Fluid and Electrolyte Therapy

PREPARED BY
B.KIRUTHIGA
LECTURER
DEPT OF PHARMACEUTICAL CHEMISTRY
Parental Fluids

Infusion:
Administration of > 100 ml fluid by parenteral route

Tonicity
Osmotic pressure of fluid in relation to plasma

Parenteral fluids can be

- **Isotonic**: osmotic pressure of the fluid = OP of the plasma = 290 mOsmol/L
- **Hypertonic**: OP > OP of plasma by > 50.
- **Hypotonic**: OP < OP of plasma at least by 50
Parental Fluids

The tonicity of fluid has direct effect on fluid and electrolyte when infused into circulation

- Hypertonic $\rightarrow$ ↑ OP of plasma $\rightarrow$ movement of water from cell to plasma $\rightarrow$ cell dehydration esp. in brain
  - Hypotonic solution $\rightarrow$ ↓ OP of plasma causing fluid to invade cells.
  - Isotonic fluid excess $\rightarrow$ ↑ ECF $\rightarrow$ ↑ blood volume $\rightarrow$ circulatory overload.
Parental Fluids

What’s the importance of knowing the osmolarity of infusion fluid

• Alert to fluid and electrolyte imbalances that may occur
• Hyperosmolar fluid should be infused in large vein with large blood volume to dilute fluid.
• Tonicity of fluid affects the rate at which it can be infused
Fluid and electrolyte therapy

Physiology of body water balance
Physiology of Body Water Balance

Body water is divided to 3 compartments

- **Intracellular**: ICF, 40-50% of body wt
- **Interstitial**: 11-15%
- **Vascular**: 5%
- **Extra-cellular fluid ECF**: interstitial + vascular

Actual amount of body water differs according to

- Age
- Sex
- Body composition
Body Fluid Compartments:

- Male (60%) > female (50%)
- Most concentrated in skeletal muscle
- TBW = 0.6xBW
- ICF = 0.4xBW
- ECF = 0.2xBW

X 50~70% lean body weight → TBW

ICF: 55%~75%

2/3

Extravascular → Interstitial fluid

3/4

Intravascular → plasma

1/3

1/4
Physiology of Body Water Balance

- **Newborn** 70% of WT water
- **1-year-old** 60% of WT water
- **Men**: higher water content due to greater muscle mass
- **Obese**: less water because fat cells have minimal ICF
  - Use ideal body weight when estimating TBW for obese
- **Elderly**: less water due to less muscle mass
Physiology of Body Water Balance

• Water moves between the 3 compartments at the level of the capillaries
• The vol in each compartment remains constant under normal conditions
• Regulated by hydrostatic and oncotic pressure
• **Hydrostatic:**
  – determined by cardiac output and arterial tone which determine BP
  – = 17 mmHg and pushes water to interstitial space
• **oncotic pressure:**
  – proteins in the vascular space pull water
Fluid compartments

- Plasma
- Interstitial
- ECF
- ICF
- Cell Membrane
- Capillary Membrane
Osmotic pressure

- keeps the vol of three compartments constant
- The concentration of electrolyte in each compartment creates osmotic pressure that holds the water in each space
Body Water Disturbances

Evaluated as total volume and individual compartments

**Dehydration:**
— Fluid volume is low in all three compartments

**Hypovolemia:**
— Low vascular fluid

**Total body water overload**
— TBW > 60%
— Not specify abnormalities in individual compartments
— Distribution of water must be known before appropriate action can be taken

**Edema**
— Collection of fluid in interstitial space due to low oncotic pressure in the vascular compartment. E.g low albumin levels
Distribution of Ions in Each Compartment

- Table 9.1

Osmolarity
- Normal 280-300 mOsmol/L
- ECF: Na and Cl
- ICF: K and Po4

- Concentration of other ions is too low to contribute to osmotic gradient
- Other osmotically active substances: glucose, urea, and lipids.
- Osmolarity is determined by all the above
- Non-Electrolyte contribution is little
**Composition of Body Fluids:**

- Cations: Ca²⁺, Mg²⁺, K⁺, Na⁺
- Anions: Cl⁻, PO₄³⁻, Organic anion, HCO₃⁻, Protein

