Fluids and electrolytes management of the surgical patient

Eman Elshiekh
Objectives

- To understand distribution fluids and electrolytes in body compartments.
- To list the normal range of electrolytes in serum.
- To understand fluid and electrolyte requirement in surgical patient.
- To know the composition of different intravenous fluids.
- To understand common electrolyte disturbances and its management.
Body fluids

- Total body water is 42 L (~60% of body weight)
- 28 L is in the intracellular and 14 L in the extracellular compartments
- The plasma volume is 3 L
- The extravascular volume is 11 L
- Total body Na+ is 4200 mmol (50% in ECF)
- Total body K+ is 3500 mmol (only about 50-60 mmol in ECF)
- Normal osmolality of ECF is 280 –295 mosmol/kg
Body Fluid Compartments:

- **ICF:** 55%~75%
  - Intravascular ➔ plasma
  - Extravascular ➔ interstitial fluid

**TBW**

- Extravascular
  - 2/3
    - Male (60%) > female (55%)
  - 1/3
    - ECF ➔ Interstitial fluid
  - 3/4
    - Intravascular ➔ plasma

- X 50~70% lean body weight
Composition of Body Fluids:

Cations

- Na⁺
- K⁺
- Ca²⁺
- Mg²⁺

Anions

- Cl⁻
- HCO₃⁻
- PO₄³⁻
- Protein

- ECF
- ICF
Composition

- Extracellular – Sodium (+), Chloride (-) and Bicarbonate (-)
- Intracellular- Potassium, Magnesium (+), Phosphate and Proteins (-)
- Maintained by ATP-driven sodium-potassium pumps
Regulation of Fluids:

Hydrostatic pressure v.s. Oncotic pressure

→ Albumin is the major determining oncotic pressure
Regulation of Fluids:

- Renal sympathetic nerves
- Renin-angiotensin-aldosterone system
- Atrial natriuretic peptide (ANP)
### Composition of GI Secretions:

<table>
<thead>
<tr>
<th>Source</th>
<th>Volume (ml/24h)</th>
<th>Na⁺⁺</th>
<th>K⁺</th>
<th>Cl⁻</th>
<th>HCO₃⁻</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salivary</td>
<td>1500 (500~2000)</td>
<td>10 (2~10)</td>
<td>26 (20~30)</td>
<td>10 (8~18)</td>
<td>30</td>
</tr>
<tr>
<td>Stomach</td>
<td>1500 (100~4000)</td>
<td>60 (9~116)</td>
<td>10 (0~32)</td>
<td>130 (8~154)</td>
<td>0</td>
</tr>
<tr>
<td>Duodenum</td>
<td>100~2000</td>
<td>140</td>
<td>5</td>
<td>80</td>
<td>0</td>
</tr>
<tr>
<td>Ileum</td>
<td>3000</td>
<td>140 (80~150)</td>
<td>5 (2~8)</td>
<td>104 (43~137)</td>
<td>30</td>
</tr>
<tr>
<td>Colon</td>
<td>100-9000</td>
<td>60</td>
<td>30</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>Pancreas</td>
<td>100-800</td>
<td>140 (113~185)</td>
<td>5 (3~7)</td>
<td>75 (54~95)</td>
<td>115</td>
</tr>
<tr>
<td>Bile</td>
<td>50-800</td>
<td>145 (131~164)</td>
<td>5 (3~12)</td>
<td>100 (89~180)</td>
<td>35</td>
</tr>
</tbody>
</table>

* Average concentration: mmol/L
Normal water exchange

<table>
<thead>
<tr>
<th>In</th>
<th>Out</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intake</td>
<td>1 L urine</td>
</tr>
<tr>
<td>metabolism</td>
<td>250 mL stool</td>
</tr>
<tr>
<td></td>
<td>600 mL insensible losses</td>
</tr>
<tr>
<td></td>
<td>skin (75%) &amp; lungs (25%)</td>
</tr>
</tbody>
</table>
Surgical patient needs

- Replacement of deficit
- Maintenance requirement
- Replacement of ongoing losses
Replacement fluids

- Assessment of patient pulse, BP, CVP, signs of dehydration.
- Estimation of losses which have already happened (volume and nature)
- Estimation of expected losses.

