# Chapter 17
# Electrolyte Disturbances

**Tricia B. Swan and Carmen J. Martinez**

**Abstract** This electrolyte disturbances chapter is full of important pearls to the identification and treatment of hyponatremia, hypernatremia, hypokalemia, hyperkalemia, hypokalemia, and hypoglycemia. The tables are a vital tool to help identify the etiology of the patient's electrolyte abnormality. Treatments are concise and bulleted for quick reference and action.

## Hyponatremia ($Na^+$ < 135 mEq/L)

### *Signs/Symptoms*

- Altered mental status
- Lethargy
- Seizures
- Coma
- Decreased tendon reflexes
- Hypothermia
- Respiratory distress or respiratory failure, Cheyne-stokes respirations
- Anorexia
- Nausea, vomiting
- Muscle cramps
- Weakness
- Agitation
- Headaches

T. B. Swan (✉)
Division of Pediatric Emergency Medicine, University of Florida, Gainesville, FL, USA
e-mail: tfalgiani@ufl.edu

C. J. Martinez
Division of Pediatric Emergency Medicine, Department of Emergency Medicine, USA Health Children's and Women's Hospital, University of South Alabama, Mobile, AL, USA
e-mail: cmartinez@health.southalabama.edu



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| Type | Etiology | Notable laboratory findings | Treatment |
|---|---|---|---|
| Pseudohyponatremia | Hyperlipidemia ($Na^+$ decreased by 0.002 × lipid mg/dL)<br>Hyperproteinemia ($Na^+$ decreased by 0.25 × [protein g/dL-8]) | Normal serum osmolality | Treat underlying cause |
| Pseudohyponatremia | Hyperglycemia ($Na^+$ decreased by 1.6 mEq/L for each 100 mg/dL rise in glucose over 100)<br>Mannitol infusion | High serum osmolality | Treat underlying cause |
| Renal loss | Diuretics<br>Adrenal insufficiency<br>$Na^+$-losing nephropathy<br>Obstructive uropathy<br>Renal tubular acidosis<br>Cerebral salt wasting | Decreased weight<br>↑ Urine volume<br>↑ Urine $Na^+$<br>↓ Urine osmolality<br>↓ Urine specific gravity | Treat underlying cause<br>Replace losses |
| Extrarenal loss | GI losses (diarrhea, vomiting)<br>Skin losses<br>Cystic fibrosis<br>Third spacing (ascites, burns, pancreatitis, etc.) | Decreased weight<br>↓ Urine volume<br>↓ Urine $Na^+$<br>↑ Urine osmolality<br>↑ Urine specific gravity | Treat underlying cause<br>Replace losses |
| Other | SIADH<br>Congestive heart failure<br>Nephrotic syndrome<br>Acute or chronic renal failure<br>Water intoxication<br>Improper formula mixing<br>Cirrhosis<br>Hypothyroidism | Increased or normal weight<br>↓ Urine volume<br>↓ Urine $Na^+$<br>↑ Urine osmolality<br>↑ Urine specific gravity | Treat underlying cause<br>Restrict fluids/free water |

## Emergent Management for Hyponatremia

- Treat symptomatic hyponatremia (seizures, coma, etc.) with IV hypertonic saline:
  - Give 4–6 mL/kg of 3% NaCl.
  - Each mL/kg of 3% NaCl will increase the serum $Na^+$ by approximately 1 mEq/L.
  - Do not increase the serum $Na^+$ to more than 130 mEq/L acutely.
- Rapid correction of hyponatremia can cause central pontine myelinolysis:
  - Avoid increasing the serum $Na^+$ more than 12 mEq/L every 24 h.
- Treat asymptomatic hyponatremia with identification of underlying cause and then disease-specific treatment such as fluid and sodium replacement, water restriction, hormone replacement, or dialysis.

## Hypernatremia ($Na^+$ > 145 mEq/L)

### *Signs/Symptoms*

- Altered mental status
- Lethargy
- Seizures
- Coma
- Decreased tendon reflexes
- Hyperthermia
- Respiratory distress or respiratory failure
- Nausea, vomiting
- Muscle cramps
- Weakness
- Irritability
- Headaches