**Osmolarity** = solute/(solute+solvent)

**Osmolality** = solute/solvent (290~310 mOsm/L)

**Tonicity** = effective osmolality

**Plasma osmolality** = 2 x (Na) + (Glucose/18) + (Urea/2.8)

**Plasma tonicity** = 2 x (Na) + (Glucose/18)
Osmolarity

- **Effective Osmolarity:**
  - Twice the Na concentration in the ECF

- **Calculation of osmolarity (mmol/Kg):**
  - \( 2 \times \text{Na (mEq/L)} + \frac{\text{glucose (mg/L)}}{18} + \frac{\text{urea (mg/L)}}{2.5} \)
The Kidney and Osmolarity

- the kidney attempt to maintain osmolarity by increasing excretion of glucose and urea when their concentrations rise
- if not possible or sufficient it will increase excretion of Na
- maintaining normal osmolarity is more important than maintaining solute composition
- when concentration of solutes in any compartment changes → water moves to reestablish osmotic pressure
Maintenance of Fluid and Electrolyte Requirements

- Maintained by equilibrium between oral intake and evaporation from skin and lungs and renal excretion.
- Loss through the evaporation depends on body surface area and respiratory rate and remains constant.
- The kidney ↑ or ↓ output by the action of ADH and aldosterone.
Average daily intake of water

- Water of metabolism (250 mL or 10%)
- Water in moist food (750 mL or 30%)
- Water in beverages (1,500 mL or 60%)

Total intake (2,500 mL)

Average daily output of water

- Water lost in sweat (150 mL or 6%)
- Water lost in feces (150 mL or 6%)
- Water lost through skin and lungs (700 mL or 28%)
- Water lost in urine (1,500 mL or 60%)

Total output (2,500 mL)
Maintenance of Fluid and Electrolyte

ADH:
- Regulates water reabsorbed in the distal tubules according to osmolarity of ECF
- ↑ osmolarity → ADH ↑ water reabsorption
- ↓ osmolarity → ↓ water reabsorption
- ↑ vascular tone and lead vasoconstriction esp. of those leading to the kidney

Aldosterone
- ↑ Na reabsorption
- secretion stimulated by low blood volume and low total Na
- ADH, aldosterone, and thirst center work to maintain total body vol and Na within 1% of normal over wide variations in daily intake.
Regulation of Fluids:

- Renal sympathetic nerves
- Renin-angiotensin-aldosterone system
- Atrial natriuretic peptide (ANP)
Fluid Requirement

• The amount of water and electrolyte that is needed to replace insensible loss,, maintain adequate perfusion and result in urine output sufficient to excrete metabolic waste varies nonlinearly with changes in body size
  – The first 10 Kg → 100ml/kg
  – The second 10 kg → 50ml/kg
  – And each Kg beyond 20 kg requires 20 ml/kg
• Same formula used for children
• Use IBW for obese patients
• In fever, add extra 10% of calculated water for every 1°C elevation.
## FLUID REQUIREMENTS

<table>
<thead>
<tr>
<th>Sources</th>
<th>Losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>Urine</td>
</tr>
<tr>
<td>1500 ml</td>
<td>1500 ml</td>
</tr>
<tr>
<td>Food</td>
<td>Stool</td>
</tr>
<tr>
<td>800 ml</td>
<td>200 ml</td>
</tr>
<tr>
<td>Oxidation</td>
<td>Skin</td>
</tr>
<tr>
<td>300 ml</td>
<td>500 ml</td>
</tr>
<tr>
<td>Resp. Tract</td>
<td></td>
</tr>
<tr>
<td></td>
<td>400 ml</td>
</tr>
<tr>
<td>Total</td>
<td>Total</td>
</tr>
<tr>
<td>2600 ml</td>
<td>2600 ml</td>
</tr>
</tbody>
</table>
Electrolyte Requirements

- Varies because the kidney constantly adjusts secretion
- \(\uparrow\) or \(\downarrow\) Na excretion to maintain normal vascular volume and composition
- Reduce Na excretion to zero by increasing K and H excretion
- Amount of electrolyte needed to maintain normal homeostasis without stimulating the secretion of ADH and aldosterone is linearly related to water requirements
- Table 9.2
- Cations must be given with an equal number of anions to maintain electrical neutrality
How to determine daily fluid and electrolyte requirements

