Sodium Disorders In The Emergency Department: A Review Of Hyponatremia And Hypernatremia

Abstract

Identifying and correcting sodium abnormalities is critical, since suboptimal management potentially leads to substantial morbidity and mortality. Manifestations of hyponatremia, which is one of the more common electrolyte abnormalities in clinical medicine, depend on multiple factors, including the chronicity of the symptoms, the absolute level of sodium, and the patient’s overall health. In symptomatic hyponatremia, emergency clinicians must understand the importance of determining the proper rate of sodium correction in order to avoid encephalopathy, cerebral edema, and death. Hypernatremia is most often due to unreplaced water that is lost from the gastrointestinal tract, skin, or the urine. Acute symptomatic hypernatremia should be corrected rapidly, while chronic hypernatremia is generally corrected more slowly due to the risks of brain edema during treatment. Special circumstances do exist in sodium management, and every patient’s presentation should be evaluated in clinical context.
**Opening Cases**

An 88-year-old woman with history of moderate dementia presents via ground ambulance for irritability and increased weakness after having 2 weeks of cough and vomiting at her extended care facility. She was found febrile and confused during morning nursing rounds. Her past medical history is significant for recent cerebrovascular accident with residual left-sided weakness and chronic kidney disease. Current medications include metformin, hydrochlorothiazide, metoprolol, and aspirin. Her vital signs on arriving in the ED are blood pressure 98/63 mm Hg, pulse 95 beats per minute, respiratory rate 24 breaths per minute, oral temperature 38.3°C, and oxygen saturation 95% on 2 L nasal cannula. On physical exam, she is frail and appears dehydrated, with intermittent confusion. Her pulmonary exam is remarkable for crackles at the right base with mild diffuse abdominal discomfort. Her chest x-ray shows right middle lobe pneumonia. Blood is obtained, and a serum chemistry panel shows sodium 152 mEq/L, potassium 4.0 mEq/L, chloride 108 mEq/L, bicarbonate 14 mEq/L, BUN 55 mg/dL, creatinine 1.7 mg/dL, and glucose 131 mg/dL. The nurse asks you what IV fluids you want and how fast . . .

A 22-year-old graduate student with new-onset seizure activity arrives in the ED from her dormitory. The paramedics state that her roommate called the ambulance because of the patient’s altered behavior and vomiting that had been worsening over the past 5 hours. The roommate also reported that she had mild asthma but no other medical problems and that she took no daily medications. Multiple empty beer cans were found scattered around the dorm room, but no empty pill bottles were seen. On EMS arrival, the patient began seizing, and 2 doses of diazepam, 1 mg each, were administered with no improvement. She arrived in the ED with intermittent tonic clonic seizure activity without return to baseline between events. Her vital signs on arrival are blood pressure 106/44 mm Hg, pulse 135 beats per minute, respiratory rate 14 breaths per minute, oral temperature 36.7°C, and oxygen saturation 90% on 100% oxygen via nonrebreather mask. Her finger-stick glucose is 154 mg/dL. Her seizures persist, despite another 10 mg of lorazepam and 20 phenytoin sodium equivalents (PE)/kg of fosphenytoin. The patient is intubated with no difficulties while a levetiracetam infusion is prepared. A friend of the patient arrives and reports that the patient had been drinking alcohol and using ecstasy at a party. At that point, blood chemistries return, revealing a sodium 104 mEq/L, potassium 2.9 mEq/L, chloride 112 mEq/L, bicarbonate 16 mEq/L, BUN 51 mg/dL, creatinine 1.5 mg/dL, and glucose 159 mg/dL. You realize that the patient’s hyponatremia needs to be emergently corrected, but you wonder: how fast is too fast?

A 33-year-old man collapses at mile 22 of his first full marathon (26.2 miles) and is rushed to the emergency medical tent staffed by EMS providers and EM physicians, including yourself. He is protecting his airway and has a bounding radial pulse, but he is confused, has edema of the fingers and wrists, and is vomiting. He has normal skin turgor and color. His running partner states that he had a mild viral illness all week but made sure to stop at every water stop during the race to try to remain hydrated. The medic establishes IV access, and vital signs reveal a blood pressure 103/60 mm Hg, pulse 121 beats per minute, temperature 38°C, and oxygen saturation 100% via nonrebreather mask. The paramedic you are working with suspects dehydration and tells you that he plans to aggressively rehydrate the athlete with 2 L of normal saline. Fortunately, you have a different plan.

**Introduction**

Disorders of sodium are the most common electrolyte disturbance in clinical medicine. Most sodium disorders are mild and require no acute therapy; Patients with heart failure, patients taking diuretics, and the elderly population are the patients most likely to be seen in the emergency department (ED) with relatively minor degrees of sodium disorders that typically require minor medication adjustments; however, emergency clinicians must recognize and treat these electrolyte abnormalities when indicated, because severe hypernatremia and hyponatremia are both associated with significant morbidity and mortality. Most deaths from sodium abnormalities are due to an underlying disease process; however, recognizing and treating the abnormality can maximize good outcomes and may attenuate complications of the underlying process. Delays in treatment or inadequate treatment of both severe hypernatremia and hyponatremia can be dangerous and even life threatening.

**Critical Appraisal Of The Literature**

An Ovid MEDLINE® search for randomized controlled trials was performed using the search terms hyponatremia and hypernatremia. Studies within the past 12 years were reviewed for practice-changing trials. A total of 36 randomized controlled trials were identified, including 1 landmark animal study. These results were added to a prior search performed 18 months ago that used the same terms with a search span back to 1985. This prior search provided more than 300 articles. A total of 91 review articles published since 2000 in the English language focused on the adult population. In addition, The National Guideline Clearinghouse and the Cochrane Database of Systematic Reviews were queried.
Etiology And Pathophysiology

Volume And Osmolarity Regulation: The Simplified Basics

There are many complex physiological interactions involved in maintaining normal serum sodium, osmolality, and euvoemia. Regulation of osmolarity is predominantly based on the hypothalamus monitoring and adjusting plasma osmolarity via the secretion of antidiuretic hormone (ADH). If osmolarity increases by a small amount, ADH is secreted to retain body water (along with an increased sense of thirst for water) and lower serum osmolarity. Conversely, if a patient’s osmolarity falls, ADH is not secreted and free water is excreted to raise serum osmolarity. Derangement in ADH can result from inappropriate secretion, as in the syndrome of inappropriate antidiuretic hormone secretion (SIADH), in which ADH is secreted even as total body water (TBW) is normal. This increased ADH secretion results in hypo-osmolarity, excess TBW, and resultant hyponatremia. Conversely, the body becomes volume depleted in diabetes insipidus, no ADH is released, and TBW dramatically decreases, leading to hypernatremia.

Volume is regulated by a number of mechanisms, but the most important is the stimulation of the renin-angiotensin system in the kidney. When intravascular volume falls, the renin-angiotensin system is stimulated and aldosterone is released from the adrenal gland, resulting in increased glomerular reabsorption of sodium in exchange for increased excretion of potassium and hydrogen. The increased sodium reabsorption will cause more water to also be reabsorbed by the kidney. If too much circulating volume is sensed by the atria, natriuretic peptides are released, resulting in a diuresis. Derangements in this system are best typified by adrenal insufficiency where there is suboptimal or no aldosterone secretion, resulting in volume contraction and hyponatremia in association with elevations in potassium and a nongap metabolic acidosis. An increase in aldosterone, as seen in Cushing syndrome, does not usually cause hypernatremia, due to other compensatory mechanisms.

Nonetheless, hypokalemia and a metabolic alkalosis do occur as the distal exchange site aggressively reabsorbs sodium in exchange for the excretion of potassium and hydrogen.