| Type | Etiology | Notable laboratory findings | Treatment |
|---|---|---|---|
| Renal loss | Diuretics<br>Diabetes insipidus<br>Nephropathy<br>Post-obstructive diuresis<br>Acute tubular necrosis (diuretic phase) | Decreased weight<br>↑ Urine volume<br>↑ Urine $Na^+$<br>↓ urine specific gravity | Treat underlying cause<br>Replace free water loss |
| Extrarenal loss | GI losses (diarrhea, vomiting)<br>Skin losses<br>Respiratory loss of free water<br>Insensible losses (premature infant, radiant warmers, phototherapy) | Decreased weight<br>↓ Urine volume<br>↓ Urine $Na^+$<br>↑ Urine specific gravity | Treat underlying cause<br>Replace free water loss |
| Other | Mineralocorticoid excess<br>Hyperaldosteronism<br>Exogenous $Na^+$ intake<br>Improper formula mixing<br>Administration of sodium containing medications or fluids (sodium bicarbonate, hypertonic saline)<br>Seawater ingestion<br>Inadequate oral intake (ineffective breastfeeding, child abuse/neglect, etc.) | Increased weight<br>↓ Urine volume<br>↓ Urine $Na^+$<br>↑ urine osmolality<br>↑ Urine specific gravity | Treat underlying cause<br>Replace free water loss<br>Stop exogenous intake or administration of sodium containing medications or fluids |

## Emergent Management for Hypernatremia

- Identify and treat underlying cause.
- Stop exogenous administration of any sodium containing fluids/medications.
- For patients with shock or severe dehydration, volume expansion with isotonic saline is recommended **regardless** of serum $Na^+$.
- Hypernatremia should not be corrected rapidly:
  Serum $Na^+$ should not be lowered more than 10–12 mEq/L per 24 h.

## Hypokalemia (K < 3.5 mEq/L)

### *Signs/Symptoms*

- Muscle weakness
- Muscle cramps
- Paralysis
- Ileus/constipation
- Areflexia
- Arrhythmias
- Respiratory distress
- Urinary retention

*ECG changes:* flattened or absent T wave, ST segment depression, presence of a U wave between T wave and P wave, ventricular fibrillation, Torsades de Pointes.

| Etiologies | |
|---|---|
| Decreased intake | Anorexia nervosa<br>Poor diet (rare) |
| Transcellular shift | Alkalosis<br>Insulin therapy<br>Albuterol therapy<br>Familiar hypokalemic periodic paralysis |
| Renal loss | Renal tubular acidosis<br>Diuretics<br>DKA<br>Excessive mineralocorticoid effect (Bartter's syndrome, Cushing syndrome, licorice ingestion, hyperaldosteronism)<br>Acute tubular necrosis<br>Fanconi syndrome<br>Antibiotics (high urine anions, especially penicillins) |

| Etiologies | |
|---|---|
| Extrarenal loss | Vomiting/excessive NG suction<br>Pyloric stenosis<br>Cystic fibrosis<br>Diarrhea<br>Laxative abuse<br>Ureterosigmoidostomy<br>Excessive sweating |
| Spurious | Leukocytosis |

### *Emergent Management for Hypokalemia*

- Obtain ECG.
- Obtain creatine kinase (CK) (hypokalemia can cause rhabdomyolysis); glucose; ABG; urinalysis; urine $K^+$, $Na^+$, and $Cl^-$; and urine osmolality.
- If respiratory paralysis or cardiac arrhythmia is present, infuse 1 mEq/kg/h.
- If patient is not critical, calculate $K^+$ deficit, and replace with potassium acetate or potassium chloride. Oral replacement is safer when feasible.
- Correct underlying causes (DKA, alkalosis, etc.).
- If IV replacement is necessary, no more than 40 mEq/L via peripheral route or 80 mEq/L via central route should be used.

## Hyperkalemia (K > 5.5 mEq/L)

### *Signs/Symptoms*

- Muscle weakness
- Paresthesias
- Paralysis
- Areflexia
- Arrhythmias
- Respiratory distress

*ECG changes:* ECG changes progress with increasing serum $K^+$ levels. Peaked T waves, prolongation PR interval, loss of P waves with widening QRS, amplified R wave, progressive widening of QRS, bradycardia, AV block, ventricular arrhythmias, Torsades de Pointes, sinus wave pattern (wide QRS merging with T wave), cardiac arrest.

| Etiologies | |
|---|---|
| Increased intake | IV or PO medications<br>Exogenous $K^+$ intake (salt substitutes)<br>Transfusions with aged blood |
| Transcellular shift | Acidosis<br>Rhabdomyolysis<br>Tumor lysis syndrome<br>Large hematomas<br>Succinylcholine<br>Exercise<br>Insulin deficiency<br>Malignant hyperthermia<br>Hyperkalemic periodic paralysis<br>Crush injuries, trauma, burns |
| Decreased renal excretion | Renal failure<br>Congenital adrenal hyperplasia<br>$K^+$-sparing diuretics<br>Renal tubular diseases<br>Urinary tract obstruction<br>Aldosterone insensitivity<br>Aldosterone deficiency<br>Lupus nephritis<br>Medications |
| Spurious | Hemolysis<br>Thrombocytosis<br>Leukocytosis<br>Tight tourniquet during lab draw |