• Determine basal need or maintenance requirements
• Correct for existing disease or imbalance
• Adjust according to clinical condition
MAINTENANCE vs. REPLACEMENT

• Maintenance:
  – Provide normal daily requirements: Water: 2.5 L
    Sodium ½ or ¼ NS
    KCl 40-60 meq/L
• Example:
  D5 ½ NS with KCL 20 meq/L running at 100 ml/hr
MAINTENANCE vs. REPLACEMENT

• Replacement:
  – Replace abnormal losses with a fluid and electrolytes similar to that which was lost.
**Table 9.2 • Maintenance Needs per 24 Hours**

<table>
<thead>
<tr>
<th>Water</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0–10 kg</td>
<td>100 mL/kg</td>
</tr>
<tr>
<td>10–20 kg</td>
<td>50 mL/kg</td>
</tr>
<tr>
<td>&gt;20 kg</td>
<td>20 mL/kg</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Electrolytes</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Na</td>
<td>3 mmol (3 mEq)/100 mL H₂O need</td>
</tr>
<tr>
<td>K</td>
<td>2 mmol (2 mEq)/100 mL H₂O need</td>
</tr>
<tr>
<td>Cl</td>
<td>2 mmol (2 mEq)/100 mL H₂O need</td>
</tr>
<tr>
<td>Ca</td>
<td>0.05–0.1 mmol (0.1–0.2 mEq)/kg</td>
</tr>
<tr>
<td>Mg</td>
<td>0.05 mmol (0.1 mEq)/kg</td>
</tr>
<tr>
<td>PO₄</td>
<td>0.1 mmol (2.8 mg)/kg</td>
</tr>
</tbody>
</table>

*Use ideal body weight in obese patients.*
How to Evaluate Water and Electrolyte Balance

• Clinical findings:
  – **Central venous pressure**: Give accurate measure of changes in blood volume
  – **Pulse**:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>High pulse and not easily obliterated</td>
<td>Circulatory overload AAND ↑ CO due to excess fluid</td>
</tr>
<tr>
<td>Bonding, not easily obliterated</td>
<td>Drop in BP, impending circulatory collapse</td>
</tr>
<tr>
<td>Regular pulse, easily obliterated</td>
<td>Low CO due to low Blood Vol.</td>
</tr>
</tbody>
</table>
Diagnosis of Fluid and Electrolyte Disorders

- **Changes in body fluids:**
  - Volume overload $\rightarrow$ edema, heart failure, ↑ weight
  - Volume depletion: signs of dehydration

- **Changes in electrolytes**
  - May be asymptomatic or symptomatic depending on type and degree of abnormality
  - Diagnosis by serum levels
  - Avoid rapid correction
Disorders of Body Water and Solute

Sodium

• The osmotically active substance in the greatest concentration in the vascular and the interstitial compartment

• **Normal conc.** 135-145 mmol/L

• Hyponatremia and hypernatremia refer only to concentration

• Do not describe whether there is total ↑, ↓ or normal sodium in the body
DIABETES INSIPIDUS

• **Signs**
  - $[\text{Na}^+] \geq 150$
  - Urine specific gravity $1.007$
  - Polyuria, clear urine
  - dDAVP $1\mu g$ sq raises urine osmolality in 2 hours

• **Treatment**
  - Free water deficit $= (0.6) \times (\text{Kg}) \times ([\text{Na}_{\text{serum}}/140] - 1)$
  - dDAVP $2\mu g$ sq every 12 hours
  - For every L water deficit $[\text{Na}^+]$ will rise 3 mEq above 140
Hypernatremia

- ↑ sodium conc. due to free water deficit
- ↑ salt intake cannot cause ↑ in total body Na if renal function is adequate

**Symptoms**
- See table 3
- Important Sx do not appear until Na > 160
- Mainly due to CNS dehydration

**Treatment**
- Depends if the cause is to little water or to much Na
- Should not be rapid as not cause new CNS problems
- Equilibrium across BBB is slower and rapid changes can cause seizures
Hypernatremia from water loss

- There is ↓ in total body water from all fluid compartments
- ↑ interstitial and intravascular Na and ↑ intracellular K to produce equilibrium

Water deficit (L) = \{ \frac{1-140}{\text{measured serum Na (mmol/l)}} \}\ x \text{body weight (kg)} \times 0.6

