

Dehydration — Isotonic, Hypotonic and Hypertonic Fluid Disorders

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Dehydration is an imbalance in the body fluid environment. This imbalance occurs when fluid loss from the body exceeds fluid intake. The body loses fluid through normal physiologic processes including respiration, urination, and sweating and through pathological conditions such as vomiting, diarrhea, and fever.



Overview

Dehydration is defined as the excessive loss of body water. The balance between fluid intake and fluid loss from the body becomes greatly disproportionate in dehydration. The severity of dehydration ranges from mild to severe, and can be fatal when fluid losses exceed more than 15% of total body water content.

Hypovolemia is another related term that means decreased circulatory volume due to the loss of blood or plasma.

Pathophysiology of Dehydration

Total body water is distributed into extracellular and intracellular compartments. The

extracellular compartment contains **one-third** of total body water and is comprised of intravascular, interstitial, and intercellular spaces. The **intracellular** compartment contains **two-thirds** of total body water and consists of the fluid inside of the body's cells. Fluid from the extracellular compartment is depleted first in a dehydrated state, followed by fluids from the intracellular space. Fluid loss from the intracellular space results in cellular shrinkage and metabolic dysfunction.

Dehydration occurs in the situation of decreased water intake, increased fluid loss, or both. In the elderly, impaired thirst sensation, chronic illness, fever, and sickness are common causes of **decreased water intake**. Common causes of **increased fluid loss** include vomiting, [diarrhea](#), diuresis, and sweating. Working in hot weather without water and electrolyte replacement is another common cause of dehydration.

Dehydration can be classified according to serum sodium concentration into **hypernatremic**, **hyponatremic**, or **isonatremic** dehydration.

- If water loss is greater in comparison to sodium loss, then serum sodium concentration increases, resulting in **hypernatremic (or hypertonic)** dehydration.
- If water loss is accompanied by excessive sodium loss, then serum sodium concentration decreases, resulting in **hyponatremic (or hypotonic)** dehydration.
- If water and sodium are lost at the same rate, then the serum sodium concentration remains the same. This is called **isonatremic (or isotonic)** dehydration.

Apart from hypernatremia and hyponatremia, other electrolyte imbalances may also occur, such as:

Hyperkalemia, which occurs in insulin dependent [diabetes mellitus](#), Addison's disease, and [kidney failure](#).

Hypokalemia, which results from increased potassium loss in severe diarrhea and vomiting.

Hypermagnesemia and **hyperphosphatemia** can also occur from increased concentrations of magnesium and phosphate respectively.

Evaluation of TBNa^+ Status

1. Decreased TBNa^+ produces signs of volume depletion, including:

- Dry mucous membranes
- Decreased skin turgor (i.e. skin tenting when the skin is pinched)
- Decreased blood pressure and increased pulse (reflex [tachycardia](#)) when sitting up from a supine position (i.e. positive tilt test)

2. Increased TBNa^+ may produce body cavity effusions (ascites) and pitting edema

- Dependent pitting edema is due to an excess of Na^+ -containing fluid in the interstitial space (> 2-3 liters)
 - Caused by low protein content in edematous fluid
 - Fluid obeys the law of gravity and moves to the most dependent portion of the body (e.g., ankles when

standing)

- Starling equation forces regulate the production of interstitial fluid; in the situation of increased TBNa+, Starling pressures are altered to produce pitting edema and body effusions
- An increase in TBNa+ increases plasma hydrostatic pressure due to an increase in plasma volume
- An increase in TBNa+ increases the weight of the patient and is the most common cause of weight gain in a hospitalized patient

3. Normal TBNa+ is associated with normal skin turgor and hydration

- Fluid movement across a capillary/venule wall into the interstitial space is driven by Starling pressures (not osmosis)
- The net direction of fluid movement depends on which Starling pressure is dominant
- An increase in plasma hydrostatic pressure or a decrease in plasma oncotic pressure (i.e. serum albumin), causes fluid to diffuse out of capillaries and venules and into the interstitial space, resulting in dependent pitting edema and body cavity effusions

Signs and Symptoms of Dehydration

Most patients with dehydration present with:

- Thirst
- Headaches
- Fatigue

Symptoms of mild dehydration include:

- constipation, dry mouth, dizziness, and low urine volume (unless the cause of dehydration is polyuria)

Symptoms of more severe dehydration include:

- dry skin, sunken eyes, dry mucous membranes, confusion, oliguria, seizures, coma, and death

Signs of hypovolemia may also be present, including:

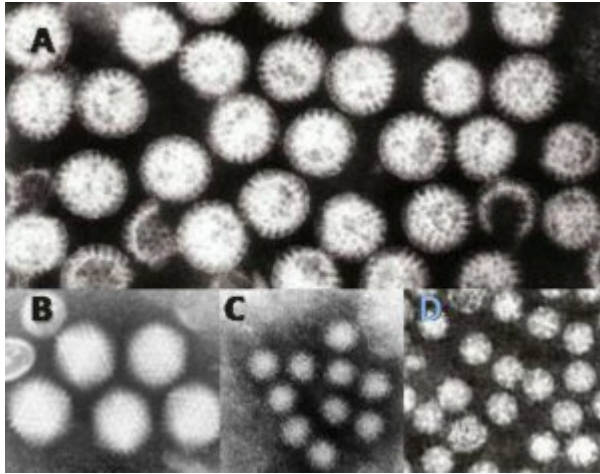
- tachycardia, orthostatic hypotension, and flat neck veins

Dehydration is more clinically evident in the elderly, especially in hot weather, due to **impaired thirst sensation**. Elderly or hospitalized patients will show signs of irritability and sometimes delirium.

The symptoms of severe dehydration include minimal urine output or zero urine output, dizziness, hypotension, tachycardia, fever, poor skin elasticity, lethargy, confusion, and coma, seizure, or shock.

Isotonic Dehydration

Isotonic dehydration is a condition in which both water and sodium are lost proportionally such that the serum sodium concentration maintains normal serum osmolality. Serum osmolality determines the movement of fluids and electrolytes across membranes. The normal serum osmolality is 285–295 mOsm/kg.



[Image](#): "Electron micrographs of viruses that cause gastroenteritis in humans. A = Rotavirus (Rotavirus), B = Adenovirus (Adenoviridae), C = Norovirus (Norovirus) and D = Astrovirus (Astroviridae). They are shown at the same magnification of approximately x 200,000" by Dr Graham Beards at en.wikipedia. License: [CC BY 3.0](#)

Causes of isotonic dehydration

- **Vomiting and diarrhea:** severe watery diarrhea and/or vomiting can be a life-threatening condition, especially in children. People with **gastroenteritis** may lose tremendous amounts of fluids and electrolytes in a short time and their oral replacement is limited due to recurrent vomiting, which can then result in severe dehydration.
- **Excessive sweating:** vigorous exercise, especially in humid weather, will increase sweating and lead to fluid and electrolyte loss.

If dehydration is not corrected, it will lead to **renal injury** from **muscle breakdown** and **lactic acidosis**.

Lab values in isotonic dehydration

Isotonic dehydration will show normal serum laboratory values, including normal osmolality of 285–295 mOsm/kg and normal serum sodium of 135–145 mmol/L.

Urine volume will be decreased (oliguria) with **low fractional sodium excretion** and increased specific gravity.

Isotonic dehydration can result in **elevated liver and pancreatic enzymes** and a **decreased glomerular filtration rate**. Dehydration also can result in a variety of **electrolyte imbalances** that will affect the clinical picture and prognosis.

Hypertonic Dehydration

Hypertonic dehydration occurs when **water excretion from the body exceeds that of sodium excretion**, resulting in an increased sodium concentration in the extracellular fluid (hypernatremia). **Blood osmolality is increased**, causing the water shift from the intracellular to the extracellular space.

Causes of hypertonic dehydration

- **Fever:** Fever will increase the respiratory rate and therefore, water loss. Sweating also increases in order to lower the body temperature. Moreover, water intake is commonly decreased during a fever which will aggravate dehydration.

