Fluids & Electrolytes

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### Body Water (as % body weight)

<table>
<thead>
<tr>
<th></th>
<th>Infant</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thin</td>
<td>80</td>
<td>65</td>
<td>55</td>
</tr>
<tr>
<td>Avg.</td>
<td>70</td>
<td>60</td>
<td>50</td>
</tr>
<tr>
<td>Obese</td>
<td>65</td>
<td>55</td>
<td>45</td>
</tr>
</tbody>
</table>
### Functional Fluid Compartments

#### EXAMPLE: 70 Kg man, TBW = 42 L (60% x TBW)

<table>
<thead>
<tr>
<th>Compartment</th>
<th>Body Wt</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ECF</strong></td>
<td>5%</td>
<td>Plasma</td>
</tr>
<tr>
<td></td>
<td>15%</td>
<td>ISF</td>
</tr>
<tr>
<td><strong>ICF</strong></td>
<td>40%</td>
<td>ICF</td>
</tr>
</tbody>
</table>

Blood Volume = 7-8 % Body wt

Hct = \[
\frac{\text{RBC volume}}{\text{RBC volume} + \text{Plasma volume}}
\]
Replacement of a 500 ml Plasma Volume Deficit

<table>
<thead>
<tr>
<th>Solution</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>LR</td>
<td>2000 ml</td>
</tr>
<tr>
<td>FFP</td>
<td>500 ml</td>
</tr>
<tr>
<td>5% albumin</td>
<td>500 ml</td>
</tr>
<tr>
<td>25% albumin</td>
<td>100 ml</td>
</tr>
</tbody>
</table>
Osmolarity

- Principal force of fluid movement
- Depends on # of active particles in solution that cannot pass through the semipermeable cell membrane
- Normal serum value = 285-300 mOsm/L
  - approximation:  $2 \times (\text{Na}) + \frac{\text{BUN}}{2.8} + \frac{\text{Glucose}}{18}$
- Urine: 70-1200 mOsm/L
  - primarily controlled by ADH
Water Balance

Intake

Oral: 800 - 1500 ml as liquids
500 - 700 ml as solids

Water of oxidation: 200 - 400 ml/day
**Water Balance**

*Output*

**Urine:** 1000 - 2500 ml/day  
⇒ need 500 - 800 ml to excrete products of catabolism

**Water of stool:** 100 - 200 ml/day

**Insensible:** 600 - 900 ml/day  
25% = Respiratory (250 - 750 ml/day)  
75% = Skin (400 - 600 ml/day)
Causes of Increased Insensible Water Losses

- Fever: < 250 ml per °F above normal
- Excessive evaporative skin losses (burns)
- Operation: 500 ml/hr
- Respirator or tracheostomy (up to 1.5 L/day)
- Hypermetabolism
Monitoring of Water Balance

- **Urine output:** 0.5-1.0 ml/kg/hr
  (30-50 ml/hr - adults)

- Daily weights

- Hematocrit, electrolytes, osmolarity

- CVP, PCWP, Cardiac Output
Baseline Fluid Requirements

**CHILDREN:**
- 1st 10 Kg → 100 ml/Kg/day
- 2nd 10 Kg → 50 ml/Kg/day
- > 20 Kg → 20 ml/Kg/day

**ADULTS:**
- 30 - 35 ml/Kg/day
Baseline Electrolyte Requirements

CHILDREN: < 20 Kg:
- Sodium: 2-3 mEq/Kg/day
- Potassium: 1-2 mEq/Kg/day
- Chloride: 1-1.5 mEq/Kg/day

ADULTS:
- Sodium: 75 - 120 mEq/day
- Potassium: 65 - 90 mEq/day
- Chloride: 85 - 145 mEq/day
## Other Body Fluid Losses

**G.I. Tract: secretes 8-10 L/day**

<table>
<thead>
<tr>
<th>Source</th>
<th>Volume</th>
<th>Na</th>
<th>K</th>
<th>Cl</th>
<th>HCO₃⁻</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saliva</td>
<td>1500</td>
<td>10</td>
<td>25</td>
<td>15</td>
<td>30</td>
</tr>
<tr>
<td>Stomach</td>
<td>1500</td>
<td>60</td>
<td>10</td>
<td>130</td>
<td>--</td>
</tr>
<tr>
<td>Duodenum</td>
<td>100-2000</td>
<td>140</td>
<td>5</td>
<td>80</td>
<td>--</td>
</tr>
<tr>
<td>Pancreas</td>
<td>100-800</td>
<td>140</td>
<td>5</td>
<td>75</td>
<td>115</td>
</tr>
<tr>
<td>Bile</td>
<td>50-800</td>
<td>145</td>
<td>5</td>
<td>100</td>
<td>35</td>
</tr>
<tr>
<td>Ileum</td>
<td>3000</td>
<td>140</td>
<td>5</td>
<td>104</td>
<td>30</td>
</tr>
<tr>
<td>Colon</td>
<td>----</td>
<td>60</td>
<td>30</td>
<td>40</td>
<td>--</td>
</tr>
</tbody>
</table>
Graphic Concept of Fluid Resuscitation
Concept of 3rd Space