- Use electrolyte free oral or IV solutions
- e.g. D5W given over 18-24 hrs
- In addition to calculated maintenance fluid and electrolyte
Hypernatremia

Hypernatremia from increase amount of Na treatment

• Removal of Na by
• Diuretics and D5W to ↑ renal elimination while maintaining total body
Severe Hyponatremia

- **Correct sodium to above 120 mEq/dl**
  - NaCl + 40 mEq/L KCl
  - 3% Saline
  - furosemide diuresis (euvolemic)
  - serial electrolytes
  - be prepared to handle seizures

- **Replace potassium**

- **Cl should correct itself**
Hyponatremia

• Na < 135
• Important symptoms do not appear until < 120
• See table 9.3
• Sx result from CNS water intoxication

Types
• Dilutional
• Depletion
• Factitious
Hyponatremia-Dilutional

- Total body sodium is ↑ but TBW is ↑ to a greater degree

**Causes:**
- cirrhosis
- CHF
- Effective cardiac output to kidney is diminished → ADH and aldosterone secretion → Na and water retention → edema due to increase size of interstitial compartment

**Treatment**
- Salt and water restriction
- Best rest to increase venous return to the heart
- Correction of the primary disorder
- Not diuretics: cause Na excretion that exceeds water elimination
# ELECTROLYTE DISORDERS

## Hypotonic Hyponatremia

<table>
<thead>
<tr>
<th>Increased ECV</th>
<th>Decreased ECV</th>
<th>Normal ECV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edematous states</td>
<td>Hypovolemic states</td>
<td>SIADH</td>
</tr>
<tr>
<td>CHF, Cirrhosis, Renal dz</td>
<td>Diuretic induced GI losses</td>
<td>Syndrome of inappropriate antidiuretic hormone</td>
</tr>
<tr>
<td>Excess of TB Na and water</td>
<td>Depletion of water and Na</td>
<td>Excess of water: dilutional</td>
</tr>
<tr>
<td>Treatment: Diuretics, Water &amp; Na restriction, CHF- cardiac glycosides</td>
<td>Water and Na replacement</td>
<td>Fluid restriction, Furosemide and NS, Chronic: Declomycin</td>
</tr>
</tbody>
</table>
Hyponatremia - Depletion

- True decrease in total body Na
- With or without water deficit
- Signs of dehydration: dry mucous membrane, skin tenting, and lethargy

**Causes:**
- GI loses: vomiting, diarrhea
- Excessive diuretics
- Adrenal insufficiency
- Replacement of losses form perspiration with solute free water

**Sodium deficit** = \( 140 - \text{measured serum Na(mmol/L)} \times \text{body weight (kg)} \times 0.6 \)
- Use 0.9% saline (155 mmol of Na) OR 3% saline (500 mmol Na)
- In addition to daily maintenance fluid and electrolyte
<table>
<thead>
<tr>
<th>Hypernatremia</th>
<th>Hyponatremia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serum level &gt; 147 mmol/L</td>
<td>Serum level &lt; 135 mmol/L</td>
</tr>
<tr>
<td>(147 mEq/L)</td>
<td>(135 mEq/L)</td>
</tr>
</tbody>
</table>

**Causes**

- Decreased water intake
- Fever
- Excessive salt intake
- Diabetes insipidus
- Hyperventilation
- Low-sodium diet with diuretics
- Diuretics
- Congestive heart failure
- Cirrhosis
- Replacement of body secretion loss with electrolyte-free solutions
- Adrenal insufficiency
- Osmotic diuresis
- Syndrome of inappropriate secretion of antidiuretic hormone
<table>
<thead>
<tr>
<th>Signs and Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thirst</td>
</tr>
<tr>
<td>Dry mucous membranes</td>
</tr>
<tr>
<td>Decreased skin turgor</td>
</tr>
<tr>
<td>Acute weight loss</td>
</tr>
<tr>
<td>Confusion</td>
</tr>
<tr>
<td>Hallucinations</td>
</tr>
<tr>
<td>Intracranial hemorrhage</td>
</tr>
<tr>
<td>Coma</td>
</tr>
<tr>
<td>Apathy or agitation</td>
</tr>
<tr>
<td>Fatigue</td>
</tr>
<tr>
<td>Anorexia or nausea</td>
</tr>
<tr>
<td>Headache</td>
</tr>
<tr>
<td>Muscle cramps</td>
</tr>
<tr>
<td>Tachycardia</td>
</tr>
<tr>
<td>Oliguria or anuria</td>
</tr>
<tr>
<td>Confusion</td>
</tr>
<tr>
<td>Seizures</td>
</tr>
<tr>
<td>Coma</td>
</tr>
<tr>
<td>Shock</td>
</tr>
</tbody>
</table>
Treatment of Hypernatremia

