

## Electrolytes disorders

Electrolytes	Normal Values
Na	135-145 mEq/L
K	3.5-5.0 mEq/L
Mg	1.4-1.8 mEq/L
Ca	8.5-10.5 mEq/L
PO4	2.6-4.5 mEq/L

### **HYPONATREMIA**

- Normal Na<sup>+</sup>: 135-145 mEq/L
- Na<sup>+</sup> determines the tonicity of the extracellular fluid and the distribution of water between extracellular cell and intracellular cell compartments
- Na<sup>+</sup> imbalance is common in ICU patients

**Na<sup>+</sup> deficit (meq)=TBW x (140- Na<sup>+</sup>)**

- **Hyponatremia** (Na<sup>+</sup> <135 mEq/L ), ↑ morbidity and mortality

#### **Signs and symptoms**

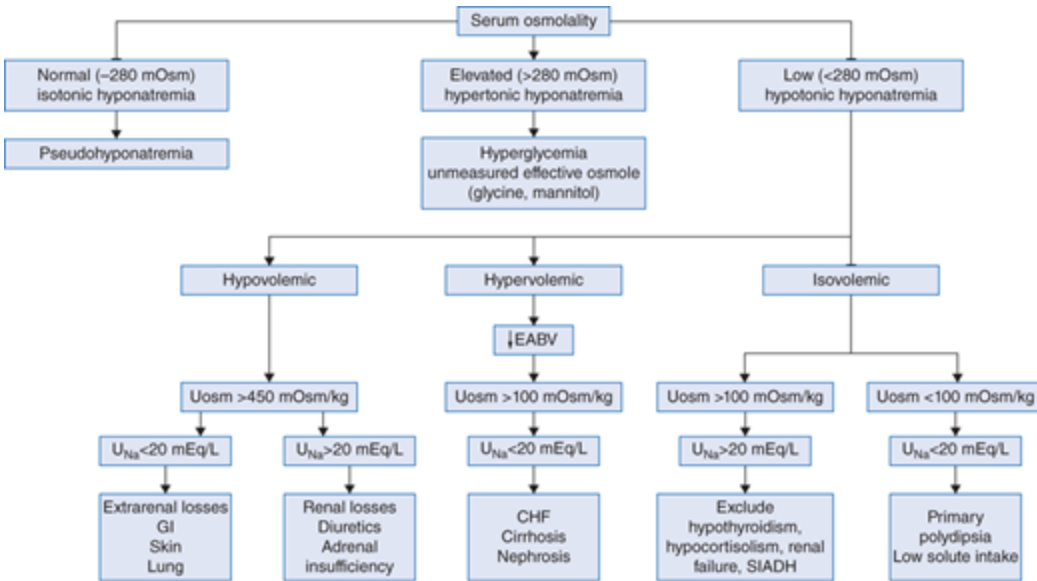
When Na<sup>+</sup> <125 mEq/L

**Acute:** cerebral edema, seizures, increased mortality risk

**Chronic:** N/V, confusion, personality changes, neurologic dysfunction, seizures

Serum sodium	Clinical manifestations
120-125	Nausea, malaise
115-120	Headache, Lethargy, obtundation, unsteadiness, confusion
< 115	Delirium, seizures, coma, respiratory arrest, death

Causes or contributing factors of hyponatremia



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## Medications that cause hyponatremia

### *Hypovolemic*

-↑ Diuretics: Thiazides diuretics, Osmotic diuretics (glucose, mannitol)

### *Isovolemic*

- Antipsychotic (haloperidol) - Antineoplastic agents
- Carbamazepine
- NSAIDs
- Opiates
- SSRI (fluoxetine) - TCA

## Treatment of hyponatremia

Types of hyponatremia	Causes	Treatment
Hypotonic hypervolemic	Fluid overload (cirrhosis, HF, renal failure...)	<ul style="list-style-type: none"> <li>● Sodium Chloride IV</li> <li>● AVP receptor antagonist</li> </ul>
Hypotonic isovolemic	SIADH	<ul style="list-style-type: none"> <li>● Diuresis and fluid restriction</li> <li>● AVP receptor antagonist</li> <li>● Stop drug that induce SIADH</li> </ul>