Replace fluid and electrolytes
Maintenance requirements

- Daily maintenance fluid requirements vary

- 70 Kg male = 2.5 - 3.0L water (30-40 ml/kg body weight)
- 2-3 mEq per Kg Na
- 1-2 mEq per Kg K


Daily maintenance fluid requirements for children

- 0-10 kg is 100 ml/kg
- 10-20 kg is 1000 ml + 50 ml/kg for each kg > 10
- >20 kg is 1500 ml + 25 ml/kg for each kg > 20
Types of IV fluids

- Crystalloids
- Colloids
Types of IV fluids

Crystalloids:
- contain Na as the main osmotically active particle
- useful for volume expansion (mainly interstitial space)
- for maintenance infusion
- correction of electrolyte abnormality
Crystalloids:

- **Isotonic crystalloids**
  - Lactated Ringer’s, 0.9% NaCl
  - only 25% remain intravascularly
- **Hypertonic saline solutions**
  - 3% NaCl
- **Hypotonic solutions**
  - D5W, 0.45% NaCl
  - less than 10% remain intra-vascularly, inadequate for fluid resuscitation
Contain high molecular weight substances do not readily migrate across capillary walls

Preparations
- Albumin: 5%, 25%
- Dextran
- Gelifundol
- Haes-steril 10%
## Common parenteral fluid therapy

<table>
<thead>
<tr>
<th>Solutions</th>
<th>Volumes</th>
<th>Na⁺</th>
<th>K⁺</th>
<th>Ca²⁺</th>
<th>Mg²⁺</th>
<th>Cl⁻</th>
<th>HCO₃⁻</th>
<th>Dextrose</th>
<th>mOsm/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECF</td>
<td>142</td>
<td>4</td>
<td>5</td>
<td></td>
<td>103</td>
<td>27</td>
<td></td>
<td></td>
<td>280-310</td>
</tr>
<tr>
<td>Lactated Ringer’s</td>
<td>130</td>
<td>4</td>
<td>3</td>
<td></td>
<td>109</td>
<td>28</td>
<td></td>
<td></td>
<td>273</td>
</tr>
<tr>
<td>0.9% NaCl</td>
<td>154</td>
<td></td>
<td></td>
<td></td>
<td>154</td>
<td></td>
<td></td>
<td></td>
<td>308</td>
</tr>
<tr>
<td>0.45% NaCl</td>
<td>77</td>
<td></td>
<td></td>
<td></td>
<td>77</td>
<td></td>
<td></td>
<td></td>
<td>154</td>
</tr>
<tr>
<td>D5W</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D5/0.45% NaCl</td>
<td>77</td>
<td></td>
<td></td>
<td></td>
<td>77</td>
<td>50</td>
<td></td>
<td></td>
<td>406</td>
</tr>
<tr>
<td>3% NaCl</td>
<td>513</td>
<td></td>
<td></td>
<td></td>
<td>513</td>
<td></td>
<td></td>
<td></td>
<td>1026</td>
</tr>
<tr>
<td>6% Hetastarch</td>
<td>500</td>
<td>154</td>
<td></td>
<td></td>
<td>154</td>
<td></td>
<td></td>
<td></td>
<td>310</td>
</tr>
<tr>
<td>5% Albumin</td>
<td>250,500</td>
<td>130-160</td>
<td>&lt;2.5</td>
<td>130-160</td>
<td>330</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25% Albumin</td>
<td>20,50,100</td>
<td>130-160</td>
<td>&lt;2.5</td>
<td>130-160</td>
<td>330</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The Influence of Colloid & Crystalloid on Blood Volume:

<table>
<thead>
<tr>
<th>Infusion volume</th>
<th>Blood volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000cc Lactated Ringers</td>
<td>200</td>
</tr>
<tr>
<td>500cc 5% Albumin</td>
<td>600</td>
</tr>
<tr>
<td>500cc 6% Hetastarch</td>
<td>1000</td>
</tr>
<tr>
<td>500cc Whole blood</td>
<td>1000</td>
</tr>
</tbody>
</table>
Noramal saline

- 154 mEq Na
- 154 mEq Cl
Ringer’s Lactate

- Na 130 mEq
- K 4 mEq
- Cl 109 mEq
- 28 mEq lactate
5% dextrose in water

50 g of dextrose
Colloids

- Albumin (molecular weight 70,000) (5 or 25%)
- Dextrans (dextran 40) or (dextran 70)
- Hydroxyethyl starch solutions
- Gelatins
FLUID AND ELECTROLYTES DISRUPTIONS

- Volume
- Electrolyte deficiency or excess
Signs of Hypovolemia:

- Diminished skin turgor
- Dry oral mucus membrane
- Oliguria
  - <500ml/day
  - normal: 0.5~1ml/kg/h
- Tachycardia
- Hypotension
- Hypoperfusion → cyanosis
- Altered mental status
Clinical Diagnosis of Hypovolemia:

- Thorough history taking: poor intake, GI bleeding…etc
- BUN : Creatinine $> 20 : 1$
  - BUN↑: hyperalimentation, glucocorticoid therapy, UGI bleeding
- Increased specific gravity
- Increased hematocrit
Treatment

Replace like with like
Signs of Hypervolemia:

- Hypertension
- Polyuria
- Peripheral edema
- Wet lung
- Jugular vein engorgement

Especially when hypo-albuminemia
Management of Hypervolemia:

- Prevention is the best way
- Guide fluid therapy with CVP level or pulmonary wedge pressure
- Diuretics
- Increase oncotic pressure: FFP or albumin infusion (may followed by diuretics)
- Dialysis
Hyponatremia

Predisposing Factors
- Diabetes mellitus (hyperglycemia)
- Cystic fibrosis
- CNS disorders (SIADH)
- Gastroenteritis
- Excessive water intake (formula dilution)
- Diuretics (thiazides and furosemide)
- Renal disease
Hyponatremia

Hyponatremic Dehydration
- Hypovolemic Hyponatremic Dehydration
  - High urine output and Na excretion
  - Increase in atrial natriuretic factor
- Euvolemic Hyponatremic Dehydration
  - ADH mediated water retention
- Hypervolemic Hyponatremic Dehydration
  - Edematous disorder (nephrotic syndrome, CHF, cirrhosis)
  - Water intoxication
Hyponatremia

Acute Hyponatremia (<24 hours)

- Early Onset (Serum Sodium <125 meq/L)
  - Nausea
  - Vomiting
  - Headache

- Later or Severe (Serum Sodium <120 meq/L)
  - Seizure
  - Coma
  - Respiratory arrest
Hyponatremia

- Chronic Hyponatremia (>48 hours)
  - Lethargy
  - Confusion
  - Muscle cramps
  - Neurologic Impairment
Hyponatremia

Management

- Na Deficit:
  - Na Deficit = (Na Desired - Na observed) \times 0.6 \times \text{body weight(kg)}
  - Replace half in first 8 hours and the rest in the following 16 hours
  - Rise in serum Na should not exceed 2 mEq/L/h to prevent Central Pontine Myelinolysis (? Existence in children)

- In cases of severe hyponatremia (<120 mEq) with CNS symptoms:
  - 3% NaCl 3-5 ml/kg IV push for hyponatremia induced seizures
  - 6 ml/kg of NaCl will raise serum Na by 5 mEq/L
Hypernatremia

- Hypernatremia leads to hypertonicity
  - Increase secretion of ADH
  - Increase thirst
- Patients at risk
  - Inability to secrete or respond to ADH
  - No access to water
Hypernatremia

Etiology

- Pure water depletion
  - Diabetes insipidus (Central or Nephrogenic)
- Sodium excess
  - Salt poisoning (PO or IV)
- Water depletion exceeding Na depletion
  - Diarrhea, vomiting, decrease fluid intake
- Pharmacologic agents
  - Lithium, Cyclophosphamid, Cisplatin
Hypernatremia