Water deficit (L) = [1 - (140/Measured Na)] × Weight (kg) × 0.6

Treatment of Hyponatremia

Dilution: Sodium and water restriction
Depletion: Sodium deficit (mmol) = (140 - Measured Na) × Weight (kg) × 0.6
Alteration in Fluid Compartment Integrity

**Causes**

- Trauma
- Tissue ischemia
- Endotoxemia
- Hypoalbuminemia
- Decreased cardiac output
Alteration in Fluid Compartment Integrity

Mechanism

• **Damage of the capillary membranes**
  – capillary leak syndrome: increase in capillary pore size
  – water, solutes, proteins flow into interstitial space (third space)
  – the leak can be localized to area of injury as in surgery to trauma or generalized as in septic shock

• **Distruption of the hydrostatic & oncotic pressure**
  – the amount of fluid lost varies with degree of injury
  – can cause severe hypovolemia that causes CV collapse and death
## Signs of hypo / hypervolaemia:

<table>
<thead>
<tr>
<th>Volume depletion</th>
<th>Volume overload</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postural hypotension</td>
<td>hypertension</td>
</tr>
<tr>
<td>Tachycardia</td>
<td>tachycardia</td>
</tr>
<tr>
<td>Absence of JVP @ 45°</td>
<td>Raised JVP</td>
</tr>
<tr>
<td>Decreased skin turgor</td>
<td>Oedema</td>
</tr>
<tr>
<td>Dry mucosa</td>
<td>Pleural effusions</td>
</tr>
<tr>
<td>Supine hypotension</td>
<td>Pulmonary oedema</td>
</tr>
<tr>
<td>Oliguria</td>
<td>Ascites</td>
</tr>
<tr>
<td>Organ failure</td>
<td>Organ failure</td>
</tr>
</tbody>
</table>
I- Hypovolemia

**Symptoms**

- Tachycardia
- Low central venous pressure
- Low pulmonary wedge pressure
- Decrease urine output
- BP is not a good measure because increase sympathetic tone can maintain normal BP

**Treatment**

- Correcting the underlying disorder
- Replacement of lost intravascular fluids with solution of same composition
- No Blood because blood elements are not lost
Parenteral Fluid Therapy:

- **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 intravascularly, inadequate for fluid resuscitation
Colloid Solutions:

- Contain high molecular weight substances → do not readily migrate across capillary walls
- Preparations
  - Albumin: 5%, 25%
  - Dextran
  - Gelifundol
  - Haes-steril 10%
Use of colloid is controversial because:
- only small amounts of protein move into 3rd space
- temporarily decrease the fluid migration rate into the third space
- may exacerbate hypovolemia after 24-36 hrs when it moves to third space itself

Uses of colloids
- albumin levels are low 20-25 g/L
- aggressive crystalloid therapy is not restoring intravascular volume

Rate fluid administration in hypovolemia
- must meet/exceed the rate of loss to maintain tissue perfusion
- urine output must al least 0.5 cc/kg/hr

Monitoring parameters:
- heart rate
- CVP
- Urine output
II- hypoalbuminemia

Result in hypovolemia with edema

Mechanism

• No capillary leak
• Low oncotic pressure moves fluid to the interstitial space

Treatment:

• Albumin or hetstarch to normalize oncotic pressure and resolve edema
III- hypovolemia due to decreased cardiac output

Causes:

- CHF
- Cardiomyopathy
- MI

- Cannot be corrected using fluids
- Hypovolemia on arterial side due pump failure
- The venous side is overloaded
- Patient may have edema

Treatment

- Drugs that improve cardiac output (inotropics)
IV- hypovolemia from blood loss

Use whole blood or packed red blood cells with normal saline or lactate ringer to raise HCT to 25% and normal circulating volume
**Major electrolytes**

