - weakness

- Severe
  - Delirium
  - Maniacal behavior
<table>
<thead>
<tr>
<th><strong>Cardiovascular</strong></th>
<th><strong>Tissue</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Tachycardia</td>
<td>Decreased saliva and tears</td>
</tr>
<tr>
<td>Hypotension</td>
<td>Dry mucous membranes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Renal</strong></th>
<th><strong>Swollen tongue</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Oliguria</td>
<td>Swollen tongue</td>
</tr>
<tr>
<td>Fever</td>
<td>Flushed skin</td>
</tr>
</tbody>
</table>
Treatment of Hypernatremia

- Calculate free water deficit
  \[ 0.6 \times \text{Total body weight} - 140 \times (0.6 \times \text{TBW}) / \text{Na} \]

- Replace free water
  - Balanced salt solution to prevent CNS symptoms
Potassium

- Normal dietary intake = 50 - 100 mEq / day
- Most is excreted in urine
- Important for cardiac and neuromuscular function
Hyperkalemia

- **Causes:**
  - Usually acute renal failure
  - Stress
  - Catabolism
  - Acidosis

- **Symptoms**
  - GI:
    - Nausea / vomiting
    - Diarrhea
  - CV:
    - Rhythm abnormalities
    - Heart block
    - Cardiac arrest
Hyperkalemia: Treatment

- Withhold exogenous potassium
- Calcium gluconate
  - Can suppress myocardial effects
- Sodium bicarbonate, insulin and D10W
  - Helps transfer K intracellular
- Dialysis
- Cation exchange resins
Hypokalemia: Causes

- More common in surgical patients
  - Prolonged use of IV solutions with K+
- Alkalosis
- Sodium loading
Hypokalemia: Symptoms and Signs

- Failure of muscle contractility
  - Cardiac, skeletal and smooth muscle
- Weakness
- Tendon reflexes
- Ileus
- EKG changes
Hypokalemia: Treatment

- Prevention
  - Replace renal and GI losses of K+ in IV solution
- Avoid cardiac toxicities
  - $\leq 40 \text{ mEq KCl / liter IV fluid}$
  - $< 20 \text{ mEq KCl / hour replacement}$
Calcium

- Critical for:
  - normal cell function
  - neural transmission, cell membrane stability
  - bone structure
  - blood coagulation

- Daily losses in feces, urine and through skin

- Daily exchange in bones, GI tract, kidneys
Hypocalcemia: Causes

- Chronic renal failure
- Multiple transfusions
- Pancreatitis
- Nutritional deficiency (esp. Vitamin D)
- Magnesium depletion
- Drugs
- Thyroidectomy / Parathyroidectomy
Management of Hypocalcemia

*Calcium < 8.0-8.5 mg/dl*

**SYMPTOMATIC**

- **SEVERE SYMPTOMS:** tetany
  - 20 ml IV 10% Calcium gluconate over 20 minutes
  - then 15 mg/kg Calcium gluconate every six hours
  - reassure patient to minimize respiratory alkalosis from hyperventilation
Management of Hypocalcemia

- MILD SYMPTOMS: paresthesias
  - Oral Calcium treatment
Management of Hypocalcemia

- SEEK CAUSE
  - consider magnesium deficiency
  - exclude hypoalbuminemia
  - measure serum phosphate (see next slide)
  - could be excess hydration
Phosphate and Hypocalcemia

- High serum phosphate
  - Suspect hypoparathyroidism

- Low or normal serum phosphate
  - Suspect bone disease
Hypercalcemia: Symptoms

- bone defects
- cardiac changes
- shock
- renal hypertension and failure
Hypercalcemia: Causes

- **1° hyperparathyroidism**
- **Malignancy**
  - With or without bone metastasis
- **Drugs**
  - Some diuretics
  - Vitamins A or D
  - Calcium carbonate
- **Metabolic disorders**
  - Osteoporosis
  - Thyrotoxicosis
  - Renal tubular acidosis
- **Pheochromocytoma** (rare)
Management of Hypercalcemia

**UNSTABLE PATIENT**

> 14 mg/dl

- Rehydrate with normal saline
- Check serum phosphate
- Give furosemide 40 mg intially then 40-80 mg q. 2 hr
  - Monitor serum electrolytes
- If patient remains unstable
  - Calcitonin 4 IU/kg subcutaneous or IM q 12°
  - Dialysis might be necessary
Management of Hypercalcemia

STABLE PATIENT

- Low serum phosphate
  - Usually 1° hyperparathyroidism, can give oral phosphate

- Normal or high serum phosphate
  - Suspect malignancy
Magnesium

- Essential for function of most enzyme systems
- Half of total magnesium is stored in bone
- Kidneys can conserve and excrete
Magnesium Deficiency: Causes

- Starvation
- Malabsorption
- GI loss
- Pancreatitis
- Alcoholism
- Diabetic ketoacidosis
- 1° aldosteronism
Magnesium Deficiency: Signs and Symptoms

*Similar to hypocalcemia*

- Weakness
- Vertigo
- Dysphagia
- Seizures
- Tetany
- Delerium
- ↑ deep tendon reflexes
Treatment of Hypomagnesemia

- Correct over-hydration
- If **severe and symptomatic**:
  - Give 4-8 ml of a 50% MgSO4 solution in 100-200 ml of D5W IV over 15 minutes
- Look for causes
- Oral supplements for stable patients
Magnesium Excess

- Rare
- Associated with:
  - Acute renal failure
  - Antacids
  - Massive trauma
  - Burns
Magnesium Excess: Signs and Symptoms

- Lethargy
- Weakness
- ↓ deep tendon reflexes
- EKG abnormalities
Treatment of Hypermagnesemia

- Withhold exogenous magnesium
- Correct acidosis
- Dialysis may be necessary
- For the symptomatic patient
  - Calcium Gluconate 10% 1-10 ml IV