emedicine from WebMD

emedicine.medscape.com

eMedicine Specialties > Pediatrics: Cardiac Disease and Critical Care Medicine > Critical Care

Hypernatremia

Ewa Elenberg, MD, Assistant Professor, Department of Pediatrics, Renal Section, Texas Children's Hospital, Baylor College of Medicine
Muthukumar Vellaichamy, MD, FAAP, Clinical Assistant Professor, Department of Pediatrics, University of Kansas School of Medicine-Wichita, Wesley Medical Center

Updated: Nov 17, 2008

Introduction

Background

Hypernatremia is defined as a serum sodium concentration of more than 145 mEq/L. It is characterized by a deficit of total body water (TBW) relative to total body sodium levels due to either loss of free water, or infrequently, the administration of hypertonic sodium solutions.[1]

In healthy subjects, the body's 2 main defense mechanisms against hypernatremia are thirst and the stimulation of vasopressin release.

Pathophysiology

Hypernatremia represents a deficit of water in relation to the body's sodium stores, which can result from a net water loss or a hypertonic sodium gain. Net water loss accounts for most cases of hypernatremia. Hypertonic sodium gain usually results from clinical interventions or accidental sodium loading. As a result of increased extracellular sodium concentration, plasma tonicity increases. This increase in tonicity induces the movement of water across cell membranes, causing cellular dehydration.

The following 3 mechanisms may lead to hypernatremia, alone or in concert:

- Pure water depletion (eg, diabetes insipidus)
- Water depletion exceeding sodium depletion (eg, diarrhea)
- Sodium excess (eg, salt poisoning)

Sustained hypernatremia can occur only when thirst or access to water is impaired. Therefore, the groups at highest risk are infants and intubated patients.

Because of certain physiologic characteristics, infants are predisposed to dehydration. They have a large surface area in relation to their height or weight compared with adults and have relatively large evaporative water losses. In infants, hypernatremia usually results from diarrhea and sometimes from improperly prepared infant formula or inadequate mother-infant interaction during breastfeeding.

Hypernatremia causes decreased cellular volume as a result of water efflux from the cells to maintain equal osmolality inside and outside the cell. Brain cells are especially vulnerable to complications resulting from cell contraction. Severe hypernatremic dehydration induces brain shrinkage, which can tear cerebral blood vessels, leading to cerebral hemorrhage, seizures, paralysis, and encephalopathy.

In patients with prolonged hypernatremia, rapid rehydration with hypotonic fluids may cause cerebral edema, which can lead to coma, convulsions, and death.

Frequency

United States

Hypernatremia is primarily a hospital-acquired condition occurring in children of all ages who have restricted access to fluids, mostly due to significant underlying medical problems such as a chronic disease, neurologic impairment, a critical illness, or prematurity. The incidence is estimated to be greater than 1% in hospitalized patients. Hospital-acquired

hypernatremia accounts for 60% of hypernatremia cases in children. Gastroenteritis contributes to the hypernatremia in only 20% of cases. The group most affected is intubated, critically ill patients. Most cases result from a failure to freely administer water to patients. The incidence of breastfeeding-related hypernatremia is 1-2%.

International

In developing nations, the reported incidence is 1.5-20%.

Mortality/Morbidity

In children with acute hypernatremia, mortality rates are as high as 20%. Neurologic complications related to hypernatremia occur in 15% of patients. The neurologic sequelae consist of intellectual deficits, seizure disorders, and spastic plegias. In cases of chronic hypernatremia in children, the mortality rate is 10%.

Race

No predilection is documented.

Sex

No sex difference is known.

Age

In the pediatric population, hypernatremia usually affects newborns and toddlers who depend on caretakers for water, as well patients of any age who have significant underlying medical problems such as a chronic disease, neurologic impairment, a critical illness, or prematurity.