- **Na, Cl, K, bicarbonate, ca, Mg, Po4**
- **Cl** is the major anion in the ECF and has no physiological function
- **K, Ca, Mg**
  - maintain membrane potential for nerve conduction and muscle contraction
  - generate the energy needed to maintain these potentials
  - do the work of body functions and movement
- **Po4**
  - the main reservoir is ICF and bone
- serum levels fall slowly when intake is low
- numerous hormonal and homeostatic mechanism exist to keep serum levels within normal range
- serum levels is low in relation to intracellular concentration
- concentration in the serum controls physiological activities
Potassium

- Amount in vascular space = 0.4% of total body K
- NL = 3.5-5 mmol/L (Serum levels are usually indicative of amount in body)

**Route of excretion:**
- Elimination by the kidney
- Can be increased when intake is high
- Kidney cannot conserve K

**Changes in acid-base balance alter location of K**

**Acidosis;**
- K exchanges for H as an attempt to hide and buffer protons in ICF

**Alkalosis**
- The opposite occurs

Serum K will rise or fall by 0.6 mmol/L for every 0.1 change in PH from 7.4
Metabolic Alkalosis and Hypokalemia

Intracellular Fluid

Extracellular Fluid

H⁺

K⁺
Metabolic Acidosis and Hyperkalemia

Intracellular Fluid

K+

Extracellular Fluid

H+
Diagnosis?

HYPERKALEMIA

**Treatment**
- $\text{CaCl}_2$ 10% - 1 ampule
- Sodium Bicarbonate - 1 ampule
- $D_{50}$ & Insulin 10 U
- $\beta_2$ - agonist nebulizer- cellular K↑
- Kayexalate®
Hyperkalemia

- True medical emergency
- Manifests as sudden cardiac arrhythmia $K > 6$
- See table
- TBK can be high, low or normal
1. Decreased Renal Excretion

Hyperkalemia: Causes

CRF and ARF

Drug induced:

- K-sparing diuretics (spironolactone, triamterine, amiloride)
- Angiotensin converting enzyme inhibitors
- NSAIDS
Hyperkalemia: Causes

2. Redistribution
   Trauma, burns
   Acidosis
   Hyperosmolar states

3. Increased intake
   Salt substitutes
   Blood transfusions
   K salts of antibiotics
Hyperkalemia Treatment

• Discontinue any exogenous sources such as Iv fluids or drugs
• **Correct by**
  – normalizing neuromuscular membrane potential
  – shifting ions back into intracellular space
  – removing K from the body
    • should be initiated as soon as possible because they act slowly
    • they will not correct cardiac arrhythmia in timely fashion
    • not acute treatment
Diarrhea
Dysrhythmia

• 68 yo female on digoxin for chronic CHF, presents to the SIU for colitis as evidenced by copious diarrhea.

• The patient is weak and lethargic and ectopic beats are noted on her ECG.
Hypokalemia

- replacement 10 mEq/hr via peripheral IV
- 10 mEq $\alpha$ 0.1 mEq/L increase in serum K
- Remember to check the Mg level too
Hypokalemia

- Can be a cardiac emergency if < 3
- Can exhibit ms weakness and malaise before ECG changes appear
- See table 9.9
Hypokalemia: Causes

1. Decreased dietary intake
2. Redistribution
   Insulin
   Metabolic Alkalosis
   Dehydration
Hypokalemia: Causes

3. Increased Urinary or GI Losses
   - Diuretics
   - NG Suction
   - Diarrhea
Hypokalemia: Causes

4. Drugs
   a. **Urinary wasting**: aminoglycosides, amphotericin B, corticosteroids, diuretics, levodopa, nifedipine, penicillins, rifampin
   b. **Gastrointestinal losses**: laxatives
   c. **Redistribution**: Beta-2 agonists, lithium
Treatment

• Correction of underlying disease or discontinuation of drug therapy contributing to hypokalemia.

• Intracellular deficit almost always accompanied hypokalemia

• Large amount may need to be given before TBK and serum K normalize

• Oral or IV shift slowly to ICF so rate of administration must be slow to prevent hyperkalemia.
Hypokalemia:
Treatment/Estimation of Deficit

If serum K > 3 meq/L:
100-200 meq required per each change in serum K of 1 meq/L

If serum K < 3 meq/L:
200-400 meq required per each change in serum K of 1 meq/L
Hypokalemia: Treatment/Estimation of Deficit

Example: Serum K = 2.5  How much K is required to correct serum K to 4.0?