Hypernatremia

Hypernatremia is defined as serum sodium > 145 mEq/L and is often associated with morbidity and mortality. It is very uncommon in previously normal patients, and in adults it is almost exclusively due to a TBW deficit. The hyperosmolar state associated with hypernatremia alters a variety of cellular functions, which contributes to metabolic, cardio-vascular, and neurologic complications. Hypernatremia results from the disequilibrium of the balance between water intake and/or the combined water loss from renal excretion and respiratory, skin, and gastrointestinal sources. Under normal conditions, water intake and losses are matched. To maintain salt homeostasis, the kidneys adjust urine concentration to match salt intake and loss.

Most hypernatremic patients have either an impaired sense of thirst or no access to water. Thus, the elderly, infants, patients in coma or with mental impairment, and those who are intubated and paralyzed are at highest risk for this disorder. Other patients at high risk of hypernatremia may have other underlying medical diseases including Conn syndrome, sickle cell disease, or various cancers. Conn syndrome is characterized by increased aldosterone secretion leading to hypernatremia, suppressed plasma renin activity, hypertension, and hypokalemia.

Hypernatremia can be divided into 3 physiologic pairings. (See Table 1.) Diabetes insipidus (a disorder leading to hypernatremia with low TBW and normal total body sodium) can lead to life-threatening hypernatremia with multiple causes. (See Table 2, page 4.)

Table 1. Types Of Hypernatremia

<table>
<thead>
<tr>
<th>Type of Hypernatremia</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypovolemic hypernatremia: decreased total body sodium and decreased TBW</td>
<td></td>
</tr>
<tr>
<td>Heat illness</td>
<td></td>
</tr>
<tr>
<td>Increased insensible losses: burns, sweating</td>
<td></td>
</tr>
<tr>
<td>Gastrointestinal loss: diarrhea, protracted vomiting, continuous gastrointestinal suction</td>
<td></td>
</tr>
<tr>
<td>Osmotic diuresis: glucose, mannitol, enteral feeding</td>
<td></td>
</tr>
<tr>
<td>Euvolemic hypernatremia: normal total body sodium and decreased TBW</td>
<td></td>
</tr>
<tr>
<td>Diabetes insipidus</td>
<td></td>
</tr>
<tr>
<td>Neurogenic</td>
<td></td>
</tr>
<tr>
<td>Elderly with “reset” osmostat</td>
<td></td>
</tr>
<tr>
<td>Hypothalamic dysfunction</td>
<td></td>
</tr>
<tr>
<td>Suprasellar or infrasellar tumors</td>
<td></td>
</tr>
<tr>
<td>Renal disease</td>
<td></td>
</tr>
<tr>
<td>Drugs (amphotericin, phenytoin, lithium, aminoglycosides, methoxyflurane)</td>
<td></td>
</tr>
<tr>
<td>Sickle cell disease</td>
<td></td>
</tr>
<tr>
<td>Hypervolemic hypernatremia: increased total body sodium and increased TBW</td>
<td></td>
</tr>
<tr>
<td>Salt tablet ingestion</td>
<td></td>
</tr>
<tr>
<td>Salt water ingestion</td>
<td></td>
</tr>
<tr>
<td>Saline infusions</td>
<td></td>
</tr>
<tr>
<td>Saline enemas</td>
<td></td>
</tr>
<tr>
<td>Intravenous sodium bicarbonate</td>
<td></td>
</tr>
<tr>
<td>Poorly diluted interval feedings</td>
<td></td>
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<tr>
<td>Primary hyperaldosteronism</td>
<td></td>
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<tr>
<td>Hemodialysis</td>
<td></td>
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<tr>
<td>Cushing syndrome</td>
<td></td>
</tr>
<tr>
<td>Conn syndrome</td>
<td></td>
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</tbody>
</table>

Abbreviation: TBW, total body water.
Hyponatremia

Hyponatremia is defined as serum sodium concentration of < 135 mEq/L. It has been associated with increased mortality, increased length of hospitalization and need for extended care admission, gait imbalance and falls, rhabdomyolysis, and bone fractures. Consequently, hyponatremia has also been linked to increased healthcare costs. The most common causes of symptomatic severe hyponatremia in adults are the following:

- Therapy with thiazide diuretics
- SIADH
- Polydipsia in psychiatric patients
- Unintentional water intoxication
- Patients recovering postoperatively

Gastrointestinal fluid loss, ingestion of dilute baby formula, and accidental ingestion of excessive water are the main causes of severe hyponatremia in infants and children.

Most patients presenting to the ED with hyponatremia are asymptomatic and do not require emergent therapy; however, if symptoms are present, the emergency clinician must be prepared to initiate treatment immediately. Symptoms are based both on the degree of hyponatremia as well as how acutely the drop in sodium occurred. Patient presentations vary from headache, lethargy, and vomiting to disorientation, seizures, encephalopathy, and death.

Hyponatremia has many causes that are subdivided based on the patient’s volume status. The causes of hyponatremia fall into 4 general categories: (1) pseudohyponatremia, (2) hypovolemic hyponatremia, (3) hypervolemic hyponatremia, and (4) euvolemic hyponatremia. (See Table 3.)

Table 2. Common Causes Of Diabetes Insipidus

<table>
<thead>
<tr>
<th>Central</th>
<th>Nephrogenic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idiopathic origin</td>
<td>Chronic renal insufficiency</td>
</tr>
<tr>
<td>Familial disease</td>
<td>Polycystic kidney disease</td>
</tr>
<tr>
<td>Neurosurgery or trauma</td>
<td>Lithium toxicity*</td>
</tr>
<tr>
<td>Cancer</td>
<td>Hypercalcemia</td>
</tr>
<tr>
<td>Hypoxic encephalopathy</td>
<td>Hypokalemia</td>
</tr>
<tr>
<td>Infiltrative disorders</td>
<td>Tubulointerstitial disease</td>
</tr>
<tr>
<td>Supraventricular tachycardia</td>
<td>Heredity</td>
</tr>
<tr>
<td>Anorexia nervosa</td>
<td>Sickle cell disease</td>
</tr>
</tbody>
</table>

Table 3. The 4 Categories Of Hyponatremia

<table>
<thead>
<tr>
<th>Pseudohyponatremia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyperglycemia</td>
</tr>
<tr>
<td>Hyperlipidemia</td>
</tr>
<tr>
<td>Hyperproteinemia (multiple myeloma, macroglobulinemia)</td>
</tr>
<tr>
<td>Laboratory or blood draw errors</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hypovolemic hyponatremia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decreased TBW and sodium, with a relatively greater decrease in sodium</td>
</tr>
<tr>
<td>Body fluid losses</td>
</tr>
<tr>
<td>Sweat, vomiting, diarrhea, GI suction</td>
</tr>
<tr>
<td>Third spacing</td>
</tr>
<tr>
<td>Bowel obstruction, burns</td>
</tr>
<tr>
<td>Renal causes</td>
</tr>
<tr>
<td>Diuretics, mineralocorticoid deficiency, osmotic diuresis, renal tubular acidosis, salt-wasting nephropathies</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hypervolemic hyponatremia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased total body sodium with a relatively greater increase in TBW</td>
</tr>
<tr>
<td>Heart failure</td>
</tr>
<tr>
<td>Chronic renal failure</td>
</tr>
<tr>
<td>Hepatic failure/cirrhosis</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Euvolemic hyponatremia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased TBW with near-normal total body sodium</td>
</tr>
<tr>
<td>SIADH</td>
</tr>
<tr>
<td>Drugs causing SIADH, including diuretics, barbiturates, carbamazepine (Carbatrol®, Epitol®, Tegretol®), chlorpropamide (Diabinese®, Insulase®), clofibrate (Atromid-S®), opioids, SSRIs, tolbutamide (Orinase®, Tol-Tab®), vincristine (Oncovin®)</td>
</tr>
<tr>
<td>Psychogenic polydipsia</td>
</tr>
<tr>
<td>Beer potomania</td>
</tr>
<tr>
<td>Hypothyroidism</td>
</tr>
<tr>
<td>Adrenal insufficiency</td>
</tr>
<tr>
<td>MDMA (ecstasy)</td>
</tr>
<tr>
<td>Accidental or intentional water intoxication</td>
</tr>
</tbody>
</table>

Abbreviations: GI, gastrointestinal; MDMA, 3,4-methylenedioxymethamphetamine; SIADH, syndrome of inappropriate antidiuretic hormone secretion; SSRIs, selective serotonin reuptake inhibitors; TBW, total body water.
Hyponatremia is sometimes considered a cause of pseudohyponatremia; however, it actually causes a dilutional hyponatremia by pulling water into the vascular space by osmosis, as glucose is osmotically active. One formula that is commonly used to correct serum sodium levels based on the degree of a patient’s hyperglycemia advocates adding 1.6 mEq/L to the measured sodium for every 100 mg/dL of glucose above 100 up to about 400, then 4 mEq/L should be added for every additional 100 mg/dL.11 It may be easier for a busy emergency clinician to remember that the maximum fall for every 100 mg elevation in blood glucose is about 2.0 to 2.5 mEq/L of sodium.