Clinical

History

- Patients in certain situations or with certain conditions are at risk for hypernatremia, as follows:
    - Hospitalized patients who receive exclusive intravenous fluids
    - Patients with coma
    - Newborns
    - Toddlers
    - Patients with diabetes insipidus
    - Patients receiving alkali therapy
    - Patients with diarrhea
    - Patients with fever
    - Patients with renal disorders (eg, dysplasia, medullary cystic disease, polycystic kidney disease, tubulointerstitial disease)
    - Patients with obstructive uropathy
    - Patients with electrolyte disturbances (eg, hypokalemia, hypercalcemia)
    - Patients with heat stroke or excessive hypotonic fluid loss
- Signs and symptoms of hypernatremia include the following:
    - Irritability
    - High-pitched cry or wail
    - Periods of lethargy interspersed with periods of irritability
    - Altered sensorium
    - Seizures
    - Increased muscle tone

- Fever
- Rhabdomyolysis[2]
- Oligoanuria
- Excessive diuresis

Physical

Skin turgor is a physical finding in patients with hypernatremia. Extracellular and plasma volumes tend to be maintained in hypernatremic dehydration until dehydration is severe (ie, when the patient loses >10% of body weight).

When dehydration is severe, skin turgor is reduced, and the skin develops a characteristic doughy appearance.

Causes

- Hypovolemic hypernatremia
  - Diarrhea
  - Excessive perspiration
  - Renal dysplasia
  - Obstructive uropathy
  - Osmotic diuresis
- Euvolemic hypernatremia
  - Central diabetes insipidus causes
  - Idiopathic causes
  - Head trauma
  - Suprasellar or infrasellar tumors (eg, craniopharyngioma, pinealoma)
  - Granulomatous disease (sarcoidosis, tuberculosis, Wegener granulomatosis)
  - Histiocytosis
  - Sickle cell disease
  - Cerebral hemorrhage
  - Infection (meningitis, encephalitis)
  - Associated cleft lip and palate
  - Nephrogenic diabetes insipidus causes
  - Congenital (familial) conditions
  - Renal disease (obstructive uropathy, renal dysplasia, medullary cystic disease, reflux nephropathy, polycystic disease)
  - Systemic disease with renal involvement (sickle cell disease, sarcoidosis, amyloidosis)
  - Drugs (amphotericin, phenytoin, lithium, aminoglycosides, methoxyflurane)
- Hypervolemic hypernatremia
  - Improperly mixed formula
  - $NaHCO_3$ administration
  - NaCl administration
  - Primary hyperaldosteronism

Differential Diagnoses

Diabetes Insipidus

Other Problems to Be Considered

Hypertonic dehydration
Salt poisoning

Workup

Laboratory Studies

The following studies are indicated in patients with suspected hypernatremia:

- Serum tests of sodium, osmolality, BUN, and creatinine levels
- Urine tests of sodium concentration and osmolality
  - In cases of hypovolemic hypernatremia, extrarenal losses show urine sodium levels of less than 20 mEq/L, and in cases of renal losses, urine sodium values are more than 20 mEq/L.
  - In euvolemic hypernatremia, urine sodium data vary.
  - In hypervolemic hypernatremia, the urine sodium level is more than 20 mEq/L.

Imaging Studies

- Imaging studies of the head should be considered in alert patients with severe hypernatremia to rule out a hypothalamic lesion affecting the thirst center.
- CT scans may help in diagnosing intracranial tumors, granulomatous diseases (eg, sarcoid, tuberculosis, histiocytosis), and other intracranial pathologies.
- MRI further delineates the pathology.

Other Tests

- Aldosterone test
- Cortisol test
- Antidiuretic hormone (ADH) test
- Corticotropin (ACTH) test

Treatment

Medical Care

Medical care involves the correction of hypernatremia. In correcting hypernatremia, do not rapidly decrease the sodium level because a rapid decline in the serum sodium concentration can cause cerebral edema. The recommended rate of sodium correction is 0.5 mEq/h or as much as 10-12 mEq/L in 24 hours. Dehydration should be corrected over 48-72 hours. If the serum sodium concentration is more than 200 mEq/L, peritoneal dialysis should be performed using a high-glucose, low-sodium dialysate.

