Fluid & Electrolyte Therapy

By

Prof. Soliman Ali Hassan

Prof. of Surgery

Taibah University
Fluid and electrolyte therapy

Learning objectives

- At the end of this lecture,
- 1-The student should have an idea about the normal body water and electrolytes distributions in extra and intravascular spaces of the body.
- 2- Discuss the causes and clinical presentations of various disturbances of body water and electrolytes esp. sodium and potassium.
- 3- The student should mention the required investigations and treatment of each of these clinical situations.
- 4- The student should discuss the different ways of fluid and electrolyte losses and how to calculate the amount and the type of fluids to be infused for deficit, maintenance and ongoing losses therapy.
- 5- He should know the preoperative, intraoperative and postoperative fluid and electrolyte monitoring and replacement.
Body Water & Its Distribution

- **Total body water:**
  - Total body water comprises 45–60% of body weight; the percentage in any individual is influenced by *age and the body weight*, but in healthy individuals it remains constant from day to day.

<table>
<thead>
<tr>
<th>Age</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>10–18</td>
<td>59</td>
<td>57</td>
</tr>
<tr>
<td>18–40</td>
<td>61</td>
<td>51</td>
</tr>
<tr>
<td>40–60</td>
<td>55</td>
<td>47</td>
</tr>
<tr>
<td>Over 60</td>
<td>52</td>
<td>46</td>
</tr>
</tbody>
</table>
Mean values of body water?

- **Adult male:** 60% of body wt
- **Adult female:** 55% of body wt (excess fat)
- **Infants & children:** 75% of body wt
- **Out of the 60%;**
  - 40% of water are intracellular
  - 20% are extracellular
Water balance

- **Water input:** 2500 ml/d
  - Exogenous: food & drinks 2200 ml/d
  - Endogenous: metabolic water 300 ml/d
- **Water output:** 2500 ml/d
  - Urine 1500 ml/d
  - Stool 100 ml/d
  - Lungs 400 ml/d
  - Skin 500 ml/d
  - Sensible water loss
  - Insensible water loss
Abnormal water balance

**Water depletion (dehydration)**

- **Causes:**
  - ↓ Intake, in starvation, difficulty of swallowing, comatose pat.
  - ↑ Loss; fever, vomiting, diarrhea etc

**Water excess (intoxication)**

- **Causes:**
  - ↑ Intake of pure water for Na depleted patient (hot weather)
  - Over infusion of iv fluids
  - Colon washout (enema) by pure water instead of N saline
Abnormal water balance

Water depletion (dehydration)

- Pathophysiological changes:
  - Blood volume will increase ADH to increase water retention by the kidney

Water excess (intoxication)

- Pathophysiological changes:
  - Blood volume will decrease ADH to increase water excretion by the kidney
Abnormal water balance

Water depletion (dehydration)
- Clinical picture:
  - Thirst
  - Generalized weakness
  - Dry tongue
  - Sunken eyes
  - Inelastic skin
  - Oliguria

Water excess (intoxication)
- Clinical picture:
  - Nausea & vomiting of clear fluid
  - Pulmonary edema & frothy sputum
  - Brain edema with convulsion & may be coma
  - Polyuria
Abnormal water balance

**Water depletion**
- **Treatment**
- Mild cases: pure water intake
- Severe cases: IV glucose 5%

**Water excess**
- **Treatment**
- Mild cases: Restrict water intake
- Severe cases: Forced diuresis by mannitol 10-20%
- Convulsion is treated by 100-250ml hypertonic saline (5% NaCl) sol.
## Electrolyte imbalance

<table>
<thead>
<tr>
<th>Normal plasma levels</th>
<th>Normal plasma levels</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cations</strong></td>
<td><strong>Anions</strong></td>
</tr>
<tr>
<td>Na</td>
<td>Cl</td>
</tr>
<tr>
<td>142 mmol/L</td>
<td>103 mmol/L</td>
</tr>
<tr>
<td>K</td>
<td>HCO$_3^-$</td>
</tr>
<tr>
<td>4 mmol/L</td>
<td>25 mmol/L</td>
</tr>
</tbody>
</table>
- ECF contains principally **sodium**, chloride, and bicarbonate, with other ions in much lower concentrations.