**Hypovolemic Hyponatremia**

Hypovolemic hyponatremia—hyponatremia in association with dehydration—occurs when there is decreased extracellular volume combined with an even greater loss of sodium. Hyponatremia secondary to body fluid losses must be differentiated from low sodium secondary to renal losses. Body fluid losses include vomiting, diarrhea, sweating, gastrointestinal suction, and “third spacing,” as in patients with bowel obstruction, burns, or intra-abdominal sepsis. Hypovolemic hyponatremia due to renal causes includes diuretic use, mineralocorticoid deficiency, renal tubular acidosis, and salt-wasting nephropathy. Hypovolemic hyponatremia can be further exacerbated when fluid losses are replaced with hypotonic saline.

Clues to the underlying cause of hypovolemic hyponatremic dehydration may be obtained by evaluating the patient’s serum bicarbonate, chloride, and potassium levels. Hyponatremic patients who have concomitant hypocloremia, alkalosis, and hypokalemia likely have hyponatremia due to protracted vomiting or prolonged gastric suction. A normal gap metabolic acidosis should alert emergency clinicians that diarrhea may be the cause of a patient’s dehydration and hyponatremia. Hyperkalemia with a normal gap acidosis may be an important clue to an underlying diagnosis of adrenal insufficiency.

**Hypervolemic Hyponatremia**

Hypervolemic hyponatremia—hyponatremia with increased extracellular volume—occurs when sodium and water are retained but water retention exceeds sodium retention. On physical examination, most of these patients present with edema. Hyponatremia with increased total body sodium occurs in patients with congestive heart failure, chronic renal failure, and hepatic failure secondary to hypoperfusion of the kidneys, causing high aldosterone secretion and decreased free water excretion.

**Euvolemic Hyponatremia**

The final category of hyponatremia includes patients who are euvoicmic but have increased TBW. The most common causes of this type of hyponatremia include SIADH, psychogenic polydipsia,12 beer potomania,13 hypothyroidism, diuretic use in patients with mild congestive heart failure, and accidental or intentional water intoxication. These patients do not present with edema because most of the increased body water is intracellular and not intravascular.

Patients prescribed various psychiatric medications including selective serotonin reuptake inhibitors (SSRIs) and carbamazepine can develop hyponatremia, likely secondary to excess water intake. The mechanism by which SSRIs cause hyponatremia is thought to be secondary to development of SIADH. Hyponatremia without edema has also been described in patients after the use of the recreational drug ecstasy (3,4-methylenedioxyamphetamine, or MDMA).14 Factors that may contribute to hyponatremia following ecstasy ingestion most commonly include excessive fluid intake secondary to central polydipsia and fluid third-spacing. Beer potomania is a specific hyposmolality syndrome related to consumption of beer, which is poor in solutes and electrolytes.

SIADH is an important cause of hyponatremia that occurs when normal control of ADH secretion is lost and ADH is secreted independent of the body’s need to conserve water. The process results from excess ADH production that causes TBW to increase, diluting the body’s sodium and causing the serum sodium to decrease. The excessive release of ADH is most commonly from the posterior pituitary gland but can also be from other ectopic sources including the lung. Patients with SIADH have inappropriately concentrated urine despite the presence of a low serum osmolality and normal circulating blood volume. Patients with SIADH have excess TBW but no signs of edema, ascites, or heart failure because most of the increased body water is intracellular and not intravascular. In general, patients with SIADH have normal acid-base status, normal potassium balance, and normal adrenal function.

The 3 most common causes of SIADH are the following: (1) pulmonary lung masses and infections, (2) central nervous system disorders, and (3) drug use. (See Table 4, page 6.) Lung cancers (especially small cell cancer), pneumonia, and tuberculosis can lead to SIADH. Central nervous system infections, masses, and psychosis can also cause SIADH. There are a large number of medications associated with SIADH, the most common of which are thiazide diuretics, narcotics, lithium, oral hypoglycemics, barbiturates, antineoplastics, and antiepileptics.

### Differential Diagnosis

Both hypernatremia and hyponatremia can present with very vague complaints involving multiple organ systems, which leads to a broad differential diagnosis. Common complaints with mild to modera-
Hypernatremia

Hypernatremia is a disease seen predominantly in the elderly, but it can also be seen in patients who depend on others to provide them with water, including infants, intubated patients, and persons with mental debilitation. Hypernatremia should be considered as part of the differential in breastfed infants in the first weeks of life and elderly patients who are institutionalized; however, most patients will also have multifactorial etiologies leading to severe hypernatremia.

Patients with hypernatremia often present with nonspecific symptoms such as irritability, nausea, weakness, abdominal pain, lethargy, and tachypnea. Patients or caregivers may have noted polyuria or polydipsia, or patients may have obvious signs of extrarenal fluid losses. Other patients may have no complaints at all. The degree of dehydration may be underestimated because intravascular volume is maintained. In severe cases of hypernatremia, coma, convulsions, pulmonary edema, and shock due to severe intracellular fluid loss can develop rapidly. Hypernatremia should be considered in any patient presenting with altered mental status, especially individuals with severe mental retardation or head injury as well as in bedridden patients who have no access to water.

Hyponatremia

The signs and symptoms of hyponatremia correlate with the rapidity at which hyponatremia develops, and they increase as sodium levels decline. Nonspecific signs of hyponatremia include anorexia, nausea, vomiting, and generalized weakness. Acutely hyponatremic patients whose sodium drops to < 120 mEq/L over 24 to 48 hours may present with severe neurologic findings including confusion, seizures, cerebral edema, coma, or brainstem herniation. Determining the hydration status of the patient may help establish the etiology of the hyponatremia and help direct subsequent treatment. The diagnosis of hypovolemic hyponatremia is more likely in the patient with diminished skin turgor, decreased capillary refill, dry mucous membranes, and orthostasis. On the other hand, the patient with jugular venous distension, peripheral edema, or pulmonary congestion is much more likely to have hypervolemic hyponatremia. Patients presenting with SIADH or other euvoletic hyponatremia will not present with edema because most of the increased body water is intracellular and not intravascular.

Diagnostic Studies

Hyponatremia

In patients with concern for hypernatremia, serum osmolarity as well as urine sodium concentration and osmolality should be obtained in addition to
Routine serum chemistries. In adults, the degree of hypernatremia almost always equals the TBW deficit. The patient’s TBW deficit can be estimated by using the following formula:

\[
\text{TBW deficit} = \text{TBW} \times \left(\frac{\text{serum Na}}{140}\right) - 1
\]

A patient’s TBW is usually calculated by multiplying the patient’s body weight in kilograms times 0.6; however, due to body fat differences based on the age and sex of the patient, it is more accurate to use the correction factors listed in Table 5.