- Fluid still within ECF (interstitial)
- Sequestered into areas of injury
- Must be replaced
- Losses are mobilized after recovery
Acute Dehydration

Most Common Fluid Disorder in Surgical Patients

Diagnosis:

• **2% body wt:** dry skin, thirst, ↑urine osmolarity, oliguria

• **4% body wt:** dry tongue and axillae, oliguria, postural hypotension, tachycardia

• **6% body wt:** LIFE THREATENING, above symptoms with lethargy, ileus

Treatment:

• Rapid infusion of balanced salt solution
• Avoid glucose-containing solutions
Chronic Dehydration

- May tolerate losses up to 10% of body wt.
- More even distribution between ECF & ICF
- Less symptomatic than acute
- **Treatment**: Slowly over a period of days
Hypotonic Dehydration (DESALTING WATER LOSS)

Most common fluid balance disorder

Etiology:

- Isotonic extrarenal losses
  - G.I. obstruction or fistula, ileus, vomiting, massive diarrhea, trauma
- Renal losses
  - osmotic diuresis, diuretic phase of ATN
Hypotonic Dehydration

Diagnosis: hypotension, tachycardia, atony, obtundation, hypothermia;
low serum Na, urine Na <20 mEq/L

Treatment:

- **Prevention:**
  - replace GI losses Q 4-6hrs if massive
  - approximate electrolyte content of fluid lost
- **Therapeutic:**
  - RAPID replacement of water and electrolytes
Hypotonic Overhydration
(Water intoxication)

Etiology:

- Overadministration of water
- Postop patients sensitive to hypotonic fluids
- Chronic visceral disease on low Na diet
- Chronic caloric starvation
  - increased endogenous water production
  - increased ADH
  - defect in Na pump due to energy deficit
- Inappropriate ADH syndrome
  - cancer, COPD, porphyria, head injury
Hypotonic Overhydration

**Diagnosis:** lethargy, stupor, coma, convulsions, weight gain, anasarca, pulmonary edema

**Treatment:**

- **Water intoxication:** Decrease water intake
  - Solute diuretic (mannitol)
  - 3% NaCl, 1/6 M Na Lactate

- **Inappropriate ADH:** Decrease water intake
  - Lithium
  - Declomycin
Hypertonic Dehydration
(Desiccation)

Etiology:

• Evaporative water loss: respiratory tract fever, burn wound

• Loss of hypotonic fluids: excess sweating (50 mEq Na/L) diarrhea (in children)

• Renal abnormalities or abnormal renal stimuli (i.e., diabetes insipidus)

• Excess solute loading: hyperalimentation (NKHC, DKA) osmotic diuretics, angio. dyes

• Water deprivation
Hypertonic Dehydration

Diagnosis:

• Dry mucus membranes, thirst, oliguria, CNS changes
• Increased BUN, Na, osmolarity

Treatment:

• Water replacement
• Monitor body weight, osmolarity, renal function
• Watch for signs of cerebral edema
## Parenteral Solutions

<table>
<thead>
<tr>
<th>Solution</th>
<th>Na</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>Cl</th>
<th>HCO₃⁻</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECF</td>
<td>142</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>103</td>
<td>27</td>
</tr>
<tr>
<td>LR</td>
<td>130</td>
<td>4</td>
<td>3</td>
<td>-</td>
<td>109</td>
<td>28</td>
</tr>
<tr>
<td>0.9% NaCl</td>
<td>154</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>154</td>
<td>--</td>
</tr>
<tr>
<td>1/2 NS</td>
<td>77</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>77</td>
<td>--</td>
</tr>
<tr>
<td>3% NaCl</td>
<td>513</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>513</td>
<td>--</td>
</tr>
</tbody>
</table>
Hyperkalemia