- ICF contains mainly **potassium**, organic phosphate, sulfate, and various other ions in lower concentrations.
- Sodium is the main extracellular cation: $142\text{mmol/L}$
- Potassium is the main intracellular cation: $140\text{mmol/L}$
Daily requirements of some important electrolytes:

Water: 35ml/kg

Na: 1 mmol/kg = (50-90 mmol/day), equivalent to 5gm/day or 500ml normal saline.

K: 1 mmol/kg = (50-70 mmol/day), supplied mainly through potassium rich food (fruit, milk and honey)

Ca: 5 mmol/d

Mg: 1 mmol/d
Sodium imbalance

- The normal serum sodium ion \([Na^+]\) ranges between **138** and **145 mmol/L**.
- Sodium level is controlled by adrenal corticoids especially aldosterone.
- **Hyponatremia**, commonly seen in clinical practice, can be classified into *mild, moderate, & severe*.
- **Mild Hyponatremia** when \([Na^+]\) lies between **130** and **138 mmol/L**,
- **Moderate Hyponatremia** when \([Na^+]\) declines to the range of **120** to **130 mmol/L**.
- **Severe Hyponatremia** is defined as an \([Na^+]\) less than **120 mmol/L**.
Sodium imbalance

Hyponatremia

- **Causes:**
  - GIT loss; excess suction, vomiting, diarrhea
  - Urine loss; chronic renal failure, salt losing kidney
  - ECF loss; burns, peritonitis, edema
  - Adreno-cortical hypofunction
  - Decreased Na intake

Hypernatremia

- **Causes:**
  - Over-infusion of N saline
  - Adreno-cortical hyperfunction; Conn’s synd. & Cushing’s synd.
  - Na retention with heart & liver failure
## Sodium imbalance

### Clinical picture of Hyponatremia
- **Decrease in ECF:**
  - *Dehydration:*
  - Sunken eyes, dry tongue, dry inelastic skin, collapsed veins
  - Hypotension, tachycardia, & shock
  - Oliguria
  - Decreased serum Na

### Clinical picture of Hypernatremia
- **Increase in ECF:**
  - *Generalized edema*
    - Puffiness of the face, Ascitis, interstitial pulmonary edema
  - Hypertension
  - Polyuria
  - Increased serum Na
Sodium imbalance

Treatment

- **For mild & moderate cases:**
  - Normal saline 0.9% or Ringer’s lactate infusion
- **Severe cases** may be treated by hypertonic saline 5%

Treatment

- Na restriction
- Furosemide diuretics
- Correction of hypoproteinaemia by iv salt free albumin
Potassium imbalance

- The mean potassium concentration ([K⁺]) in ECF is **4 mmol/L**.
- More than **98% of the body's potassium** is located in the ICF compartment.
- Renal excretion of potassium is regulated by mineralocorticoid (aldosterone) levels

- **Hyperkalemia** is defined as [K⁺] that exceeds **5.0 mmol/L**
- **Hypokalemia**, those have a [K⁺] lower than **3.5 mmol/L**.
Potassium imbalance

Hypokalemia

- **Causes:**
- Excess K loss as in:
  - Frequent vomiting, severe diarrhea
  - Intestinal fistula
  - Furosemide diuretic leading to excess loss of K in urine (> 30meq/24h)
  - Alkalosis; intracellular K shift

Hyperkalemia

- **Causes:**
- K retention as in:
  - Acute or Chronic renal failure
  - Acidosis
  - Uncontrolled Diabetics
Potassium imbalance

**Hypokalemia**

- **Clinical picture:**
  - Decreased muscle contractility and in extreme cases death may result from paralysis of the muscles of respiration.
  - Generalized malaise & weakness
  - Paralytic ileus
  - Cardiac arrhythmias
  - **ECG changes:**
    - Prolonged Q-T interval, depressed S-T segment & inverted T wave

**Hyperkalemia**

- **Clinical picture:**
  - Nausea, vomiting, colicky abdominal pain, and diarrhea may occur
  - Muscle twitches
  - Irritability & restlessness

- **ECG changes:**
  - Wide QRS
  - Peaked T wave
Potassium imbalance

Treatment

- Correcting the cause of hypokalemia
- If the patient is able to eat, potassium should be given orally (K tab, syrup, fruit juices)
- With mild hypokalemia (3–3.5 meq / L), slow iv infusion of Kcl amp. trying to avoid Hyperkalemia

Treatment

- 1- 10 mL of 10% calcium chloride over a 10-minute:
  - (an infusion of calcium gluconate will transiently reverse cardiac depression from hyperkalemia without changing the serum potassium concentration.)
- 2- IV Na bicarbonate → alkalosis → intracellular K shift *Dose:*50-100 mEq over a 10-to 20-minute
- 3- 500 ml 20% glucose + 10 units insulin
  - Insulin stimulates deposition of potassium with glycogen
Treat. Of Hypokalemia

- **In moderate to severe hypokalemia** ( < 3 meq/L): Potassium may be administered slowly at a rate of 20–30 meq / h.