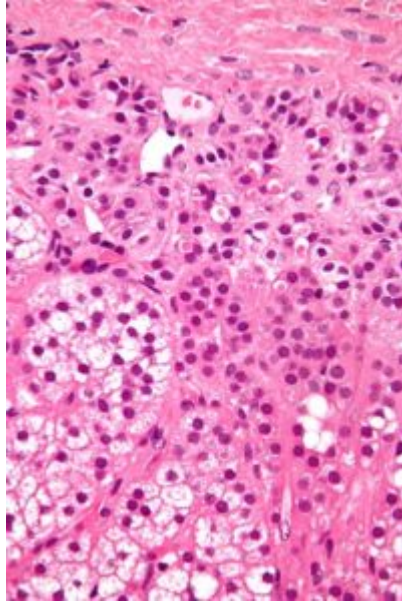


Image: "Micrograph of spironolactone bodies. H&E stain." by Nephron - Own work. License: [CC BY-SA 3.0](https://creativecommons.org/licenses/by-sa/3.0/)

- **Polyuria:** Increased water loss in urine causes hypertonic dehydration and may occur in **diabetes mellitus, diabetes insipidus, or with diuretic use**
- Decreased water intake
- Excessive sweating
- End stage renal disease
- Drinking urine or sea water for survival.

Lab values in hypertonic dehydration

Serum osmolality will exceed 300 mOsm/kg, while **serum sodium** will be greater than 150 mEq/L.

Urine volume will decrease, unless the cause of dehydration is polyuria or diuretic use.

Specific gravity will be high and fractional excretion of sodium will also increase.

Compartment Alteration	POsm/Na ⁺	ECF Volumen	ICF Volume	Conditions
Hyperglycemia	Increased ↑ Glucose ↓ Na ⁺ (dilutional effect)	Contracted	Contracted	<ul style="list-style-type: none"> • Diabetic ketoacidosis • Hyperosmolar nonketotic coma (type 2 diabetes)
	Hypertonic Changes			
Hypotonic loss of Na	Increased ↓ TBN ⁺ / ↓ ↓ TBW	Contracted	Contracted	<ul style="list-style-type: none"> • Osmotic diuresis: glucose • Sweating

Loss of water	Increased TBN ⁺ / ↓ ↓ TBW	Contracted (mild) (Normal skin turgor)	Contracted	<ul style="list-style-type: none"> • Insensible water loss: fever • Diabetes Insipidus
Hypertonic gain of Na	Increased ↑ ↑ TBN ⁺ / ↑ TBW	Expanded	Contracted	<ul style="list-style-type: none"> • Infusion of a Na⁺-containing antibiotic • Infusion of NaHCO₃

Hypotonic Dehydration

Hypotonic dehydration occurs when **sodium loss is greater than water loss**, thereby resulting in a **decrease in serum osmolality**. This causes a shift of water from the extracellular space into the intracellular space. The cells will swell and cerebral edema may occur.

Hyponatremia can be acute or chronic. If sodium loss occurs for a period of more than 48 hours, it becomes chronic hyponatremia, and the body may adapt to this state. Sodium imbalance mainly manifests as **neurological symptoms** ranging from headaches, nausea, lethargy, and potentially confusion, coma, and death.

The term hyponatremia should be used with caution in cases of dehydration, as most cases of hyponatremia imply **excess water retention** rather than dehydration.

Causes of hypotonic dehydration

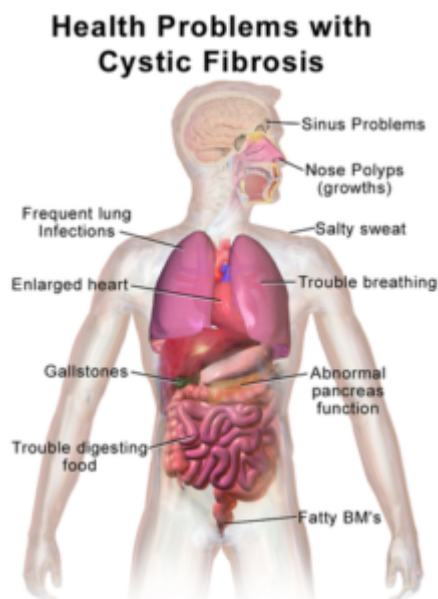


Image: "Health problems with cystic fibrosis" by Blausen.com staff. "Blausen gallery 2014". Wikiversity Journal of Medicine. DOI:10.15347/wjm/2014.010. License: [CC BY 3.0](https://creativecommons.org/licenses/by/3.0/)