For example, a 78-year-old male patient weighing 60 kg is brought to the ED with altered mental status. He is found to have a serum sodium of 160 mEq/L. The patient’s TBW deficit is:

\[(0.5 \times 60 \text{ kg}) \times (160/140) - 1 = 30 \times (1.143 - 1) = 4.29 \text{ (4290 mL)}\]

**Hyponatremia**

In order to determine whether the etiology of the hyponatremia is secondary to renal causes, a spot urine sodium and/or urine chloride should be obtained. Patients with hypovolemic hyponatremia due to renal causes will have elevated urine sodium levels > 20 mEq/L, as their kidneys cannot retain sodium or chloride. Thus, their kidneys are inappropriately wasting sodium even in the face of hyponatremia. On the other hand, patients with hypovolemic hyponatremia due to nonrenal causes typically have a low urine sodium or chloride (< 20 mEq/L) as they try to retain solute. Thus, these patients are appropriately retaining sodium due to their hyponatremia. Patients with euvolemic hyponatremia typically have a urine sodium concentration > 20 mEq/L, whereas those with renal causes of hypervolemic hyponatremia or with SIADH have sodium levels > 20 mEq/L, as their kidneys are not retaining sodium.

When interpreting serum sodium levels, always consider the possibility of sampling error if the reported value does not seem consistent with the patient’s presentation, and confirm that a diuretic, such as furosemide (Delone®, Furocot®, Lasix®), has not been recently administered, as these will increase urinary sodium losses. It is essential that adrenal insufficiency be considered when a dehydrated patient has both hyponatremia and hyperkalemia.

Comparing the serum osmolality to the urine osmolality may help diagnose the cause of the patient’s hyponatremia. The serum osmolality should normally mirror the patient’s volume status. Thus, a volume-contracted dehydrated (hyperosmolar) patient should have a concentrated urine with high osmolality and a volume-overloaded (hypo-osmolar) patient should have a very dilute hypo-osmolar urine. If a hyponatremic hypo-osmolar patient has a nonmaximally dilute urine and is wasting sodium, SIADH should be suspected. Similarly, if a hyperosmolar hypernatremic patient has a dilute urine (and is wasting free water), diabetes insipidus should be expected.

**Table 5. Correction Factors For Calculating Body Water Deficit**

<table>
<thead>
<tr>
<th>Population</th>
<th>Correction Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children and adult males</td>
<td>Total body weight (kg) x 0.6</td>
</tr>
<tr>
<td>Adult females</td>
<td>Total body weight (kg) x 0.5</td>
</tr>
<tr>
<td>Elderly males</td>
<td>Total body weight (kg) x 0.5</td>
</tr>
<tr>
<td>Elderly females</td>
<td>Total body weight (kg) x 0.46</td>
</tr>
</tbody>
</table>

**Treatment**

**Hyponatremia**

The treatment of hyponatremia has 3 interdependent goals:

1. Quickly correct underlying shock, hypoperfusion, or significant hypovolemia with normal saline;
2. Treat the underlying cause of hyponatremia (such as fever, vomiting, diarrhea, or diabetes insipidus); and
3. Carefully lower the serum sodium level, usually by replacing the body’s total water deficit.

Until hypoperfusion and hypovolemia are corrected, homeostatic mechanisms for sodium balance will promote sodium resorption to maintain intravascular volume, even at the expense of the serum sodium concentration.

The rate of correction in hyponatremia is extremely important to minimize complicating the patient’s care and avoid life-threatening cerebral edema and seizures. There are no data to suggest that the etiology of the hyponatremia alters the likelihood of developing osmotic demyelination with overly rapid correction. The rate of correction of hypernatremia must be taken into account before deciding on the most appropriate therapy for any patient with hypernatremia.

In adult patients who have developed hypernatremia over a short period of time due to sodium loading, rapid correction at 1 to 2 mEq/L/h by lowering serum sodium is relatively safe.19,20 Nonetheless, in patients with chronic hypernatremia or in cases where the duration of hypernatremia is unknown, rapid correction of the water deficit should be avoided. In this patient population, slow correction of hypernatremia over a period of 2 to 3 days should be expected.
Clinical Pathway For Management Of Hypernatremia
In The Emergency Department

Hypernatremia
Serum sodium > 145 mEq/L

Hypovolemic
• TBW decreased
• Total body sodium decreased

• Urine osmolality > 600 mOsm/kg
• Urine sodium < 20 mEq/L

• Insensible losses
• GI losses
• Burns
• Heat illness

Euvolemic
• TBW decreased
• Total body sodium normal

• Urine osmolality 300-600 mOsm/kg
• Urine sodium > 20 mEq/L

• Osmotic diuresis
• Hyperglycemia
• Mannitol
• Urea
• Enteral feeds

Hypervolemic
• TBW increased
• Total body sodium increased

• Urine sodium > 20 mEq/L

• Cushing syndrome
• Conn syndrome
• Primary hyperaldosteronism
• Salt ingestions

Hemodynamically stable?
YES

Sodium elevation acute?
YES

NO

Rapid lowering of serum sodium 1-2 mEq/L/24h (Class I)

Slow correction over period of 48 h at no more than 0.5 mEq/L/h or 10-12 mEq/L/24h (Class I)

Diabetes insipidus
Reverse underlying causes (Class I)

Adequate thirst?
YES

NO

Drink fluid to replace urine losses

Removal of excess sodium; consider D5W and diuretics

IV fluids that are hypotonic compared to serum sodium (Class I)

Desmopressin (Class II)

Indeterminate

Each action in the clinical pathways section of Emergency Medicine Practice receives a score based on the following definitions.

Class I
• Always acceptable, safe
• Definitely useful
• Proven in both efficacy and effectiveness
Level of Evidence:
• One or more large prospective studies are present (with rare exceptions)
• High-quality meta-analyses
• Study results consistently positive and compelling

Class II
• Safe, acceptable
• Probably useful
Level of Evidence:
• Generally higher levels of evidence
• Nonrandomized or retrospective studies: historic, cohort, or case control studies
• Less robust randomized controlled trials
• Results consistently positive

Class III
• May be acceptable
• Possibly useful
• Considered optional or alternative treatments
Level of Evidence:
• Generally lower or intermediate levels of evidence
• Case series, animal studies, consensus panels
• Occasionally positive results

Indeterminate
• Continuing area of research
• No recommendations until further research
Level of Evidence:
• Evidence not available
• Higher studies in progress
• Results inconsistent, contradictory
• Results not compelling


Abbreviations: D5W, 5% dextrose in water; GI, gastrointestinal; IV, intravenous; NS, normal saline, TBW, total body water.

Class Of Evidence Definitions

This clinical pathway is intended to supplement, rather than substitute for, professional judgment and may be changed depending upon a patient’s individual needs. Failure to comply with this pathway does not represent a breach of the standard of care.

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Clinical Pathway For Management Of Hyponatremia In The Emergency Department

Hyponatremia
Sodium < 135 mEq/L

Serum osmolality?

High, due to:
• Hyperglycemia
• Mannitol

Low (contracted) hypovolemic

Normal, due to:
• Pseudohyponatremia
• Hyperlipidemia
• Paraproteinemia
• Blood draw/laboratory error

Low (hypotonic)

Low, due to:
• Pseudohyponatremia
• Hyperlipidemia
• Paraproteinemia
• Blood draw/laboratory error

Treat with:
• Fluid restriction (Class I)
• Sodium restriction (Class I)
• Diuretics (CHF) (Class II)
• Vaptans (Class II)
• Albumin (cirrhosis) (Class III)
• Paracentesis (cirrhosis) (Class III)
• Hemodialysis (renal failure) (Class III)

Extracellular fluid volume?