- One of the following equations may be used to calculate body water deficit:
  - The equations are based on a goal of plasma sodium concentration of 145 mEq/L. In children, total body water (TBW) is 60% of their lean body weight. Therefore, TBW = 0.6 X weight. Babies are an exception to these equations and may have a TBW as much as 80% of their body weight.
    - Water deficit (in L) = [(current Na level in mEq/L ÷ 145 mEq/L) - 1] X 0.6 X weight (in kg)
    - Water deficit (in L) = [(current Na level in mEq/L - 145 mEq/L)/145 mEq/L) - 1] X 0.6 X weight (in kg)
    - Water deficit (in L) = [1- (145 mEq/L ÷ current Na level in mEq/L)] X 0.6 X weight (in kg)
  - Example calculation: A child weighs 10 kg and has a plasma sodium concentration of 160 mEq/L. By using the first equation, water deficit (in L) = [(160 mEq/L ÷ 145 mEq/L) - 1] X 0.6 X 10 = 0.62 L.

- The volume of replacement fluid needed to correct the water deficit is determined by using the concentration of sodium in the replacement fluid. The replacement volume can be determined as follows:
    - Replacement volume (in L) = TBW deficit X [1 ÷ 1 - (Na concentration in replacement fluid in mEq/L ÷ 154 mEq/L)]
    - Example calculation: If the patient from the example calculation above has a TBW of 0.62, and if the replacement fluid contains 0.45% NaCl (Na concentration of 77 mEq/L), the replacement volume (in L) = 0.62 L X [1 ÷ 1 - (77 mEq/L ÷ 154 mEq/L)] = 1.25 L. This volume has to be replaced slowly over 48-72 hours.

- The election of intravenous fluid is based on the following:
    - If the patient is hypotensive, normal saline (lactated Ringer solution, or 5% albumin solution) should be used regardless of a high serum sodium concentration.
    - In hypernatremic dehydration, 0.45% or 0.2% NaCl should be used as a replacement fluid to prevent excessive delivery of free water and a too-rapid decrease in the serum sodium concentration.
    - In cases of hypernatremia caused by sodium overload, sodium-free intravenous fluid (eg, 5% dextrose in water) may be used, and a loop diuretic may be added.
    - The serum sodium concentration should be monitored frequently to avoid too-rapid correction of hypernatremia.
    - In cases of associated hyperglycemia, 2.5% dextrose solution may be given. Insulin treatment is not recommended because the acute decrease in glucose, which lowers plasma osmolality, may precipitate cerebral edema.
    - Once the child is urinating, add 40 mEq/L KCl to fluids to aid water absorption into cells.
    - Calcium may be added if the patient has an associated low serum calcium level.

- Serum sodium levels should be monitored every 4 hours.

Consultations

Consultation is also recommended for patients with renal dysplasia, medullary cystic disease, reflux nephropathy, or polycystic disease.

- Critical care specialist: Patients with symptomatic hypernatremia may need to be transferred to a pediatric ICU for appropriate treatment and monitoring.
- Endocrinologist: Consult an endocrinologist for patients with primary hyperaldosteronism.
- Nephrologist: Consult a nephrologist in cases of renal failure, obstructive uropathy, and serum sodium levels of more than 180 mEq/L for possible peritoneal dialysis.

Diet

- In diabetes insipidus, a sodium-restricted and protein-restricted diet should be prescribed.

Medication

The medications described below are used in patients with diabetes insipidus who have hypernatremia.

Vasopressin and vasopressin analogs

Desmopressin is a synthetic ADH with actions mimicking vasopressin. These agents are used to treat diabetes insipidus, which deprives the kidney of its capacity to produce concentrated urine. This effect results in large volumes of dilute urine (polyuria) and excessive thirst (polydipsia). Serum sodium concentrations may be elevated, but hypernatremia is most likely to be severe when fluid is restricted.

Desmopressin acetate (DDAVP)

Structural analog of vasopressin (ADH), the endogenous posterior pituitary hormone that maintains serum osmolality in a physiologically acceptable range. Works in neurohypophysial (eg, central) diabetes insipidus. Exerts similar antidiuretic effects. Vasopressin increases resorption of water at level of renal collecting duct, reducing urinary flow and increasing urine osmolality.