		<ul style="list-style-type: none"> <li>• Demeclocycline (off label)</li> </ul>
Hypotonic hypovolemic	Diuretics, salt-wasting syndromes, adrenal insufficiency blood loss or vomiting/ diarrhea	<ul style="list-style-type: none"> <li>• Underlying cause</li> <li>• Stop hypotonic solutions</li> <li>• 3% sodium chloride for severe symptoms and Na &lt; 120 mEq/L</li> </ul>

#### IV replacement therapy

Solution	Dextrose (g/100mL)	[Na <sup>+</sup> ] (mEq/L)	[Cl <sup>-</sup> ] (mEq/L)	Tonicity	Distribution		Free Water/L
					% ECF	% ICF	
D5W	5	0	0	Hypotonic	40	60	1000 mL
0.45% Sodium chloride	0	77	77	Hypotonic	73	37	500 mL
0.9% Sodium chloride	0	154	154	Isotonic	100	0	0 mL
3% Sodium chloride	0	513	513	Hypertonic	100	0	-2331 mL

#### Arginine Vasopressin Receptor Antagonist

Drug	Dose	Safety/ Monitoring
Conivaptan (Vaprisol) Injection	<p>LD: 20 mg IV over 30 minutes</p> <p>MD: 20 mg continuous IV infusion over 24 hours; can increase to 40 mg IV daily Na does not increase at desired rate; do not use &gt; 4 days</p> <p>CrCl &lt; 30 ml/min: avoid</p> <p>Decrease dose in moderate and</p>	<p><b>CONTRAINDICATIONS</b></p> <p>Hypovolemic hyponatremia, concurrent use with strong CYP450 3A4 inhibitors, anuria</p> <p><b>WARNING</b></p> <p>Overly rapid correction of hyponatremia (&gt; 12 mEq/L/24 hours) is associated with ODS (life-threatening)</p> <p><b>SIDE EFFECTS</b></p>

	severe hepatic impairment	<p>Orthostatic hypotension, fever, hypokalemia, infusion site reactions (&gt; 60%)</p> <p><b>MONITORING</b></p> <p>Rate of Na increase, BP, volume status, urine output</p>
<p><b>Tolvaptan (Samsco)</b></p> <p>Tablet</p> <p>Selective AVP antagonist [vasopressin 2 (V2) only]</p>	<p>15 mg PO daily;</p> <p>max 60 mg PO daily; limited to ~ 30 days due to hepatotoxicity</p> <p>CrCl &lt; 10 ml/min: avoid</p> <p>Avoid fluid restriction in first 24 hours of therapy</p>	<p><b>BOXED WARNINGS</b></p> <p>Should be initiated and re-initiated in a hospital under close monitoring of serum Na</p> <p>Overly rapid correction of hyponatremia (&gt; 12 mEq/L/24 hours) is associated with ODS (life-threatening); consider slower correction with severe malnutrition, alcoholism or advanced liver disease</p> <p><b>CONTRAINDICATIONS</b></p> <p>Patients who are unable to sense or respond appropriately to thirst, urgent need to raise Na, hypovolemic hyponatremia, use with strong CYP3A4 inhibitors, anuria</p> <p><b>WARNINGS</b></p> <p>Hepatotoxicity (avoid use &gt; 30 days and in liver disease/cirrhosis)</p> <p><b>SIDE EFFECTS</b></p> <p>Thirst, nausea, dry mouth, polyuria, weakness, hyperglycemia, hypernatremia</p> <p><b>MONITORING</b></p> <p>Rate of Na increase, BP, volume status, urine output, signs of drug-induced hepatotoxicity</p>