Treat. Of Hyperkalemia

- **If the previous methods fail:**
  - 4- the ion exchange resin; sodium polystyrene sulfonate (Kayexalate): 50gm in 70% sorbitol orally or by repeated enema.
    - This drug binds potassium in the intestine in exchange for sodium.
    - It is often given with sorbitol to induce osmotic diarrhea to enhance the rate of potassium removal.
  - 5- Immediate haemodialysis
Calcium Imbalance

- Normal serum calcium 8.5-10.5mg% (2.2-2.5mmol/L)
- Hypocalcaemia may be latent or manifested.
- It may follow thyroid surgery due accidental removal of parathyroid glands.
- It can occur with acute pancreatitis and in severe alkalosis (hyperventilation).

Clinically:
- Hyper active deep reflexes, muscle and abdominal cramps, carpopedal spasm & rarely convulsions.

Treatment:
- IV ca gluconate for acute cases
- Vit D and oral ca for chronic cases.
1- **Crystalloid solutions:**

A number of electrolyte solutions are available for parenteral administration.

**Why we use crystalloids?**

- inexpensive
- easy to store for long period
- very low incidence of adverse reactions
- a variety of formulas are available
- effective for use as replacement or maintenance fluids
- no special compatibility testing is required.
- no religious objections to their use
Crystalloid solutions

- The amount of iv fluid is determined by assessment of:
  - 1- the patient’s daily requirements of fluid & electrolytes,
  - 2- the existing fluid deficits,
  - 3- the ongoing fluid losses.
- Potassium, magnesium, or calcium can be added to parenteral solutions according to the patient’s requirements.
## COMMONLY USED CRYSTALLOID SOLUTIONS

<table>
<thead>
<tr>
<th>Solution</th>
<th>Electrolyte (mEq/L)</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Saline sol.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td><strong>0.9% N. saline</strong></td>
<td>154 — — — 154</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>0.45% NaCl</strong></td>
<td>77 — — — 77</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>0.33% NaCl</strong></td>
<td>56 — — — 56</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>0.2% NaCl</strong></td>
<td>34 — — — 34</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>3.0% NaCl</strong></td>
<td>513 — — — 513</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>5.0% NaCl</strong></td>
<td>855 — — — 855</td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

- The normal saline is **isotonic**
- The last 2 types are **hypertonic**
- Other types of lower conc. are **hypotonic**
### COMMONLY USED CRYSTALLOID SOLUTIONS

<table>
<thead>
<tr>
<th>Solution</th>
<th>Electrolyte (mmol/L)</th>
<th>Na⁺</th>
<th>K⁺</th>
<th>Ca²⁺</th>
<th>Mg²⁺</th>
<th>Cl⁻</th>
<th>Lactate⁻</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ringer’s lactate</td>
<td></td>
<td>130</td>
<td>4</td>
<td>4</td>
<td>---</td>
<td>109</td>
<td>28</td>
</tr>
<tr>
<td>Hartmann’s</td>
<td></td>
<td>130</td>
<td>4</td>
<td>2.7</td>
<td>—</td>
<td>109</td>
<td>28</td>
</tr>
<tr>
<td>Dextrose saline</td>
<td></td>
<td>30</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>30</td>
<td>—</td>
</tr>
</tbody>
</table>

The metabolism of lactate in the liver results in production of an equivalent amount of bicarbonate.
Special Solutions

- Some crystalloid solutions used for special purposes; for example:
  - 8.4% Bicarbonate solution
  - Mannitol 10-20%
The best physiological solutions:

1- Lactated Ringer’s solution is the best physiological (electrolytes conc. Nearly similar to plasma.)

It is ideal for the replacement of existing fluid deficits esp. GIT losses.
2- **Isotonic saline (0.9% or normal saline)**

Useful in patients with **hyponatremia or hypochloremia**.

- **N.B:** Excess infusion of both sodium and chloride can lead to **Hypernatremia**
- & acid–base disturbances, **hyperchloremic metabolic acidosis**.
The hypotonic types 0.45%, 0.33%, and 0.2% have an excess free water and can result in RBCs haemolysis if rapidly infused.

