

## Sodium Disorders

Stephen Sigworth, MD, MSHA

General Internists are often called to consult on sodium disorders in hospitalized patients. Due to its multiple etiologies, a systematic approach is best in evaluating sodium imbalance. This chapter will address both hypernatremia and hyponatremia and offer diagnostic tools to determine the etiology, and discuss treatment modalities to return the patient to a eunatremic state.

### Hypernatremia

Hypernatremia is defined as serum sodium levels greater than 145 mmol/L.<sup>1</sup> Hypernatremia is primarily a water deficit in relation to intravascular sodium levels. Individuals with either a thirst-impairment or in a setting that may limit access to fluids are at risk of becoming hypernatremic. Typically, patients with mild hypernatremia may have weakness, lethargy, insomnia or hyperpnea. Those with more extreme levels of hypernatremia exhibit CNS related symptoms due to the intracellular water loss of brain cells, and subsequently have altered mental status, seizures or become comatose.

Hypernatremia typically results from three different mechanisms. The first is extrarenal water loss through the skin (excessive sweating, extensive burns), gastrointestinal tract (diarrhea, vomiting, chronic nasogastric suctioning) or lungs (tachypnea).

The second mechanism is diuresis due to osmotic and nonosmotic causes. The major osmotic causes include diuretic use, hyperglycemia, uremia, mannitol or a post-obstructive diuresis. The major cause of nonosmotic diuresis is diabetes insipidus. This can originate centrally or from the kidneys. Central diabetes insipidus can result from recent trauma or neurosurgery, tuberculosis, sarcoidosis, meningitis, cerebral aneurysms, encephalitis or Guillain-Barre Syndrome. Nephrogenic diabetes insipidus can result from intrinsic renal disease, hypercalcemia, hypokalemia, or drugs such as lithium, democlocycline, amphotericin B or vasopressin.

The third mechanism is sodium overload. This can happen from parenteral infusion of sodium bicarbonate or hypertonic saline, exogenous sodium ingestion, hypertonic dialysis, primary hyperaldosteronism or Cushing's Syndrome

### Treatment

The method of sodium correction is under debate, but all recommend slow correction over the first 24 hours. Correcting the imbalance too rapidly can result in cerebral edema, which can lead to death. In either case, water replacement is the mainstay of treatment. If the patient has a workable gastrointestinal tract and is able to take water by mouth or via other enteral device, providing free water is the ideal replacement modality. If the patient can only receive parenteral therapy, then a hypotonic solution should be used. In most cases, correcting water deficits are best done with hypotonic saline or D<sub>5</sub>W (5% dextrose in water). Isotonic saline should only be used if intravascular resuscitation is immediately required to maintain blood pressure. Once the patient is stabilized, the fluid should be switched to one that is hypotonic.

One method for safer resolution of hypernatremia can be achieved by decreasing serum sodium levels by 10 mmol/L per day. By using the following formula, the effect of a change in serum sodium with one liter of infusate is calculated, then extrapolated to how many liters are required to achieve a net change of 10 mmol/L.

$$\text{Change in Serum Na} = \frac{\text{Infusate Na} - \text{Serum Na of patient}}{\text{Total body water} + 1}$$

Infusate Na =	0	D <sub>5</sub> W
	34	0.2% NaCl in D <sub>5</sub> W
	77	0.45% NaCl in H <sub>2</sub> O
	154	0.9% NaCl in H <sub>2</sub> O

$$\begin{aligned} \text{Total Body Water} &= 0.6 \times \text{weight (kg) for males} \\ &0.5 \times \text{weight (kg) for females} \\ &0.5 \times \text{weight (kg) for elderly males} \\ &0.45 \times \text{weight (kg) for elderly females} \end{aligned}$$

Another method is to calculate the water deficit of the patient (see below), then replace half the water deficit over the first 24 hours, with the remainder replaced over the subsequent one to two days

$$\begin{aligned} \text{Calculated Water Deficit (L)} &= \\ &0.6 \times (\text{weight in kg}) \times [(\text{Plasma Na} / 140) - 1] \end{aligned}$$

Whichever method you choose, be careful to not correct too rapidly due to severe neurological complications or death.

### Hyponatremia

Hyponatremia is a more common consultative problem for the General Internist. It is defined as a

serum sodium level less than 136 mmol/L and often results from excess water intake in relation to water excretion.<sup>2</sup> The most frequent causes of hyponatremia in hospitalized patients are thiazide use, the post-operative setting and SIADH. Psychiatric patients may exhibit excessive polydipsia as the primary etiology. Importantly, hyponatremia may occur in any volemic state. Mild cases are associated with headache, nausea, lethargy and confusion. Severe cases involve seizures, coma, brainstem herniation and death, which results from cerebral edema as water travels into brain cells. Typically, symptoms become more prominent when sodium levels fall below 125 mmol/L.

There are two important laboratory tests to order when evaluating hyponatremia. The first is serum osmolality, which denotes intravascular tonicity. The second is the urine sodium (can be obtained from a random urine sample), which illustrates the ability of the kidney to retain water and concentrate urinary solutes.