Step 1
To increase from 2.5 to 3.0: 200-400 meq X 0.5=100-200meq

Step 2
To increase from 3.0 to 4.0: 100-200 meq X 1.0=100-200meq

Total=200-400meq
Hypokalemia

**IV Replacement:**

- Ideal IV rate 10 mmol/hr KCL
- >10 can cause pain and phelephitis at the IV site
- **dose:** 30-40 mmol in D5W over 3-4 hrs
- serum K is checked after 1-2 hr
- patients with severe hypokalemia and continued K wasting require large doses
- may need 20-50 mmol/hr using a central line to avoid phlebitis
Hypokalemia

**Oral replacement:**

- KCL cause GI irritation and vomiting when given > 20 mmol/dose or 60 mmol/day
- Bad taste
- Large deficits cannot be replaced by mouth
Hypokalemia

**hypokalemia secondary to hyponatremia**

- always accompanied by hypochloremic alkalosis
- renal conservation of Na causes secretion of K and H
- for every 3 mmol Na reabsorbed 2 mmol K and 1 mmol H are excreted

**TX**

- Correction of hypoantremia and alkalosis with hypokalemia
- KCL is TOC
- Cl loading will lead to excretion of bicarbonate and resolution of alkalosis
Chloride

- Major anion in ECF
- Has no physiological function
- Goes up and down with TBNa
- Changes cause acid-base disturbances; because electrical neutrality must be maintained and so serum HCO3 will change
- In acidosis or alkalosis changes in CL should not be corrected by giving or restricting Cl
- Until the cause of acid-base disorder is corrected
- CL levels may normalize naturally
Hyperchloremia

- **CL > 105 mmol/L**

**Causes:**
- Metabolic acidosis or respiratory alkalosis
- Hypernatremia
- Chloride loading

**Treatment**
- Correct underlying disorder

<table>
<thead>
<tr>
<th>Cause</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metabolic acidosis or respiratory alkalosis</td>
<td>Correct the disturbance</td>
</tr>
<tr>
<td>Chloride loading</td>
<td>Adjust IV fluid&lt;br&gt;Use acetate salts instead of chloride salts&lt;br&gt;Change NS to lactate ringer or ½ NS</td>
</tr>
<tr>
<td>Hypernatremia due to over ingestion of NaCl</td>
<td>Free water replacement and diuresis</td>
</tr>
<tr>
<td>Hypernatremia due to water loss</td>
<td>Electrolyte free water replacement</td>
</tr>
</tbody>
</table>
Hypochloremia:

- CL < 95 mmol/L

**Causes:**
- chloride loss through vomiting or diarrhea
- nasogastric suction
- diuretic therapy
- hyponatremia: compensatory mechanism to maintain electrical neutrality in ECF

<table>
<thead>
<tr>
<th>Cause</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nasogastric suction or vomiting</td>
<td>Replacement of the volume lost with high chloride containing solutions e.g. NS or lactated ringer</td>
</tr>
<tr>
<td>Loss of large amounts of Cl and acid</td>
<td></td>
</tr>
<tr>
<td>diuretics</td>
<td>increasing NaCl intake</td>
</tr>
<tr>
<td></td>
<td>reducing diuretic dose</td>
</tr>
<tr>
<td>hyponatremia and hypokalemia</td>
<td>saline and KCl</td>
</tr>
</tbody>
</table>
Calcium

• Stored in the bone
• Only 1% of body Ca is in fluid spaces
• NI = 2.2-2.6 mmol/L
• 50% is bound to albumin and other protein
• the other 50% is the free active form
• serum levels do not change with daily intake and excretion
• serum levels are controlled by parathyroid hormone, vit D and calcitonin
• through regulation of GI absorption, renal excretion, skeletal deposition or resorption.
• there is an inverse relationship with Po4
Calcium

Relation to albumin

• low serum albumin will result in low Ca lab values
• does not mean low ionized Ca
• each 10-gm/L change in albumin will change Ca by 0.2 mmol/l in the same direction
Calcium

Relation to acid-base imbalances

- acidosis → more H are bound to albumin as an attempt to buffer → displacement of Ca ions from binding sites → increase free calcium
- the opposite is true for alkalosis
- for each 0.1 change in PH → ionized Ca changes by 0.42 mmol/L in the opposite direction
HYPERCALCEMIA