Limited fluid shift (euvolemic)
• CHF
• Cirrhosis
• Nephrotic syndrome
• Toxemia of pregnancy
• Renal failure

Treat with:
• Elimination of underlying cause (Class I)
• Free water restriction (Class I)
• Hypertonic saline (Class I)
• Vaptans (Class II)
• Demeclocycline (Class indeterminate)

High (expanded) hypervolemic

• CHF
• Cirrhosis
• Nephrotic syndrome
• Toxemia of pregnancy
• Renal failure

Treat with:
• Fluid restriction (Class I)
• Sodium restriction (Class I)
• Diuretics (CHF) (Class II)
• Vaptans (Class II)
• Albumin (cirrhosis) (Class III)
• Paracentesis (cirrhosis) (Class III)
• Hemodialysis (renal failure) (Class III)

Extrarenal losses
• Diarrhea
• Vomiting
• Burns
• Sweating
• Blood loss
• Third spacing

Treat underlying cause (Class I)
• Trial of volume expansion with 0.9% NS (Class I)
• 3% hypertonic saline (severe) (Class II)
• Consider potassium repletion (diuretics) (Class II)

Renal losses
• Diuretics
• Osmotics
• Renal tubal acidosis
• Cerebral salt wasting
• Primary adrenal insufficiency

Treat underlying cause (Class I)
• Trial of volume expansion with 0.9% NS (Class I)
• 3% hypertonic saline (severe) (Class II)

Renal losses
• Diuretics
• Osmotics
• Renal tubal acidosis
• Cerebral salt wasting
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Treat underlying cause (Class I)
• Trial of volume expansion with 0.9% NS (Class I)
• 3% hypertonic saline (severe) (Class II)

Note: Treatments are listed in order from most recommended to consideration.
Abbreviations: CHF, congestive heart failure; MDMA, 3,4-methylenedioxymethamphetamine; NS, normal saline; SIADH, syndrome of inappropriate antidiuretic hormone secretion.
days has been recommended, at no more than 0.5 mEq/L/h or 10 to 12 mEq/L/24h.\textsuperscript{19}

Typically, patients can be started on normal saline for volume replacement until they are hemodynamically stable and then changed to half-normal saline at 100 mL/h once their vital signs have normalized. The treatment of central diabetes insipidus with desmopressin (DDAVP\textsuperscript{19}), a synthetic analogue of ADH available in subcutaneous, intranasal, and oral preparations, is an effective means of improving polyuria. Table 6 shows the most common dosing regimens.

For fluid-overloaded patients with hyponatremia, the proper therapy is water administration or its parenteral equivalent, D5W, in conjunction with furosemide. This combination achieves negative sodium balance with neutral or negative fluid balance.

**Hyponatremia**

Treatment of hyponatremia must be guided by the patient’s clinical presentation, severity of symptoms, estimated duration of illness, fluid status, and underlying etiology for the sodium disturbance. There are 2 groups of hyponatremic patients that will require treatment with either normal saline or hypertonic saline. The 2 groups include patients with: (1) severe but asymptomatic hyponatremia with a sodium level ≤ 110 mEq/L, and (2) acute symptomatic hyponatremia with a sodium level < 120 mEq/L.

Most patients presenting to the ED with hyponatremia are stable and require no emergent therapy; however, asymptomatic patients who have severe hyponatremia with serum sodium levels of ≤ 110 mEq/L and those who have acute alterations in mental status, seizures, or new focal findings due to hyponatremia with serum levels < 120 mEq/L need immediate intervention. Table 7 presents the sodium concentration of various infusates. The following equation is helpful to estimate the effect of 1 L of any infusate on serum sodium:

\[
\text{Change in serum Na}^+ \,(\text{mEq/L}) = \frac{\text{infusate Na}^+ \,(\text{mEq/L}) - \text{serum Na}^+ \,(\text{mEq/L})}{\text{TBW} + 1}
\]

For the past 30 years, the treatment of hyponatremia has remained controversial. In the early 1980s, central pontine myelinolysis, now more accurately labeled as osmotic demyelination syndrome, was described with rapid correction of sodium. Central nervous system damage due to hyponatremia may be caused by cerebral edema and increased intracranial pressure, by osmotic fluid shifts during overly aggressive treatment, or both. When subjected to a hyponatremic environment, neurons become depleted of sodium and potassium as they attempt to limit their own osmolarity to prevent intracellular fluid shifts that would lead to cerebral edema. If fluid therapy raises extracellular sodium levels too quickly, fluid is pulled out of neurons and diffuse demyelination may occur, leading to flaccid paralysis and, often, death due to this osmotic demyelination syndrome.\textsuperscript{21}

While reports of sodium disturbances leading to demyelination syndromes were being published, reports were also being made claiming that severe hyponatremia itself could cause life-threatening brain damage. As of today, the rate at which profound hyponatremia should be corrected is the focus of continued clinical debate. There is no consensus about the optimal treatment of symptomatic hyponatremia. In his well-known 1990 article, Tomas Berl discusses the difficult clinical dilemma that physicians face with patients presenting with symptomatic hyponatremia because of the different clinical guidelines and lack of true consensus.\textsuperscript{22} There is a very fine line between correcting the sodium too quickly versus too slowly, and inappropriate management can be devastating.

Fortunately, over the past few years, we are coming closer to a consensus regarding the optimal treatment of hyponatremia. There is agreement among physicians that correction should occur at a sufficient pace and magnitude to reverse the manifestations of hypotonicity, but not so rapid and large to pose a risk of developing osmotic demyelination. In patients with chronic hyponatremia, neurologic sequelae are more likely to occur with rapid rates of sodium correction.\textsuperscript{23,24}

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**Table 6. Desmopressin Dosing**

<table>
<thead>
<tr>
<th>Route</th>
<th>Dosage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intranasal</td>
<td>5-40 mcg/qd or divided q8-12h</td>
</tr>
<tr>
<td>Oral</td>
<td>Initially 0.05 mg q12h, Effective range: 0.1-1.2 mg divided q8-12h</td>
</tr>
<tr>
<td>Subcutaneous</td>
<td>2-4 mcg/qd, divided q12h</td>
</tr>
</tbody>
</table>

Abbreviation: q, every.

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**Table 7. Characteristics Of Infusates**

<table>
<thead>
<tr>
<th>Infusate</th>
<th>Infusate Na(^+) (mEq/L)</th>
<th>Extracellular Fluid Distribution (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3% hypertonic saline</td>
<td>513</td>
<td>100</td>
</tr>
<tr>
<td>0.9% NS</td>
<td>154</td>
<td>100</td>
</tr>
<tr>
<td>LR</td>
<td>130</td>
<td>97</td>
</tr>
<tr>
<td>½NS</td>
<td>77</td>
<td>73</td>
</tr>
<tr>
<td>0.2% NaCl + D5W</td>
<td>34</td>
<td>55</td>
</tr>
<tr>
<td>D5W</td>
<td>0</td>
<td>40</td>
</tr>
</tbody>
</table>

Abbreviations: D5W, 5% dextrose in water; LR, lactated Ringer; NS, normal saline.
A prospective study looking at neurological outcomes with serial magnetic resonance imaging in hyponatremic patients found that the correction rate of hyponatremia plays a significant role in the pathogenesis of pontine lesions in individuals with profound hyponatremia who undergo large increases in sodium concentration as a result of severe initial hyponatremia. A comparative multicenter study evaluating 64 patients concluded that patients with severe chronic hyponatremia are most likely to avoid neurologic complications when their electrolyte disturbance is corrected slowly.

After weighing the available evidence, Adrogué and Madias recommended a targeted rate of correction that does not exceed 8 mEq/L on any day of treatment. Remaining within this target, the initial rate of correction can be 1 to 2 mEq/L/h for several hours in patients with severe symptoms. In order to minimize the likelihood of osmotic demyelination syndrome, it is essential that symptomatic patients with severe hyponatremia not have their serum sodium levels rise by any more than a total of 10 to 12 mEq/L within the first 24 hours. In a multicenter trial of patients with hyponatremia, no neurologic complications were observed in patients corrected by < 12 mEq/L/24h or by < 18 mEq/L/48h.