In hyperosmotic (>285 mOsm) hyponatremia, an extracellular shift of water occurs secondary to high solute concentrations in the vascular space. The most common etiology is hyperglycemia, or the exogenous infusion of hypertonic solutions such as mannitol. If hyperglycemic, serum sodium levels can be falsely low due to the solute concentration and can be corrected by using the following equation:

$$\text{Corrected Sodium} = [0.016 \times (\text{serum glucose} - 100)] + \text{serum Na}$$

Isosmotic (280-285 mOsm) hyponatremia can result from isotonic infusion of solutions such as mannitol, without transcellular water shifts. A state of "pseudohyponatremia" can result from hypertriglyceridemia or hyperproteinemia, which can also give falsely low serum sodium levels and can be corrected with the following equation:

$$\text{Corrected Sodium} = \frac{\text{Serum Na} \times 93}{99 - 1.03 (\text{triglyceride gm/L}) - 0.73 (\text{protein gm/L})}$$

Treatment for both isosmotic and hyperosmotic hyponatremia is to treat the underlying cause, which will subsequently correct the sodium imbalance.

In hypoosmotic (< 280 mOsm) hyponatremia, determining the volume status of the patient enables one to determine the etiology of the sodium imbalance. Determining volume status is derived

from a constellation of physical exam and laboratory findings, which include but are not limited to: orthostasis, pulse, pulmonary edema, peripheral edema in dependant areas of the body, moisture of oropharynx, and laboratory levels of BUN and creatinine, along with their ratio.

If the patient is hypervolemic, the hyponatremia usually results from problems with renal excretion of water and subsequent fluid overload. Nephrotic syndrome, cirrhosis, congestive heart failure and renal failure are the primary disorders that comprise this category. Water restriction and close monitoring of sodium levels are recommended. Occasionally, a diuretic is required in the hypervolemic patient to improve water balance more quickly.

If the patient is isovolemic and the urine Na is < 10, the primary cause is excessive water ingestion, with the obvious treatment of water restriction. When urine Na is > 20, causes typically include thiazide use, hypothyroidism, adrenal insufficiency, post-operative state, pain, severe nausea, HIV, positive pressure ventilation and SIADH. The latter syndrome results from retention of water due to excess ADH and the subsequent volume expansion. There are many potential sources for the excess of ADH, including but not limited to neoplastic causes (often associated with oat cell tumors), CNS insults effecting hypothalamic osmoreceptors, pulmonary disease and drugs (tricyclics, SSRIs, phenothiazines, opiates, chlorpropamide, antineoplastics such as vincristine and cyclophosphamide, and related hormones oxytocin and desmopressin). Treatment for SIADH is water restriction (~ 1 L / day). Resistant cases may require democlocycline or lithium.

In the hypovolemic patient, renal sodium loss can result from diuretic use, adrenal insufficiency, osmotic diuresis, RTA or salt wasting nephropathies. Extrarenal sodium losses are typically from the gastrointestinal tract, skin or lungs. In these instances, treatment requires infusion of isotonic saline with close monitoring of sodium levels. Once the patient becomes euvolemic, their hyponatremia often resolves.

#### Treatment

The fear of correcting hyponatremia too quickly can have profound neurologic consequences, including central pontine myelinolysis and death. Treatment is controversial, but changes in plasma sodium levels should not exceed 8-12 mmol/L over the first 24 hours. Furosemide may be given concomitantly with isotonic saline so as to maintain a euvolemic state

and preventing intravascular overload. In very symptomatic cases (seizures or coma), hypertonic saline can be used to correct the hyponatremia more quickly.

The same equation used in hypernatremia can be used in hyponatremia. By using the following formula, the effect of a change in serum sodium with one liter of infusate is calculated, then extrapolated to how many liters are required to achieve the desired net change.

Change in serum sodium =

$$\frac{\text{Infusate Na} - \text{Serum Na of patient}}{\text{Total body water} + 1}$$

Infusate Na =   154    0.9% NaCl in H<sub>2</sub>O  
                  513    3% NaCl in H<sub>2</sub>O  
                  855    5% NaCl in H<sub>2</sub>O

Total Body

Water       = 0.6 x weight (kg) for males  
              0.5 x weight (kg) for females  
              0.5 x weight (kg) for elderly males  
              0.45 x weight (kg) for elderly females

## References

1. Adrogué HJ, Madias NE. Hypernatremia. N Engl J Med 2000; 342:20, 1493-1499
2. Adrogué HJ, Madias NE. Hyponatremia. N Engl J Med 2000; 342; 21, 1581-1589
3. Singer GG, Brenner BM. Fluid and Electrolyte Disturbances. In: Fauci AS et al, editors. *Harrison's Principles of Internal Medicine*. 14<sup>th</sup> ed. New York: McGraw Hill, Inc;1998. p265-277.
4. Szerlip H, Pavelsky PM, Cox M. Disorders of Volume and Tonicity in the Surgical Patient. In: Goldman DR et al, editors. *Perioperative Medicine*. 2<sup>nd</sup> ed. McGraw Hill, Inc;1994. p591-605.