## *Emergent Management for Hyperkalemia*

- Obtain ECG.
- Continuous cardiac monitoring.
- Obtain repeat specimen; do not delay treatment waiting on repeat lab results!
- Stop all $K^+$ infusions or medications.
- If ECG changes are present:
  - IV administration of 10–20 mg/kg (max 500 mg) calcium chloride or 100 mg/kg/dose (max dose 3 g/dose) calcium gluconate over 5 min to stabilize cardiac membrane.
  - **Patient must remain on cardiac monitor and infusion stopped if HR < 60, (bradycardia can be fatal).**
  - Shift $K^+$ intracellularly:

    Give IV sodium bicarbonate 1–2 mEq/kg over 5–10 min (if metabolic acidosis is present).
    Give 5 mg nebulized albuterol.
    Give IV insulin + glucose infusion (must give glucose with insulin therapy to prevent hypoglycemia).

- Initiate dialysis if renal failure.
- Kayexalate 1 g/kg PO or PR to bind K+ (does not work immediately).
- Give mineralocorticoids if deficiency is suspected.
- Correct any co-existing magnesium deficiency.

## Hypocalcemia ($Ca^{++}$ < 7 mg/dL in Preterm Infant, <8 mg/dL in Term Infant, or < 9 mg/dL in Children)

### *Signs/Symptoms*

- Muscular irritability
- Weakness
- Tetany
- Paresthesias
- Fatigue
- Muscle cramps
- Altered mental status
- Seizures
- Laryngospasm
- Cardiac arrhythmias
- Prolonged QT interval
- Trousseau sign (carpopedal spasm after arterial occlusion)
- Chvostek sign (perioral twitch with stimulus of the facial nerve)

### *Etiologies*

| Early Neonatal (1-3 days) | Late Neonatal (3 days- 6 weeks) | Infants/Children |
|---|---|---|
| • Prematurity<br>• Poor intake/delayed feeds<br>• Increased calcitonin<br>• Hypoxic encephalopathy<br>• Neonatal asphyxia<br>• Intrauterin growth restriction<br>• Exchange transfusion (citrate load)<br>• Infant of a diabetic mother<br>• Hypomagnesemia<br>• Hypoalbunemia<br>• Maternal hyperparathyroidism<br>• Dietary phosphate loading | • Hypoparathyroidism<br>• Maternal hypercalcemia<br>• DiGeorge Syndrome<br>• Velo-cardio-facial Syndrome<br>• Cow's milk tetany (high phosphate load with cow's milk)<br>• Chronic diarrhea<br>• Malabsorption<br>• Alkaline treatements<br>• Hypomagnesemia<br>• Severe infantile osteopetrosis<br>• Renal disease | • Hypoparathyroidsim<br>• Autoimmune disease<br>• Vitamin D deficiency (espicially if strictly breastfeeding without supplementation)<br>• Wilson's disease<br>• Hyperphospatemia from improper forumla mixing<br>• Excessive use of phosphorus containing enemas<br>• Total parental nutrition (TPN)<br>• Blood transfusion<br>• Chelation therapy<br>• Acute severe illness<br>• Malabsorption<br>• Pancreatitis<br>• Respiratory or metabolic alkalosis<br>• Renal disease/renal failure<br>• Hypomagnesemia<br>• Medications |

### *Emergent Management for Hypocalcemia*

- Obtain ECG (causes arrhythmias/prolonged QT).
- Obtain total and ionized $Ca^{++}$ levels, phosphate level, alkaline phosphatase, magnesium level, total protein, complete metabolic profile, 25-OH vitamin D, parathyroid hormone (PTH) level, albumin, ABG (acidosis increased ionized calcium), chest X-ray to visualize the thymus, ankle and wrist X-rays to assess for rickets, and urine studies for calcium, phosphate, and creatinine.
- Correct hypomagnesemia first if present (if $mg^{++} < 1.5$ mg/dL) before calcium infusion.
- Stop any medication or infusions that may bind calcium (blood transfusions, TPN).
- Treatment for severe tetany, seizures, or cardiac arrhythmias:
  - 10% IV calcium gluconate 100 mg/kg given slowly over 10 min.
  - **Patient must remain on cardiac monitor and infusion stopped if HR < 60 (bradycardia can be fatal)**.
  - Never mix calcium with fluids containing phosphate or bicarbonate.
- If patient is stable, replacement therapy can be oral.
- Address and treat any underlying causes.