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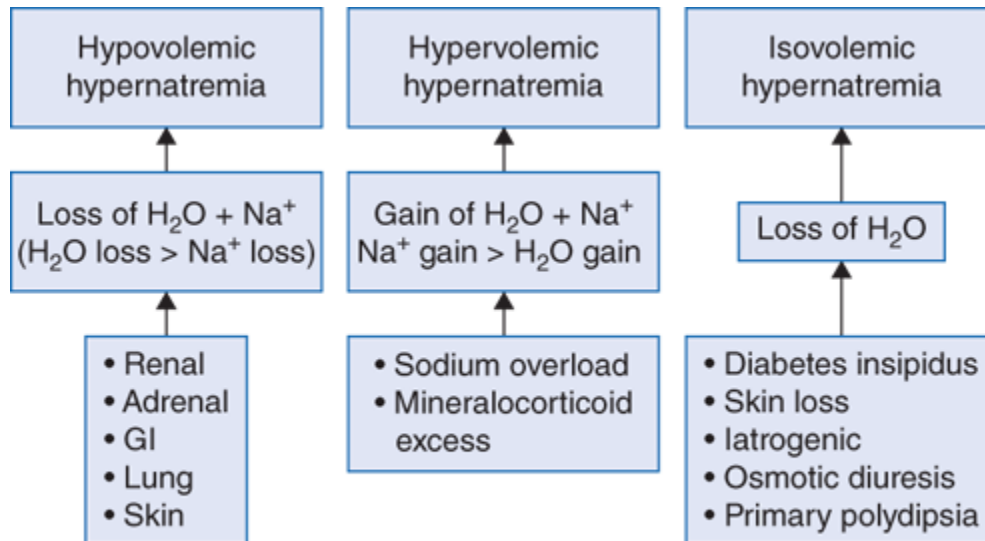
## Hypernatremia

- ( $\text{Na}^+ > 145 \text{ mEq/dL}$ ),  $\uparrow$  morbidity if  $\text{Na}^+ > 160 \text{ mEq/dL}$
- Hypertonic state resulting in **cellular dehydration**

**Signs and symptoms:** thirst, dry mucous membranes, weight loss, weakness, irritability, confusion, hallucinations, ICH, coma, seizures, death

**Treatment** depends on cause: too little water or too much  $\text{Na}^+$

Types of hypernatremia	Causes	Treatment
Hypertonic hypervolemic	Intake of hypertonic fluids	<ul style="list-style-type: none"> <li>• Diuresis</li> </ul>
Hypertonic isovolemic	Diabetic insipidus (decrease antidiuretic hormone)	<ul style="list-style-type: none"> <li>• Demopressin</li> </ul>
Hypertonic hypovolemic	Dehydration (Vomiting, diarrhea)	<ul style="list-style-type: none"> <li>• Fluid</li> </ul>



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## **Hypokalemia:**

**Classification:** mild (3-3.5 mEq/L), moderate (2.5-3 mEq/L), or severe (<2.5 mEq/L)

**Causes:** B-agonists, loop & thiazide diuretics, sorbitol, insulin overdose, aminoglycosides, amphotericin B, cisplatin, licorice, diarrhea, laxatives, hyperaldosteronism

**Signs/symptoms:** muscle cramps, weakness, arrhythmias, myalgias, ECG changes

### **Treatment:**

Food sources are often insufficient for replacement potassium chloride salts are most effective, potassium phosphate if there is hypophosphatemia and potassium sulfate in hypomagnesemia. Bicarbonate is useful for hypokalemia with concomitant metabolic acidosis.

IV potassium can be used in patients with severe deficiency, those exhibiting severe symptoms such as ECG changes, or patients unable to tolerate oral supplements. IV therapy is more likely to cause hyperkalemia and may cause damage to the veins and infusion site pain. Typically, 10 to 20 mEq of potassium is diluted in at least 100 mL of 0.9% sodium chloride and administered through a peripheral vein over 1 hour. Larger amounts can be diluted in larger total volumes and infused at a rate not exceeding 40 mEq/h for severe hypokalemia. For IV infusion rates exceeding 10 mEq/h, ECG monitoring is recommended.

Potassium-sparing diuretics such as spironolactone, triamterene, and amiloride are alternatives to oral supplements.