Dosing

Adult

PO: 0.05 mg PO bid initially; titrate to effect; usual range 0.1-0.2 mg/d divided bid/tid
Intranasal: 10-40 mcg/d divided qd/bid; titrate dose to achieve control of excessive thirst and urination; not to exceed 40 mcg/d
Note: The nasal spray pump can only deliver doses of 10 mcg (0.1 mL) or multiples of 10 mcg (0.1 mL); if doses other than this are needed, the rhinal tube delivery system is preferred

Pediatric

PO: 0.05 mg PO divided bid initially; titrate to effect
Intranasal: 3 months to 12 years: 5-30 mcg/d divided qd/bid
Note: The nasal spray pump can only deliver doses of 10 mcg (0.1 mL) or multiples of 10 mcg (0.1 mL); if doses other than this are needed, the rhinal tube delivery system is preferred

Interactions

Coadministration with demeclocycline and lithium decrease effects; fludrocortisone and chlorpropamide increase effects

Contraindications

Documented hypersensitivity; platelet-type von Willebrand disease

Precautions

Pregnancy

B - Fetal risk not confirmed in studies in humans but has been shown in some studies in animals

Precautions

Avoid overhydration in patients to benefit from its hemostatic effects

---

Vasopressin (Pitressin)

Exogenous, parenteral form of ADH. Antidiuretic and increases resorption of water at renal collecting ducts.

Dosing

Adult

5-10 U IM/SC bid/qid; titrate to effect
Continuous IV infusion: 0.5 mU/kg/h (ie, 0.0005 U/kg/h) IV initially; double dosage every 30 min prn, not to exceed 10 mU/kg/h IV (ie, 0.01 U/kg/h)

Pediatric

2.5–10 U IM/SC bid/qid; titrate to effect
Continuous IV infusion: Administer as in adults

Interactions

Lithium, epinephrine, demeclocycline, heparin, and alcohol may decrease effects; chlorpropamide, urea, fludrocortisone, and carbamazepine may potentiate effects

Contraindications

Documented hypersensitivity; coronary artery disease

Precautions

Pregnancy

B - Fetal risk not confirmed in studies in humans but has been shown in some studies in animals

Precautions

Caution in cardiovascular disease, seizure disorders, nitrogen retention, asthma, or migraine; excessive doses may result in hyponatremia

Diuretics

These drugs promote the excretion of water and electrolytes by the kidneys. They are used in patients with nephrogenic diabetes insipidus.

Hydrochlorothiazide (Esidrix, HydroDIURIL)

Works by increasing excretion of sodium, chloride, and water by inhibiting sodium ion transport across renal tubular epithelium. Resulting sodium depletion reduces glomerular filtration rate, enhancing reabsorption of fluid in proximal portion of nephron, decreasing delivery of sodium to ascending limb of loop of Henle and consequently reducing capacity to dilute urine.

Dosing

Adult

25-100 mg/d PO qd or intermittently

Pediatric

Infants <6 months: Up to 3 mg/kg/d PO divided bid, total range 12.5-37.5 mg/d
Children 6 months to 2 years: 1-2 mg/kg/d PO divided qd/bid, total range 12.5-37.5 mg/d
Children 2-12 years: 1-2 mg/kg/d PO divided qd/bid, not to exceed 37.5-100 mg/d

Interactions

Thiazides may decrease effects of anticoagulants, antigout agents and sulfonylureas; thiazides may increase toxicity of allopurinol, anesthetics, antineoplastics, calcium salts, loop diuretics, lithium, diazoxide, digitalis, amphotericin B, and nondepolarizing muscle relaxants

Contraindications

Documented hypersensitivity; anuria or renal decompensation

Precautions

Pregnancy

C - Fetal risk revealed in studies in animals but not established or not studied in humans; may use if benefits outweigh risk to fetus

Precautions

Caution in renal disease, hepatic disease, gout, diabetes mellitus, and erythematosus

Follow-up

Further Inpatient Care

- Record daily body weights in patients with hypernatremia.
- Frequently monitor electrolyte concentrations.
- Restrict sodium and protein intake.

- Treat the underlying disease.

Further Outpatient Care

- Treat the underlying disease.
- Restrict sodium and protein intake.

Transfer

- Patients with symptomatic hypernatremia should be transferred to a pediatric intensive care unit for appropriate treatment and close monitoring.
- Patients should be transferred to a facility that has dialysis in case of renal failure or in case the serum sodium concentration is more than 180 mEq/L.