## Hypercalcemia ($Ca^{++} > 11$ mg/dL)

### *Signs/Symptoms*

- Muscular irritability
- Weakness
- Lethargy
- Altered mental status/coma
- Seizures
- Abdominal cramping
- Cardiac arrhythmias
- Shortened QT interval
- Polyuria
- Polydipsia
- Pancreatitis
- Renal calculi
- Nausea, vomiting, anorexia

| Etiologies |
| --- |
| •Hyperparathyroidism<br>•Vitamin D intoxication<br>•Excessive exogenous calcium administration<br>•Malignancies<br>•Prolonged immobilization<br>•Thiazide diuretics<br>•Granulomatous diseases (such as sarcoidosis)<br>•Hyperthyroidism<br>•Williams Syndrome<br>•Milk-alkali syndrome |

### *Emergent Management for Hypercalcemia*

- Obtain ECG (causes arrhythmias/shortened QT).
- Obtain total and ionized $Ca^{++}$ levels; phosphate level; alkaline phosphatase; total protein; complete metabolic profile; 25-OH vitamin D; parathyroid hormone (PTH) level; albumin; urine studies for calcium, phosphate, and creatinine; abdominal X-ray; renal ultrasound to assess for renal calculi.
- Address and treat any underlying causes.
- Hydration to increase urine output and $Ca^{++}$ elimination, may give NS boluses for rapid hydration.
- Furosemide for diuresis.
- Severe or refractory hypercalcemia may require dialysis.

## Hypoglycemia (Glucose <50 mg/dL)

### *Signs/Symptoms*

- Diaphoresis
- Tachycardia
- Pallor
- Trembling/jitteriness
- Headache
- Confusion
- Altered mental status
- Lethargy

- Apnea
- Nausea, vomiting
- Difficulty speaking
- Weakness
- Seizures
- Ataxia
- Vision changes
- Poor feeding

| Etiologies | |
|---|---|
| Glucose use increased | Hyperinsulinism: Insulin-producing tumor, ingestion of oral hypoglycemic agent, insulin therapy or overdose<br>Large tumors (e.g., Wilms', neuroblastoma)<br>Hyperthermia<br>Growth hormone deficiency<br>Polycythemia<br>Infant of diabetic mothers |
| Glucose availability decreased | Decreased oral intake<br>Fasting<br>Malnutrition<br>Diarrhea<br>Vomiting<br>Inborn errors of metabolism<br>Inability to mobilize glucose<br>Ineffective gluconeogenesis<br>Inadequate glycogen reserve<br>Ineffective glycogenolysis |
| Availability of alternative fuel decreased | Low/absent fat stores<br>Enzyme deficiency in fatty acid oxidation |
| Others | Sepsis<br>Shock<br>Cardiogenic shock<br>Burns<br>Reye's syndrome<br>Medications<br>Salicylate ingestion<br>Alcohol ingestion<br>Other ingestions (esp. cardiac meds)<br>Adrenal insufficiency<br>Hypothyroidism<br>Panhypopituitarism<br>Hepatitis/liver failure |

## *Emergent Management for Hypoglycemia*

- **Immediate treatment of hypoglycemia: Rule of 50 (dextrose fluid × mL/kg = 50):**
  - **D50 = 1 mL/kg fluid bolus**
  - **D25 = 2 mL/kg fluid bolus**
  - **D10 = 5 mL/kg fluid bolus**
  - **D5 = 10 mL/kg fluid bolus**
- Once initial hypoglycemia has been corrected, begin infusion with D10-containing fluids at 1.5–2 × MIVF rate.
- Administer stress dose of glucocorticoid (2 mg/kg of hydrocortisone).
- Laboratory studies: CBC, blood culture, complete metabolic panel, ammonia, glucagon, c-peptide, lactate, pyruvate, carnitine level, ABG, acylcarnitine profile, cortisol level, growth hormone, plasma amino acids, urine organic acids, urinalysis, urine culture.
- Do not delay therapy with dextrose in order to obtain labs: Give glucose immediately!
- Inborn errors of metabolism/genetic disorders and ingestion should be high on your differential diagnosis in infants or children presenting with hypoglycemia.

## *Quick Hits Electrolyte Disturbances Pearls*

1. Rapid correction of hyponatremia can cause central pontine myelinolysis, avoid increasing the serum $Na^+$ more than 12 mEq/L every 24 h.
2. For patients with shock or severe dehydration with hypernatremia, volume expansion with isotonic saline is recommended regardless of serum $Na^+$.
3. For patients receiving IV calcium infusions, they must remain on cardiac monitor and infusion stopped if HR <60 (bradycardia can be fatal)!
4. Prompt recognition and treatment of hypoglycemia in children is critical: remember the “rule of 50” for dextrose administration!