For this reason,

5% dextrose (50 g dextrose per liter) is added to these solutions to increase the tonicity & prevent haemolysis.
Hypertonic saline solutions (3% NaCl and 5% NaCl)

Used for patients with moderate & severe Hyponatremia.

They appear to increase the intravascular volume and the total volume required for resuscitation may be decreased.

Patients resuscitated with hypertonic solutions may develop: Hypernatremia and hyperosmolar coma.
2- Colloid solutions (Plasma expanders)

- Colloids are large molecular weight substances ($\text{MW} > 30,000$).
- In normal plasma, the plasma proteins (albumin, globulin & fibrinogen) are the major colloids present.
- Colloids are important in capillary fluid dynamics because they stay long in the circulation & are effective at exerting an osmotic force across the wall of the capillaries.
The general problems with colloid solutions are:

1- Much **higher cost** than crystalloid solutions

2- Small but **significance** incidence of adverse reactions (anaphylactic reactions)
Types:

1- HUMAN ALBUMIN

Albumin 4.5%

2- Synthetic plasma expanders.

1- DEXTRANS: highly branched polysaccharide molecules

- Dextran 40; Mw 40,000 (Rheomacrodex)
- Dextran 70; Mw 70,000 ['Macrodex'].
- Dextran 110

2- Hydroxyethyl STARCH

- Hetastarch (Hespan)
3- Gelatins

A large molecular weight protein formed from hydrolysis of collagen.

There are 3 types of gelatin solutions:

1- Succinylated or modified fluid gelatins (Gelofusine, Plasmagel, Plasmion)

2- Urea-cross-linked gelatins (Polygeline)

3- Oxy-polygelatins (Gelifundol, ‘Haemaccel’ Hoechst)
The disadvantages of gelatin solutions is that it has a high viscosity and a tendency to gel and solidify if stored at low temperatures.
Clinical uses:

- **4.5% albumin**, act initially by increasing plasma oncotic pressures.
- *2-3 units can be given iv over 30 min.*
- Valuable in burns (plasma loss) & hypoalbuminaemia of chronic liver diseases & malignancy
- No risk of transmission of hepatitis.
- **Dextran 40** has an immediate effect in restoring the plasma volume in hypovolemia.
- Because of its low molecular weight, it is rapidly excreted by the kidney.
- Sometimes it can induce rouleaux formation in small blood vessels.
- **Dextran 70, 110** are long acting - remained in the circulation longer than dextran 40 (6 to 8 hours.)
- A maximal dosage of dextran:
  - 20 ml/kg (about 1,500 ml for an adult 70kg).
Disadvantages of dextran:

1- Interference with cross-matching, so the cross-matching should be done before dextran have been used.

2- Dextran interferes with hemostasis; it induces an acquired von Willebrand’s syndrome.

Von Willebrand's disease (vWD) is the most common hereditary coagulation abnormality.

It arises from deficiency of von Willebrand factor (vWF), required for platelet adhesion.
Polygeline is supplied as a 3.5% solution with electrolytes (Na+ 145, K+ 5.1, Ca++ 6.25 & Cl- 145 mmol/l).

It is sterile, contains no preservatives and can be stored for 3 years when stored at temperatures less than 30°C.

Polygeline is used for the replacement of acute blood loss & used in heart-lung machines in cardiovascular surgeries.
- **Hydroxyethyl starch:**
  - Anaphylactic reactions occur in about 0.1% of cases.
  - Some patients experience **severe pruritis**.
  - It can **adversely** affect **the coagulation**
  - The maximum recommended dose is **20 ml/kg**
Preoperative Fluid & Electrolyte Therapy

- **You have to replace:**
- 1- The preexisting volume and electrolyte losses *(replacement; deficit therapy).*
- 2- To replace normal daily requirements *(maintenance therapy).*
- 3- Replacement of ongoing fluid losses.
1- Replacement therapy (deficit therapy)

- These solutions are used to replace ECF.
- They are all isotonic.
- *Intracellular fluid volume does not change.*
- Used for patients with trauma, patient with hypovolaemia, during operative procedures.
If used to replace blood loss, 3 to 4 times the volume lost must be administered.

Up to 20% loss of blood volume (loss of 1,000 mls) can be safely replaced with a 3,000-4,000 ml lactated Ringer solution.