Deterrence/Prevention

- Parents and caregivers should avoid making oral rehydration solutions at home or adding salt to any commercial infant formula.
- Treat the underlying cause.

Complications

- Seizures can occur because of hypernatremia per se, which is rare. They usually occur during the treatment of hypernatremia because of a rapid decline in serum sodium levels. Therefore, slowly correcting hypernatremia is important.
- Other complications include the following:
    - Mental retardation
    - Intracranial hemorrhage
    - Intracerebral calcification
    - Cerebral infarction
    - Cerebral edema, especially during treatment
    - Hypocalcemia
    - Hyperglycemia

Prognosis

- Patients usually recover from hypernatremia.
- Patients with recurrent hypernatremic dehydration develop neurologic sequelae, especially infants with diabetes insipidus.

Patient Education

- Parents and caregivers should avoid making oral rehydration solutions at home or adding salt to any commercial infant formula.
- Parents, especially breastfeeding mothers, should watch for neonatal dehydration and perinatal care.
- The breastfed infant should be routinely monitored during the first weeks of life.[3]
- In patients with diabetes insipidus, the following is indicated:
    - Monitor weight and urine output because clinically significant changes in sodium values are associated with

changes in weight.

- Restrict sodium and protein intake.
- The patient should drink liberal amounts of water.
- The patient and parents should ensure thirst develops before taking or giving medications.

Miscellaneous

Medicolegal Pitfalls

- Rapid correction of sodium levels in patients with chronic hypernatremia

References

1. Conley SB. Hypernatremia. *Pediatr Clin North Am*. Apr 1990;37(2):365-72. [Medline].
2. Abramovici MI, Singhal PC, Trachtman H. Hypernatremia and rhabdomyolysis. *J Med*. 1992;23(1):17-28. [Medline].
3. Konetzny G, Bucher HU, Arlettaz R. Prevention of hypernatraemic dehydration in breastfed newborn infants by daily weighing. *Eur J Pediatr*. Sep 26 2008;[Medline].
4. Avner ED. Clinical disorders of water metabolism: hyponatremia and hypernatremia. *Pediatr Ann*. Jan 1995;24(1):23-30. [Medline].
5. Berl T. Disorders of water metabolism. In: Schrier RW, ed. *Renal and Electrolyte Disorders*. 5th ed. Lippincott-Raven; 1997.
6. Brown RG. Disorders of water and sodium balance. *Postgrad Med*. Mar 1993;93(4):227-8, 231-4, 239-40 passim. [Medline].
7. DeVita MV, Michelis MF. Perturbations in sodium balance. Hyponatremia and hypernatremia. *Clin Lab Med*. Mar 1993;13(1):135-48. [Medline].
8. Finberg L. Hypernatremic (hypertonic) dehydration in infants. *N Engl J Med*. Jul 26 1973;DA - 19730822(4):196-8. [Medline].
9. Ho L, Bradford BJ. Hypernatremic dehydration and rotavirus enteritis. *Clin Pediatr (Phila)*. Aug 1995;34(8):440-1. [Medline].
10. Lin M, Liu SJ, Lim IT. Disorders of water imbalance. *Emerg Med Clin North Am*. Aug 2005;23(3):749-70, ix. [Medline].
11. Molteni KH. Initial management of hypernatremic dehydration in the breastfed infant. *Clin Pediatr (Phila)*. Dec 1994;33(12):731-40. [Medline].
12. Moritz ML, Ayus JC. Preventing neurological complications from dysnatremias in children. *Pediatr Nephrol*. Dec 2005;20(12):1687-700. [Medline].
13. Moritz ML, Ayus JC. The changing pattern of hypernatremia in hospitalized children. *Pediatrics*. Sep 1999;104(3 Pt 1):435-9. [Medline].
14. Moritz ML, Manole MD, Bogen DL, Ayus JC. Breastfeeding-associated hypernatremia: are we missing the diagnosis?. *Pediatrics*. Sep 2005;116(3):e343-7. [Medline].
15. Palevsky PM. Hypernatremia. *Semin Nephrol*. Jan 1998;18(1):20-30. [Medline].
16. Paneth N. Hypernatremic dehydration of infancy: an epidemiologic review. *Am J Dis Child*. Aug 1980;134(8):785-92. [Medline].