- Cancers associated with hypercalcemia
  - bone
  - breast
  - kidney
  - colon
  - thyroid
  - multiple melanoma

- Treatment
  - hydration
  - diuretics-lasix
  - mithramycin
  - corticosteroids
  - calcitonin-osteoclast resorption
  - phosphate
Hypercalcemia

• corrected total Ca > 2.6 mmol/L or ionized ca > 1.15 mmol/L

Clinical manifestations

• see table 9.10
• mental changes do not correlate with degree of hypercalcemia
Hypercalcemia

Serum level >
  2.6 mmol/L (total, corrected)
      (10.3 mg/dL)
  1.2 mmol/L (ionized)
      (2.3 mEq/L)

Bone neoplasms
Hyperparathyroidism
Hypervitaminosis D
Prolonged immobilization
Sarcoidosis
Paget’s disease
Acidosis
Idiopathic hypercalcemia
Alkalosis of infancy
Hypervitaminosis A
Aluminum osteodystrophy
General Measures

• Managing hypercalcemia will be directed at reducing bone resorption and increasing urinary excretion of calcium.
• Avoid immobilization
• Stop drugs which inhibit urinary calcium excretion e.g thiazides
Hospital based Management

• 1. For ALL patients
• Intravenous fluids: Isotonic saline (0.9% NaCl) @ 300-400 ml/hr
For hypercalcemia ≥ 4 mmol/L

- IM/SC Calcitonin: 4-8 IU/kg q 6h x 2d
- PLUS
- IV Pamidronate (started concurrently with calcitonin): 90 mg in 250 mL NS over 1 hour
- OR
- IV Zoledronic acid (started concurrently with calcitonin): 4 mg in 100 mL NS over 15 minutes
For hypercalcemia ≥ 3.5 mmol/L

• IV Pamidronate: 90 mg in 250 ml NS over 1 hour
• OR
• IV Zoledronic acid: 4 mg in 100 ml NS over 15 minutes
For hypercalcemia < 3.5 mmol/L with symptoms

• IV Clodronate 1500 mg in 500 ml NS over 4 hours, with observation over 48 hours; if no response then use Pamidronate or Zoledronic acid as above

• OR

• IV Pamidronate 60-90 mg in 250 ml NS over 1 hour

• OR

• 4.3. IV Zoledronic acid 4 mg in 100 ml NS over 15 minutes
For hypercalcemia unresponsive to other measures

- IV Mithramycin (Plicamycin) 25 μg/kg repeat in 48 hours if no response; 12.5 μg/kg if pre-existing renal or hepatic dysfunction
HYPOCALCEMIA

• Chvostek’s sign - facial muscle spasm
• Trousseau’s sign - carpal spasm
• Treatment
  – monitor ECG
  – IV calcium
  – follow up labs
  – oral calcium supplements
    • normal is 1 gram/day
Hyperphosphatemia

• Causes
  1. Renal impairment
  2. Increased intake

• Treatment
  Phosphate binders: Alternagel, Amphojel, Calcium Supplements
<table>
<thead>
<tr>
<th>Component</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium</td>
<td>135-145 meq/L</td>
</tr>
<tr>
<td>Potassium</td>
<td>3.5-5.0 meq/L</td>
</tr>
<tr>
<td>Chloride</td>
<td>95-105 meq/L</td>
</tr>
<tr>
<td>Bicarbonate</td>
<td>22-28 meq/L</td>
</tr>
<tr>
<td>Calcium</td>
<td>9-11 mg/dL</td>
</tr>
<tr>
<td>Phosphate</td>
<td>3.2-4.3 mg/dL</td>
</tr>
<tr>
<td>Glucose</td>
<td>70-110 mg/dL</td>
</tr>
<tr>
<td>BUN</td>
<td>8-18 mg/dL</td>
</tr>
<tr>
<td>Creatinine</td>
<td>0.6-1.2 mg/dL</td>
</tr>
<tr>
<td>Osmolality (P)</td>
<td>280-295 mOsm/kg</td>
</tr>
<tr>
<td>Osmolality (U)</td>
<td>50-1200 mOsm/kg</td>
</tr>
</tbody>
</table>
• THANK YOU