- **Addison's disease**
- **Renal tubular acidosis**
- **Iatrogenic causes**; hypotonic fluids or plain water used for IV hydration in patients with heat stroke or diarrhea.
- **Diuretics**; [loop](#), [thiazide](#), and osmotic diuretics especially with prolonged use.
- **Cystic fibrosis**

Lab values in hypotonic dehydration

Serum sodium and serum osmolality will be less than the normal range.

Urine specific gravity will be decreased

Urine sodium excretion will be decreased.

Isotonic and Hypotonic Fluid Disorders: Summary

Compartment Alteration	POsm/Na ⁺	ECF Volume	ICF Volume	Conditions
	Normal	Normal	Normal	Normal
Isotonic and Hypotonic Changes				
Isotonic loss	Normal ↓TBNa ⁺ / ↓TBW	Contracted	Normal	<ul style="list-style-type: none"> • Adult diarrhea • Loss of whole blood
Isotonic gain	Normal ↑TBNa ⁺ / ↑TBW	Expanded	Normal	<ul style="list-style-type: none"> • Excessive Isotonic Saline
Hypertonic loss of Na ⁺	Decreased ↓ ↓TBNa ⁺ / ↓TBW	Contracted	Expanded	<ul style="list-style-type: none"> • Loop diuretics • Addison's disease • 21-Hydroxylase deficiency
Hypotonic gain of Na ⁺	Decreased TBNa ⁺ /↑ ↑TBW	Expanded	Expanded	<ul style="list-style-type: none"> • SIADH • Compulsive water drinker
	Decreased ↑TBNa ⁺ /↑ ↑TBW	Expanded Starling pressure alteration	Expanded	<ul style="list-style-type: none"> • Right-sided heart failure • Cirrhosis • Nephrotic syndrome

Complications of dehydration:

- **Hypovolemic shock:** Severe dehydration will lead to low blood volume and hypovolemic shock. It can lead to major end organ damage through acidosis and [can cause acute kidney injury](#) which can potentially be fatal.
- **Seizures:** Sodium imbalance can cause abnormal neuronal excitability, resulting in confusion, seizures, delirium, and coma. Another cause of seizures in dehydrated patients is iatrogenic, caused by a rapid correction of underlying serum sodium abnormalities. Hypotonic saline, if used in hypernatremic patients, will rapidly decrease the plasma osmolality, and water will shift to the intracellular space, resulting in brain edema and seizures.
- **Cardiac arrhythmias:** Potassium imbalances caused by dehydration may affect muscles and cause life-threatening cardiac arrhythmias, fatigue, weakness, and muscle breakdown.
- **Heat stroke:** During exercise or while working in a hot environment, fluid intake is recommended in order to avoid heat exhaustion, or even heat stroke.
- **Kidney failure:** Possible causes of kidney injury include hypovolemic shock with low blood supply to the kidneys, acidosis due to hypovolemia, muscle breakdown, and electrolyte disturbances.
- **Thrombosis:** Increased blood viscosity from dehydration will lead to venous thrombosis. Patients may present with [DVT](#), portal vein thrombosis, or

pancreatitis. Fever will also increase thrombosis risk and limit water intake.

- **Coma and death:** Low blood pressure in severe dehydration will decrease the [blood supply to the brain](#) and could cause coma or death, particularly in elderly patients.

Prevention of Dehydration

Adequate hydration is recommended during all activities to prevent dehydration. Water intake is the key to replacing the fluid lost during exercise, in hot weather, during hospitalization, and in elderly patients with impaired thirst sensation.

Hospitalized patients should be carefully monitored for water intake and total fluid output in order for early detection of any fluid imbalances.

Children with vomiting and diarrhea should not be given plain water to replace fluid lost as this could lead to the development of hyponatremia and water intoxication.