17. Roscelli JD, Yu CE, Southgate WM. Management of salt poisoning in an extremely low birth weight infant. *Pediatr Nephrol*. Apr 1994;8(2):172-4. [Medline].

18. Trachtman H. Cell volume regulation: a review of cerebral adaptive mechanisms and implications for clinical treatment of osmolal disturbances: II. *Pediatr Nephrol*. Jan 1992;6(1):104-12. [Medline].

19. Visser L, Devuyst O. Physiopathology of hypernatremia following relief of urinary tract obstruction. *Acta Clin Belg*. 1994;49(6):290-5. [Medline].

Keywords

hypernatremia, high serum sodium, pure water depletion, sodium excess, water depletion exceeding sodium depletion, total body water, TBW, Na, salt poisoning, dehydration, thirst, sodium loading, diabetes insipidus, diarrhea, gastroenteritis, dysplasia, medullary cystic, polycystic, tubulointerstitial disease, obstructive uropathy, heat stroke, rhabdomyolysis, oligoanuria, craniopharyngioma, pinealoma, sarcoid, tuberculosis, Wegener granulomatosis, histiocytosis, sickle cell disease, meningitis, encephalitis, cleft lip and palate, amyloidosis

Contributor Information and Disclosures

Author

Ewa Elenberg, MD, Assistant Professor, Department of Pediatrics, Renal Section, Texas Children's Hospital, Baylor College of Medicine
Ewa Elenberg, MD is a member of the following medical societies: American Academy of Pediatrics, American Medical Association, and American Society of Nephrology
Disclosure: Nothing to disclose.

Coauthor(s)

Muthukumar Vellaichamy, MD, FAAP, Clinical Assistant Professor, Department of Pediatrics, University of Kansas School of Medicine-Wichita, Wesley Medical Center
Muthukumar Vellaichamy, MD, FAAP is a member of the following medical societies: American Academy of Pediatrics, American College of Chest Physicians, and American Medical Association
Disclosure: Nothing to disclose.

Medical Editor

G Patricia Cantwell, MD, Associate Clinical Professor, Department of Pediatrics, University of Miami; Director of Pediatric Critical Care Medicine, Miller School of Medicine, Jackson Children's Hospital
G Patricia Cantwell, MD is a member of the following medical societies: American Academy of Pediatrics, American College of Emergency Physicians, American Heart Association, American Trauma Society, National Association of EMS Physicians, Society of Critical Care Medicine, and Wilderness Medical Society
Disclosure: Nothing to disclose.

Pharmacy Editor

Mary L Windle, PharmD, Adjunct Assistant Professor, University of Nebraska Medical Center College of Pharmacy, Pharmacy Editor, eMedicine
Disclosure: Pfizer Inc Stock Investment from broker recommendation; Avanir Pharma Stock Investment from broker recommendation

Managing Editor

Barry J Evans, MD, Assistant Professor of Pediatrics, Temple University Medical School; Director of Pediatric Critical Care and Pulmonology, Associate Chair for Pediatric Education, Temple University Children's Medical Center
Barry J Evans, MD is a member of the following medical societies: American Academy of Pediatrics, American College of Chest Physicians, American Thoracic Society, and Society of Critical Care Medicine
Disclosure: Nothing to disclose.

CME Editor

Mary E Cataletto, MD, Associate Director, Division of Pediatric Pulmonology, Winthrop University Hospital; Professor of Clinical Pediatrics, State University of New York at Stony Brook; Director of Children's Sleep Services, Winthrop University Hospital
Mary E Cataletto, MD is a member of the following medical societies: American Academy of Pediatrics and American College of Chest Physicians
Disclosure: Shering Plough Pharmaceuticals Honoraria Consulting

Chief Editor

Timothy E Corden, MD, Associate Professor of Pediatrics, Co-Director, Policy Core, Injury Research Center, Medical College of Wisconsin; Associate Director, PICU, Children's Hospital of Wisconsin
Timothy E Corden, MD is a member of the following medical societies: American Academy of Pediatrics, Phi Beta Kappa, Society of Critical Care Medicine, and Wisconsin Medical Society
Disclosure: Nothing to disclose.

Further Reading