Most cases of osmotic demyelination syndrome occur in the alcoholic, malnourished, and elderly population, although this devastating side effect can occur in healthy, young patients as well. Patients with osmotic demyelination syndrome develop a flaccid paralysis, dysarthria, dysphagia, and hypotension. If a patient develops these symptoms during therapy, stop all sodium-containing fluids and administer D5W immediately to temporarily lower serum sodium levels. Reversal of symptoms has been shown, experimentally, in numerous animal studies and also in 3 human case reports.

For relatively asymptomatic patients with sodium values of 115 to 135 mEq/L, a trial of free water restriction to < 0.8 L/d to 1.25 L/d can be attempted. This includes all fluids, including water contained in food and medications. Serum sodium level should be measured at regular intervals to look for improvement.

In more-severe cases, when the sodium is ≤ 120 mEq/L and the patient has either alterations in mental status, focal neurological findings, or seizures, hypertonic saline is indicated. A consensus statement in 2005 suggested that 3% hypertonic saline be used for symptomatic patients, either as a 100 mL (513 mEq of Na+/L) rapid infusion followed by 100 mL/h or at a rate of 1 to 2 mL/kg/h. If a second bolus is required, an additional 100 mL of the 3% solution may be administered over the next 50 minutes. Correction of hyponatremia by 4 to 6 mEq/L within 6 hours, with bolus infusions of 3% saline if necessary, is sufficient to manage the most severe manifestations of hyponatremia. In a prospective observational study of 58 patients with euvoletic acute symptomatic severe hyponatremia, administration of 100 mL of 3% hypertonic saline resulted in a mean increase in serum sodium of 2 mEq/L. Studies have also shown that infusing 3% saline at a rate of 1 to 2 mL/kg/h results in an increase in serum sodium of 1 mEq/L/h to 2 mEq/L/h.

Potassium deficits must also be replaced aggressively when treating hyponatremic patients. If patients are retaining volume and not diuresing adequately, furosemide can be used. Many authorities recommend concomitant furosemide, although some recommend avoiding it or reserving it for patients with extracellular fluid volume expansion.

Patients may be able to make full neurologic recoveries from osmotic demyelination syndrome with the re-induction of hyponatremia in these extreme cases. In patients with refractory hyponatremia, demeclocycline (Declomycin®) induces nephrogenic diabetes insipidus and helps to correct hyponatremia in a dosage of 600 to 1200 mg daily.

**Hypovolemic Hyponatremia**

Treatment of hypovolemic hyponatremia begins with rehydration. Hypotensive, dehydrated patients are volume resuscitated with normal saline, but once they are hemodynamically stable, the infusion rate is slowed. Typically, the normal saline is started at 500 to 1000 mL/h until the blood pressure is stable and then slowed to 200 mL/h with frequent sodium checks. If the sodium is < 120 mEq/L, the sodium should only be allowed to rise by an average of 0.5 mEq/h and 10 to 12 mEq/d. It is also essential to treat the underlying cause of hyponatremia.

**Hypervolemic Hyponatremia**

Normal saline and hypertonic saline can cause pulmonary edema in the hypervolemic hyponatremic patient. Fluid and sodium restriction is the preferred treatment of patients with hypervolemic hyponatremia. Patients with congestive heart failure contributing to their hyponatremia will usually benefit from diuretics that will increase water secretion and cause vasodilation to improve cardiac output. In patients with liver failure, consider utilizing albumin and diuretics and performing a paracentesis to improve the underlying pathology. Hemodialysis is an alternative in patients with renal impairment and will be required in significantly hyponatremic renal failure patients with volume overload. When dispositioning the patient, it is important to discuss water restriction with the inpatient service because it may make the largest impact in these patients’ long-term care.
Euvolemic Hyponatremia

The mainstay of treatment for euvolemic hyponatremia is free-water restriction. As the hypo-osmolality in SIADH results from a relative abundance of water in the intracellular and extracellular volumes and is maintained by a reduced ability to excrete water, the restriction of oral free water intake is usually the most effective therapy and was recommended by a 2007 expert panel on hyponatremia.27 Nonetheless, the use of water restriction is insufficient to treat acute severe hyponatremia, and it is not recommended as the sole intervention in severely symptomatic hyponatremia in which a more rapid correction rate is necessary. The only definitive treatment of SIADH is elimination of its underlying cause. In cases of hyponatremia associated to oxcarbazepine (Trileptal®) and other antiepilepsy medications, all cases resolved spontaneously when the drug treatment was stopped.37

Somewhat surprisingly, the use of normal saline in patients with SIADH may cause the serum sodium to decrease even more, as free water is retained and hypertonic urine is excreted; however, a trial of normal saline may be considered when trying to differentiate between a hypovolemic patient and a euvolemic patient. From a study of a series of 17 patients with chronic SIADH, Musch and Decaux concluded that the infusion of 0.9% normal saline raises the serum sodium when the urine osmolality is < 530 mOsm/L.38 If a patient is symptomatic due to a rapid decrease in serum sodium concentration, treatment with hypertonic saline is recommended. Demeclocycline and lithium are rarely utilized in the treatment of SIADH due to their many side effects and nephrotoxicity. Rapid correction of hyponatremia can be obtained via hemodialysis. To minimize the risks of osmotic demyelination syndrome, hemodialysis is reserved for patients with documented renal failure and is utilized in a very careful manner.

A 2007 expert panel assessed the potential contributions of aquaretic nonpeptide small-molecule arginine vasopressin receptor antagonists, also known as vaptans, to hyponatremia therapies.27 Currently, intravenous conivaptan (Vaprisol®) and oral tolvaptan (Samsca®) are FDA approved for use in the treatment of euvolemic and hypervolemic hyponatremia. In 2 multicenter randomized double-blind placebo-controlled trials known as the SALT-1 and SALT-2 clinical trials, the efficacy of tolvaptan was evaluated in patients with euvolemic or hypervolemic hyponatremia and was found to increase serum sodium concentrations at day 4 and day 30 more than placebo.39 In addition, a recent single-center study retrospectively examined 18 patients who were hyponatremic due to SIADH who were treated with conivaptan. The study found that 66.7% of the patients had an absolute increase in serum sodium of at least 4 mEq/L within 24 hours.40

Special Circumstances

Exercise-associated hyponatremia (EAH) is the occurrence of hyponatremia during or up to 24 hours after prolonged physical activity. EAH is defined by a serum or plasma sodium concentration < 135 mEq/L. Approximately 5% to 30% of endurance cyclists, triathletes, and runners may develop hyponatremia during their events, and although most will be asymptomatic, life-threatening hyponatremia can occur and fatalities have been reported.41,42 Several risk factors have been identified for the development of EAH, including exercise duration > 4 hours, female gender, low body weight, excessive drinking during the event, preexercise dehydration, nonsteroidal anti-inflammatory agents, and lack of heat acclimation. In the majority of athletes that develop EAH, there is an increase in TBW relative to that of total body exchangeable sodium, leading to a dilutional effect.

The incidence of EAH was very rare prior to 1981, when there was a movement that encouraged athletes to consume as much fluid as possible during races; however, excessive water and sports beverage intake is not the sole explanation for the development of EAH.

Ideally, medical facilities would be able to rapidly assess sodium at the end of an endurance event, but recognizing EAH by clinical criteria is often necessary if equipment is not available. As emergency clinicians, it is important to be familiar with the differences between dehydration and EAH, as the inappropriate administration of fluids can be devastating.43 The spectrum of EAH ranges from bloating, nausea, vomiting, edema (particularly of ring fingers and wrists), and headache all the way to hyponatremic encephalopathy that develops as a result of cerebral edema leading to altered mental status, seizures, pulmonary edema, and death. More commonly, dehydrated athletes have poor skin turgor, excessive thirst, sunken eyes, and postural hypotension. EAH often becomes symptomatic after the event, as water continues to be absorbed from the gastrointestinal tract.