Intravenous fluids can be used for fluid replacement in unconscious patients with severe dehydration while plain water, sports drinks with electrolytes, and oral rehydration solutions are used for the prevention and treatment of mild dehydration. Electrolyte monitoring is mandatory for patients using diuretics for a prolonged period of time.

Treatment of Dehydration

Treatment approaches vary according to age and severity of dehydration.

Treatment of the cause should always be considered, along with treatment of symptoms, and fluid replacement. Urine output should be monitored in hospitalized patients as an indicator of treatment efficacy and renal function recovery.

In severe dehydration, restoration of the blood volume is the main goal and is achieved with a fluid bolus of 20 mL/kg isotonic saline or lactated Ringer's solution. Adults can use oral fluids if they are conscious and able to drink, otherwise, intravenous fluids should be used. Correction of electrolyte abnormalities should follow.

Infants and children with dehydration

Children are vulnerable to the effects of dehydration. Water deprivation can complicate gastroenteritis or fever and lead to severe dehydration with neurological manifestations and electrolyte imbalances.

Treatment options include fluid replacement orally if the child is conscious and able to drink. Water, fluids, and an oral rehydration solution can be used. In severe cases, intravenous fluids should be used.

Breastfeeding and a normal diet should be continued, as long as the treatment with fluid replacement avoids weight loss or developmental delays in the infant.

Treatment of cases with isonatremic dehydration

A fluid bolus should be given to restore the blood volume according to severity, followed by maintenance therapy with 0.9% normal saline. 20 mL/kg of isotonic sodium solution or lactated Ringer's solution is given to restore hydration. Oral intake should be encouraged as early as possible.

Treatment of cases with hyponatremia

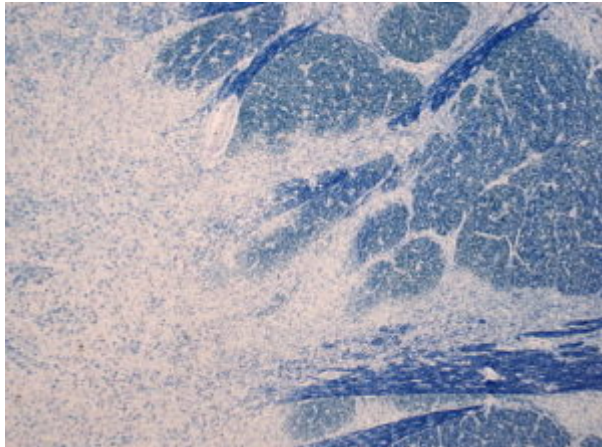


Image: "Loss of myelinated fibers at the basis pontis in the brainstem (Luxol-Fast blue stain)" by Jensflorian - Own work.
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Patients may present with acute cerebral edema. Early steps should include stabilization of the patient, securing of the airway, and maintenance breathing and [circulation](#).

In severe acute cases involving seizures and coma, management of hyponatremia is accomplished with hypertonic saline 3%. Correction of hyponatremia should start at a rate of 4-6 mEq/L/hour.

In chronic hyponatremia, correction of sodium concentration should be done using normal saline 0.9% at a rate of 10-12 mEq/L/day during the first 2 days. Rapid correction of hyponatremia will lead to central pontine myelinolysis, resulting in permanent injury to the [brain stem](#), quadriplegia, and cranial nerve paralysis.

To calculate the sodium deficit:

Sodium deficit = (normal sodium level - serum level) * volume of distribution * weight.

Treatment of cases with hypernatremia

The first step in treating hypernatremia is volume restoration with isotonic saline or lactated Ringer's solution.

Following this, a slow correction of the hypernatremia at a rate of 10 mEq/L/24hours is required to avoid cerebral edema and death as a complication. 5% dextrose in 0.9% sodium chloride can be used with frequent monitoring of the serum sodium every 4 hours.

Hyperglycemia and hypocalcemia sometimes follow hypernatremic dehydration, so serum glucose and calcium levels should be monitored closely.

Note: Antidiarrheal agents, routine antibiotics, and antiemetics should be avoided in this situation as they may worsen the condition.

References

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Notes