**Etiology:**
- Renal insufficiency, stored blood
- Severe injury, cellular damage
- Metabolic acidosis (in exchange for H⁺)
- Iatrogenic

**Symptoms:** nausea, vomiting, diarrhea, colic weakness, depressed DTR’s
Hyperkalemia

**Diagnosis:** peaked T waves; prolonged ST, QRS

**Complications:** arrhythmias, ventricular fibrillation

**Treatment:**
- **Glucose-insulin-bicarbonate:** 50 cc D$_{50}$
  - 10-25 units regular insulin
  - 1 amp NaHCO$_3$
- **Calcium gluconate (10%):** 50-100 cc
- **Kayexalate:** 5-10 gm po QID or 30 gm enema Q 3-6h
- **Dialysis:** when K$^+$ > 7 mEq/L
Hypokalemia

Etiology:
- GI tract losses, alkalosis
- Renal excretion (diuretics)
- K into cells (insulin)
- Administration of K-free fluids
- Hyperaldosteronism
- Chronic hypercortisolism

Symptoms: nausea, vomiting, weakness
- ileus, depressed DTR’s
Hypokalemia

**Diagnosis:** flat T wave, prolonged QT, U wave

**Complications:** DIGITALIS TOXICITY

**Treatment:** potassium supplements

(< 20 mEq/hr)
Hypercalcemia

Etiology:
- Hyperparathyroidism
- Bony metastases
- Tumors secreting pseudoparathormone

Symptoms: CNS (weakness)
- GI (anorexia)

Treatment:
- 0.9% Saline, furosemide
- Mithramycin
- Chelating agents
- Steroids
Hypocalcemia

Etiology:
- Hypoparathyroidism
- Soft tissue infections
- Pancreatitis
- Renal failure

Symptoms: circumoral numbness, tingling
           hyperreflexia, tetany, cramps

Treatment: Calcium chloride or gluconate
Metabolic Acidosis

Etiology:

• Increased organic acid
  – diabetic ketoacidosis, lactic acidosis
  – cellular hypoxia (shock, airway obstruction, sepsis)

• Decreased renal excretion of acid
  – oliguric renal failure
  – hyperchloremia
  – obstructive uropathy

• Abnormal loss of bicarbonate
  – diarrhea
  – small bowel or pancreatic fistula
Metabolic Acidosis

Compensation:
• Hyperventilation, early
• Renal, late

Treatment:
• Correct underlying problem
• NaHCO$_3$
• Na lactate
• THAM (alkali w/o Na)
Metabolic Alkalosis

Etiology:

• Loss of HCl
  – NG suction, vomiting

• Loss of KCl
  – vomiting, diarrhea
  – diuretics, steroids, aldosteronism
Metabolic Alkalosis

Compensation:

• generally uncompensated by lungs
• renal excretion of bicarbonate

Treatment:

• Chloride replacement
• Potassium replacement
• 0.1 N HCl or ammonium chloride
Respiratory Acidosis

Etiology:
- Hypoventilation
- A-V shunting

Compensation: renal

Treatment: mechanical ventilation
Respiratory Alkalosis

Etiology:
- pain
- sepsis
- fever
- early ARDS

Compensation: renal

Treatment:
- Pain management
- Ventilatory support (CPAP/PEEP)
- Search for possible underlying sepsis
## Interpretation of Blood Gases

<table>
<thead>
<tr>
<th></th>
<th>pH</th>
<th>pCO₂</th>
<th>HCO₃</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metabolic alkalosis</strong></td>
<td>↑</td>
<td>—</td>
<td>↑</td>
</tr>
<tr>
<td><strong>Metabolic acidosis</strong></td>
<td>↓</td>
<td>—</td>
<td>↓</td>
</tr>
<tr>
<td><strong>Respiratory acidosis</strong></td>
<td>↓</td>
<td>↑</td>
<td>—</td>
</tr>
<tr>
<td><strong>Respiratory alkalosis</strong></td>
<td>↑</td>
<td>↓</td>
<td>—</td>
</tr>
</tbody>
</table>
Analysis of Acid-Base Balance

- $pCO_2 \uparrow 10 \text{ mm Hg} > 40 \Rightarrow pH$ decreases 0.08

- $HCO_3 \uparrow 10 \text{ mEq} > 25 \Rightarrow pH$ increases 0.15

- Bicarbonate deficit (mEq):
  - $(25 - HCO_3) \times (0.2 \times \text{Body wt}) \text{ or } B.E. \times (0.3 \times \text{Body wt})$
  - Replace $\leq 50\%$ at a time