Medical providers at endurance events need to be aware of EAH and avoid incorrectly diagnosing dehydration and erroneously beginning normal saline infusions. The specific treatments will depend on the clinical presentation of the patient. Most athletes with mild, asymptomatic hyponatremia that would likely be recognized only on laboratory testing will improve with fluid restriction, until they spontaneously diurese. The definitive treatment for EAH encephalopathy is immediate administration of a 100 mL bolus of 3% intravenous saline. If the patient is not clinically improving after the initial bolus, the athlete can be treated with up to 2 additional 100 mL 3% NaCl bolus infusions at 10-minute
1. “The extended-care facility sent the elderly patient here for treatment of her urinary tract infection.”
   Often, the elderly patient cannot provide a good history on arrival to the ED. Always check electrolytes in elderly patients with underlying medical problems.

2. “The patient was significantly dehydrated from her gastrointestinal illness, so 2 large-bore IVs were established, and I ran normal saline in on the pressure bag as fast as possible.”
   Never correct sodium disorders too rapidly. Be aware that normal saline is not always the initial fluid of choice in hyponatremia or hypernatremia.

3. “After the marathon, the runner presented to the medical tent complaining of headache and nausea. The medic gave her a 32-ounce bottle of water and a 16-ounce bottle of sports beverage and told her to drink them both quickly.”
   Always consider hyponatremia in any runner or endurance athlete with altered mental status. After a long endurance event, altered behavior, nausea, vomiting, and headache may not be secondary to dehydration.

4. “The patient is currently undergoing chemotherapy for lung cancer and presented to the ED with cold-like symptoms. She was found to have a sodium of 116 mEq/L. On review of her records, her sodium at her last oncology clinic visit, 2 weeks prior, was 119 mEq/L.”
   Never raise serum sodium by more than 10 to 12 mEq/d in patients with chronic hyponatremia.

5. “The patient presented with fatigue, weakness, diarrhea, loss of appetite, and weight loss. Her sodium was found to be 126 mEq/L on evaluation. She said she had been craving salty foods for the past month and had also noticed some significant hair loss.”
   Always consider adrenal insufficiency in hyponatremia patients who are either dehydrated, acidotic, and/or hyperkalemic.

6. “The patient presented from her dormitory with seizure activity, and her sodium was found to be 131 mEq/L. I began intravenous fluid replacement to correct her hyponatremia, but I didn’t evaluate her for meningitis.”
   Mild to moderate hyponatremia (sodium 125 mEq/L to 135 mEq/L) does not cause altered mental status or seizures. Look for another cause.

7. “A diabetic patient presented via ground EMS with altered mental status and tachycardia. Her venous blood gas, obtained immediately, revealed a blood sugar of 650 mg/dL and a sodium of 118 mEq/L.”
   Hyperglycemia can cause hyponatremia; correct the glucose elevation, not the sodium fall. The body tries to maintain stable osmolarity in the setting of profound hyperglycemia.

8. “The patient’s sodium improved from 120 mEq/L on arrival to 130 mEq/L at the time the admission request was initiated. She was transferred to the observation area to await her bed upstairs in the medical wing. The nurse called me to report that the patient was significantly hypotensive and having stroke-like symptoms.”
   Always check sodium hourly in patients with severe hyponatremia.

9. “He came to the ED with a blood sugar that was very elevated, but his serum sodium was normal.”
   A significantly hyperglycemic patient with a normal sodium level is very dehydrated and has hypernatremic dehydration.

10. “He was brought to the ED from a bar because his friends were concerned that he had something slipped into his drink. They informed the emergency clinician that, although he drinks frequently, he had never acted this drunk before.”
    Remain cautious when diagnosing alcohol intoxication without further evaluation. Sodium abnormalities frequently occur in heavy alcohol abuse and MDMA (ecstasy) dependence.
intervals. In this special population of hyponatremic patients, the emergency clinician can assume that the hyponatremia is acute and be comforted by the fact that there are no reported cases of osmotic demyelination syndrome with aggressive treatment of EAH. After initial stabilization, either in the field or in the hospital, EAH can be treated with standard hyponatremia protocols.

Controversies And Cutting Edge

Multiple literature sources continue to state that there is controversy in the management of hyponatremia; fortunately, fluid management strategies are becoming more standardized in emergency medicine. Newer agents, such as the vaptans, have shown promising results and may be useful in the treatment of hyponatremia. Hyponatremia is increasingly recognized as an independent prognostic marker that adversely affects morbidity and mortality in heart failure. Current research is looking at the addition of vaptans to a standard heart failure treatment regimen in hyponatremic patients and whether they may offer additional survival benefits. The efficacy of vaptans may be beneficial as an adjunctive therapy and may prevent hyponatremia in cases of EAH as well.

It remains uncertain whether sodium disturbances are a marker of poor prognosis or an active contributor to adverse outcomes, but evidence of direct adverse effects on multiple organ systems continues to emerge in the medical literature.

Time- And Cost-Effective Strategies

1. Do not treat sodium abnormalities in a patient when the finding is incidentally discovered in a laboratory draw in a completely asymptomatic patient with mild sodium abnormalities.
2. Water restriction may be the only necessary intervention in some patients with sodium abnormalities.
3. Be cautious when prescribing medications—especially diuretics—for elderly patients, in order to avoid potential sodium disturbances and their complications.
4. Educate ancillary staff on blood draw techniques to avoid false hyponatremia from a blood sample drawn near an infusion site using D5W or D5½NS.
5. Inform the community about the risks of exercise-associated hyponatremia and the important preventative recommendations to avoid serious illness and hospitalization.

Disposition

Disposition of patients with hypernatremia or hyponatremia will vary for each individual patient depending on the severity of symptoms, the etiology of the underlying cause of the electrolyte abnormality, the degree of sodium abnormality, and the patient’s response to treatment.

In all patients with hyponatremia and hypernatremia, the cause should be identified and treated. Some conditions, such as congestive heart failure or the use of diuretics, are obvious causes of hyponatremia. Other causes, such as SIADH and endocrine deficiencies, usually require further evaluation before identification and appropriate treatment.

Patients who are asymptomatic or those with mild symptoms can often be discharged home to follow up closely with primary care providers. Some patients with underlying cardiac disease or endocrine abnormality will require expert consultation and likely admission, while patients with unstable vital signs, altered mental status, or seizure activity may require intensive care admission.

The prognosis for hyponatremia generally depends on the underlying etiology causing the sodium disturbance. In general, acute hyponatremia that occurs in < 48 hours is more dangerous than hyponatremia that develops slowly over time. In the general adult hospitalized population, Anderson et al found that mortality rates were 60-fold higher in patients with even asymptomatic hyponatremia compared to patients with normal sodium levels. Patients with hypernatremia often have other serious comorbidities, so it is difficult to precisely evaluate mortality directly due to hypernatremia; however, delays in treatment or inadequate treatment increase both morbidity and mortality, especially in elderly patients.

Summary

Sodium abnormalities can be a challenging issue in the ED because they are often difficult to manage appropriately in both the acute and the chronic phase. It is important to not only be able to differentiate between the 4 categories of hyponatremia and the 3 types of hypernatremia but also to understand the treatment approach in the emergency setting. Physical examination findings are vague, but patient history often leads to considering sodium disorders in the differential diagnosis. Acute symptomatic hyponatremia, whether self-induced, drug-related, or hospital-acquired, is a medical emergency that demands immediate recognition and intervention. Inappropriate correction of sodium abnormalities can rapidly lead to morbidity and mortality. It remains uncertain whether dysnatremia is a marker of poor prognosis or an active contributor to adverse
outcomes, but evidence of direct adverse effects on multiple organ systems is emerging.