The volume of fluid required for resuscitation is estimated by monitoring the vital signs.
Monitoring during infusion

1- The aim of initial therapy is the normalization of pulse rate, blood pressure, and tissue perfusion.

2- The best monitor of tissue perfusion in critically ill patients is:

2- Urine output with an indwelling Foley catheter

Urine output of greater than 0.5 mL/kg/h should be achieved.
3- **CVP** is monitored by

1- **Central venous catheter**
- It measures the pressure in the right side of the heart.
- Central venous pressures of 5 - 12 mmHg or 6 - 15 cm H2O are considered normal.
- Pressures **above** ; means volume overload or cardiac failure.
- Pressures **below** ; means hypovolemia

2- **PCWP**: (pulmonary artery (Swan Ganz) catheter)
- It measures the pressure in the left side of the heart.
- Normally; PCWP is 8-12 mm Hg & the pulmonary artery pressure is 25 mmHg.
2- Maintenance Fluid Therapy

(Daily requirements)

- Maintenance fluid replacement is aimed at replacing fluids normally lost during the day.
- Dextrose 5% is the standard solution,
- Na⁺ and K⁺ can be added as required.
- Maintenance fluid replacement should be given after resuscitation (the re-establishment of normal hemodynamic status).
1- Amount of maintenance fluids is determined by the sensible (urine & stool) and insensible losses (skin, lung).

**Insensible water loss = 8 - 12 ml/kg/d**

& increases 10% for every degree of body temperature above 37.2°C (99°F).

For example, a 70-kg man without a fever has a daily insensible water loss of about 840 ml.

**Added to** the amount of urinary and stool losses (1500 ml urine + 100 ml stool)

1600 + 840 = 2440 ml/day
2- Second method to calculate the amount of maintenance fluids?

<table>
<thead>
<tr>
<th>Body Weight</th>
<th>Fluid Requirement/ day</th>
</tr>
</thead>
<tbody>
<tr>
<td>For 0–10 kg</td>
<td>Give 100 ml/kg/d</td>
</tr>
<tr>
<td>For next 10–20 kg</td>
<td>Give 50 ml/kg/d</td>
</tr>
<tr>
<td>For weights &gt; 20 kg†</td>
<td>Give 20 ml/kg/d</td>
</tr>
</tbody>
</table>

†For elderly patients or patients with cardiac disease, this amount should be reduced to 15 ml/kg/d.

So, 70 kg man needs the sum of A, B, C

Thus, the total daily water requirement for a 70-kg man is about 2500 ml/d.
3- Third method is the rough estimation of daily requirements of fluid therapy by giving **30-40ml/kg** of body weight

For 70 kg adult, we give 30-40X70 = 2100-2800ml
3- Replacement of Ongoing Fluid Losses

- **Ongoing losses after major surgery** comes from nasogastric tubes, ileostomies, fistulas, and can be easily measured.

- In addition, the electrolyte contents of these fluids should be predicted and replaced with precision.

- Ongoing losses should be detailed on a flow chart beside the patient bed showing the intake and output of all fluids.
Intra-operative Fluid Therapy

- **Anesthesia** interrupts normal baroreceptor reflexes, so that the patient with volume depletion, may become acutely *hypotensive on induction of anesthesia.*

- For this reason, adequate resuscitation before surgery is mandatory.

- Blood loss during surgery, is grossly estimated by the surgeon and losses *above 500 ml should be replaced* during the operation.
Lactated Ringer solution, is given at a rate of 500 to 1000 ml/h during the operation.

The rate of infusion is measured by ? Drops/min (15 drops= 1 ml)

500ml can be given over 4h by 30 drops/min

Close monitoring of blood pressure, CVP and urine output.
Postoperative Fluid Therapy

- In general:
  - 1- isotonic solutions (normal saline & dextrose 5%) should be used during the early postoperative period.
  - 2- It is best not to give potassium supplements during the early 3-4 days, post-operative (No ringer’s or Hartmann’s) unless they are specifically required.
  - Careful monitoring of vital signs, urinary output, and central venous pressure if necessary.
Renal failure in the postoperative period may be expected by low urine volumes.

- **Oliguric** renal failure, less than 500 ml/d
- **Anuric** renal failure > 200ml/d

**Occurs in patients with:**

- Pre-existing renal disease
- Hypotensive patients before or during surgery
- Patients receiving nephrotoxic drugs.
Thank You