Signs and symptoms

- Disturbances of consciousness
  - Lethargy or Confusion
- Neuromuscular Irritability
  - Muscle twitching, hyperreflexia
- Convulsions
- Hyperthermia
  - Skin may feel thick or doughy
Hypernatremia

Management

- Normal Saline or Ringer lactate to restore volume
- Hypotonic solution (D5 1/4 NS) to correct calculated deficit over 48 hours

  - Water Deficit
    - Normal body H2O - Current body H2O
  - Current body water
    - 0.6 x body weight (kg) x Normal Na/Observed Na
  - Normal Body water
    - 0.6 x body weight (kg)

- Decrease Na concentration at a rate of 0.5 mEq/hr or ~ 10 mEq/day: Faster correction can result in Cerebral Edema
Potassium

- Most abundant intracellular cation
- Normal serum values 3.5-5.5 mEq
- Abnormalities of serum K are potentially life-threatening due to effect in cardiac function
Hypokalemia

- **Diagnosis**
  - **Symptoms**
    - Arrhythmias
    - Neuromuscular excitability (hyporreflexia, paralysis)
    - Gastrointestinal (decreased peristalsis or ileus)
  - Serum K < 3mEq/L
  - ECG:
    - Flat T waves
    - Short P-R interval and QRS
    - U waves
Hypokalemia

<table>
<thead>
<tr>
<th>Nutritional</th>
<th>GI Loss</th>
<th>Renal Loss</th>
<th>Endocrine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor intake</td>
<td>Diarrhea</td>
<td>Renal tubular acidosis</td>
<td>Insulin therapy</td>
</tr>
<tr>
<td>IVF low in K</td>
<td>Vomiting</td>
<td>Chronic renal disease</td>
<td>Glucose therapy</td>
</tr>
<tr>
<td>Anorexia</td>
<td>Malabsorbtion</td>
<td>Fanconi's syndrome</td>
<td>DKA</td>
</tr>
<tr>
<td></td>
<td>Intestinal fistula</td>
<td>Gentamicin,</td>
<td>Hyperaldosteronism</td>
</tr>
<tr>
<td></td>
<td>Laxatives</td>
<td>Amphotericin</td>
<td>Adrenal adenomas</td>
</tr>
<tr>
<td></td>
<td>Enemas</td>
<td>Diuretics</td>
<td>Mineralocorticoids</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bartter's syndrome</td>
</tr>
</tbody>
</table>

**Bartter’s syndrome:** Hyperreninemia and hyperaldosteronism
Hypokalemia

Management:
- Cardiac Arrhythmias or Muscle Weakness
  - KCl IV (cardiac monitor)
- PO K - Depend of etiology
  - Hypophosphatemia = KPO4
  - Metabolic acidosis = KCl
  - Renal tubular acidosis = K citrate
Hyperkalemia

Differential Diagnosis
- Pseudohyperkalemia - from blood hemolysis
- Metabolic Acidosis
- Chronic Renal Failure
- Congenital Adrenal Hyperplasia
  - Females = Usually Dx at birth - Ambiguous Genitalia
  - Males = Dehydration, hyponatremia, hyperkalemia
- Medications
  - ACE inhibitors and NSAID’s
Hyperkalemia

Diagnosis:

- Symptoms
  - Cardiac Arrhythmias
  - Paresthesias
  - Muscle weakness or paralysis

- ECG
  - Peaked T waves
  - Short QT interval (K>6 mEq)
  - Depressed ST segment
  - Wide QRS (K>8 mEq)
Hyperkalemia

Management

- Close cardiac monitoring
- Life-threatening hyperkalemia
  - Intravenous Calcium - rapid onset, duration < 30 min
  - NaHCO3 or glucose and insulin
- Ion exchange resins
  - Sodium polystyrene sulfonate (Kayexelate)
    - PO or Enema
- Hemodyalisis