**Case Conclusions**

Your elderly patient had multiple medical concerns that required emergent evaluation. You diagnosed her with severe hypernatremia, likely secondary to her underlying disease processes, combined with a lack of access to free water. In addition to her pneumonia, she had been having gastrointestinal losses from vomiting, along with her known underlying renal insufficiency. On arrival, she was hypotensive and febrile. You immediately established 2 large-bore IVs, placed her on 2 L oxygen via nasal cannula, and obtained a finger-stick blood glucose. You began her management by correcting her hypoperfusion and hypovolemia with a 500-mL NS bolus followed by a second 500-mL NS bolus for her persistent hypotension after the pulmonary exam and confirmation of her past medical history. You then began treatment of the underlying causes of her hypernatremia with antipyretics, antiemetics, and antibiotics for her fever, vomiting, and pneumonia, respectively. After 2 NS boluses, her vital signs normalized, and slow correction of hypernatremia was initiated with ½ NS at 100 mL/h over 48 hours as an inpatient.

Your grad student patient was suffering from hypernatremia likely secondary to the use of MDMA (ecstasy) at the party. On arrival, she was having seizure activity that was unresponsive to benzodiazepines, so you secured her airway with endotracheal intubation, confirmed bilateral breath sounds, and established 2 large-bore IVs. You rechecked her blood glucose and administered naloxone. She did not have any improvement, so you administered 100 mL of 3% NS over 10 minutes, followed by a second bolus of 100 mL of the 3% solution en route to the ICU. The patient’s sodium was slowly corrected over 72 hours, and she was successfully extubated and hemodynamically stable on hospital day 3.

Based on the athlete’s normal skin turgor and color, the edema of his upper extremities, the lack of hyperthermia, and reports that he had been drinking water at every race stop, you suspected EAH and sent him to the ED.

In the ED, his serum sodium level was found to be 112 mEq/L, and a 100-mL bolus of 3% IV NS was immediately initiated. The patient continued to be confused and vomiting, and a second 100-mL 3% NS bolus infusion was given, after which, his mental status began to clear. An NS infusion at a rate of 200 mL/h was started, and he was discharged 12 hours later, feeling well.

**References**

Evidence-based medicine requires a critical appraisal of the literature based upon study methodology and number of subjects. Not all references are equally robust. The findings of a large, prospective, randomized, and blinded trial should carry more weight than a case report.

To help the reader judge the strength of each reference, pertinent information about the study will be included in bold type following the reference, where available. In addition, the most informative references cited in this paper, as determined by the authors, are noted by an asterisk (*) next to the number of the reference.

1. An 89-year-old male with a history of dementia presents to the ED with confusion and vomiting. On evaluation in the ED, his vital signs are stable, but he is lethargic and disoriented. Further history was unobtainable. Laboratory evaluation is remarkable for a sodium of 165 mEq/L, potassium of 4.6 mEq/L, chloride of 118 mEq/L, bicarbonate of 28 mEq/L, BUN of 31 mg/dL, and creatinine of 1.1 mg/dL. Urine-specific gravity is 1.030. His hyponatremia is most likely due to:

a. Lack of free water intake and secondary dehydration
b. Central diabetes insipidus
c. Diuretic medications
d. Nephrogenic diabetes insipidus
2. Which class of diuretics is most likely to lead to hyponatremia?
   a. Carbonic anhydrase inhibitors
   b. Potassium-sparing diuretics
   c. Loop diuretics
   d. Thiazide diuretics

3. Which of the following is the most likely to cause pseudohyponatremia?
   a. Rhabdomyolysis
   b. Hepatic failure
   c. Renal failure
   d. Hyperlipidemia

4. How much would the emergency clinician expect a patient’s sodium to increase after receiving 100 cc of 3% hypertonic saline intravenously?
   a. 1.0 mEq/L
   b. 2.0 mEq/L
   c. 3.5 mEq/L
   d. 4.0 mEq/L

5. A 45-year-old female patient with history of Conn disease presents with a sodium of 150 mEq/L. She weighs 70 kg. What is her calculated TBW deficit?
   a. 2.3 L
   b. 2.5 L
   c. 2.8 L
   d. 3.0 L

6. A 50-year-old women with a history of type 2 diabetes, coronary artery disease, and end-stage renal disease presents to the ED with generalized weakness and decreased appetite. She was last dialyzed 6 days ago, and she also ran out of her insulin 6 days ago. She is slightly hypertensive, but otherwise her vitals are stable and physical examination is unremarkable. Laboratory results reveal a serum sodium of 126 mEq/L, serum potassium of 5.3 mEq/L, serum chloride of 103 mEq/L, serum bicarbonate of 18 mEq/L, and glucose of 750 mg/dL. ECG and chest x-ray are unremarkable. Which of the following is the next best appropriate treatment?
   a. Immediate hemodialysis
   b. Restrict free water to correct hyponatremia
   c. Restart home subcutaneous insulin regimen
   d. Initiate intravenous insulin therapy

7. A 73-year-old female presents to the ED with diarrhea, vomiting, and fever for 2 days. Her vital signs in triage include a temperature of 39.4°C, pulse of 117, and blood pressure of 100/51 mm Hg. She appears dehydrated with dry mucous membranes. Her abdominal examination is remarkable for mild diffuse tenderness with no rebound or guarding. On laboratory evaluation, she has a sodium of 156 mEq/L, potassium of 4.1 mEq/L, chloride of 118 mEq/L, bicarbonate of 19 mEq/L, BUN of 30 mg/dL, creatinine of 1.6 mg/dL, and glucose of 71. Urine osmolality is 800 mOsm/kg, and serum osmolality is 330 mOsm/kg. Which of the following statements is true?
   a. This is most likely diabetes insipidus
   b. Intravenous D5W should be the initial fluid of choice
   c. Free water deficit is 1.7 L
   d. Intravenous NS should be the initial fluid of choice

8. If a patient develops flaccid paralysis, dysarthria, dysphagia, and hypotension during the treatment of hyponatremia, what is the initial therapy of choice?
   a. D5W bolus
   b. ½NS bolus
   c. D5NS at 100 mL/hour
   d. NS at 2x maintenance

9. A 68-year-old woman with a history of small cell lung cancer is brought in for headache and fatigue for the past 2 days. She is awake and alert, with normal vital signs, and has a nonfocal neurologic examination with a serum sodium of 127 mEq/L. What is the appropriate management of her hyponatremia?
   a. Free water restriction
   b. Hypertonic saline bolus
   c. Intravenous furosemide
   d. NS bolus

10. A runner is brought in after collapsing during a race. She has been careful to drink both water and sports electrolyte beverages at each mile marker. She is confused and combative despite 10 mg of diazepam. What is the most appropriate treatment after she suffers a tonic-clonic seizure?
    a. 5% dextrose solution
    b. Fosphenytoin
    c. Hypertonic saline
    d. Lorazepam
Emergency Medicine Approach to the Evaluation and Treatment of Pulmonary Embolism

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In the United States, it is estimated that between 600,000 and 900,000 individuals will suffer from acute pulmonary embolism each year, with an estimated 200,000 to 300,000 hospital admissions, many from the emergency department. Despite decades of research on the topic, the diagnosis remains elusive in many situations, and the fatality rate remains high. This issue of *Emergency Medicine Practice* will present a succinct review of the current evidence guiding the emergency medicine approach to the diagnosis and treatment of pulmonary embolism. Key to this approach is the idea of risk stratification: using factors from the history and physical examination as well as key diagnostic results to guide both the work up and treatment for the individual patient you are caring for. The pathophysiology of disease, decision support tools used both in the evaluation for pulmonary embolism and in assessing the severity of disease, and current treatment options will be discussed.

An Evidence-Based Review Of Transient Ischemic Attack

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A transient ischemic attack (TIA) may seem underwhelming to patients and providers, but it should always be considered a true medical emergency. Caused by temporary focal central nervous system hypoperfusion, a TIA is often a warning of an impending stroke. Patients presenting to the emergency department with a TIA are at the highest risk of stroke within the next 48 hours, and it is critically important for the emergency practitioner to recognize this opportunity to initiate primary stroke prevention strategies. Since the last issue of *Emergency Medicine Practice* on TIA in 2008, there have been numerous studies focusing on improved risk stratification and early management strategies in TIA. This issue will serve as a practical, evidence-based, up-to-date review of TIA for the emergency clinician.
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