## **Hyperkalemia:**

**Classifications:** Mild (5-5.6 mEq/L), moderate (6.1-6.9 mEq/L), or severe (>7 mEq/L)

**Causes:** Spironolactone, amiloride, triamterene, renal insufficiency, heparin, ACE & ARBs

**Signs/symptoms:** palpitations, arrhythmias, asystole

**\*\*Occurs in patients with renal disease\*\***

## Treatment

Therapy	Dose	Route	Onset /Duration	Monitoring	Physiologic effect
Albuterol	10-20 mg	Inhalation	30 min/1-2h	palpitations/ HR	Increases intracellular K <sup>+</sup> intake
Calcium	1 g	IV	1-2 min/10-30 min	ECG, Ca <sup>+</sup> level	Increases cardiac membrane potential
Furosemide	20-40 mg	IV	5-15 min/4-6h	Urine output	Increases renal K <sup>+</sup> elimination
Insulin	5-10 U	IV	30 min/2-6h	Blood glucose	Increases intracellular K <sup>+</sup> uptake
Dextrose	25 g	IV	30 min/2-6h	Blood glucose	Increases intracellular uptake following insulin release
Sodium bicarbonate	50-100 mEq	IV	30 min/2-6h	Volume status, pH	Increases intracellular K <sup>+</sup> concentration
Hemodialysis	4h		immediate	Volume status	Increases K <sup>+</sup> elimination

**Magnesium:** Normal level 1.4 – 1.8 mEq/L

**Hypermagnesemia:**

**Symptoms:** Flushing, muscle weakness, lethargy, bradycardia, decreased respiration, hypotension, Diminished deep tendon reflexes

**Causes:**

- Renal insufficiency/failure
- Adrenal insufficiency
- Excessive use of antacids containing magnesium

**Treatment:**

Discontinue magnesium therapy, Loop or Thiazide Diuretics, NS, Dialysis

**Hypomagnesemia:**

**Symptoms:** confusion, Increased deep tendon reflexes, tachycardia, insomnia, neuromuscular irritability, seizure, muscle cramps, tremor

**Causes:** malnutrition, malabsorption, chronic alcoholism, urinary losses, vomiting diarrhea, medication

**Treatment:**

If Mg < 1mEq/L with life threatening symptoms (seizure or arrhythmias) – IV magnesium sulfate.

If Mg < 1mEq/L without life threatening symptoms – IV or IM formulation of magnesium replacement

If Mg > 1mEq/L – Oral magnesium oxide

Potassium sparing diuretics such as amiloride, triamterene – reduce renally magnesium excretion

**Calcium:** Normal 8.5 – 10.5 mg/dl

**Hypercalcemia:**

**Symptoms:** Bone pain, arrhythmias, cardiac arrest, kidney stones, muscle weakness, excessive urination



**Causes:** Calcium supplementation, Hyperparathyroidism, immobilization, multiple myeloma, milk alkali syndrome, medication ex. Lithium, vit D, parathyroid hyperplasia or adenoma, alcohol, neoplasm (breast cancer, lung cancer), volume depletion

**Treatment:**

NS, calcitonin IM/SQ, bisphosphonates (IV zoledronic acid, pamidronate), dialysis

**Hypocalcemia:**

**Symptoms:** convulsions, arrhythmia, tetany, stridor and spasm

**Causes:** Decreased PTH and vit D, hypoparathyroidism, renal failure, pancreatitis, inadequate intestinal absorption, deposition of ionized calcium into bone or soft tissue, blood administration.

**Treatment:** calcium, Vit D

**Phosphorus:** Normal level 2.6 – 4.5 mg/dl

**Hyperphosphatemia:**

**Symptoms:** muscle cramps, tetany, numbness, tingling, bone and joint pain

**Causes:** Hypoparathyroidism, Vit D toxicity, Bisphosphonates

**Treatment:**

Low potassium diet

Phosphate binders:

- Aluminium based
- Calcium based
- Aluminium and calcium free based

**Hypophosphatemia:**

**Symptoms:** Muscle weakness, respiratory failure

**Causes:** Increased insulin secretion, Hyperparathyroidism, acute respiratory alkalosis, Vit D deficiency, chronic alcohol, phosphate binders

### **Treatment:**

- Sodium phosphate IV/Oral, Potassium phosphate oral
- If the serum phosphate concentration is greater than or equal to 1.25 mg/dL (0.40 mmol/L), we give 0.08 to 0.24 mmol/kg over six hours (up to a maximum total dose of 30 mmol)
- If the serum phosphate concentration is less than 1.25 mg/dL (0.40 mmol/L), we give 0.25 to 0.50 mmol/kg over 8 to 12 hours (up to a maximum total dose of 80 mmol)
- Dipyridamole (75mg 4 times daily): increase renal phosphate reabsorption.