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AN OVERVIEW ON SODIUM IMBALANCE FROM AN EMERGENCY PHYSICIAN PERSPECTIVE

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ABSTRACT

The body regulates the fluid concentration within the body, along with the solutes, within a narrow range by the action of multiple receptors, hormones, and organs. Sodium is the principal extracellular cation, and thus it affects the flow of water from the extracellular compartment into the intracellular compartment. Sodium imbalances can be life-threatening as they may cause cerebral edema leading to brain herniation or brain shrinkage leading to cerebral vein rupture in the cases of hyponatremia and hypernatremia, respectively. We aimed to review the literature looking into sodium imbalances, along with the acute phase management. PubMed database was used for articles selection, from where papers were obtained and reviewed. The regimen for correcting sodium imbalances depends on multiple factors, including the severity of the symptoms, the concentration of serum sodium, and the patients' risk factors. This is put to avoid overcorrection and its complications. In the case of hyponatremia, overcorrection may lead to osmotic demyelination syndrome. As for hypernatremia, over-correction may lead to cerebral herniation. It is imperative to know the rate for correction and the etiologies for sodium imbalances as they are the cornerstone of therapy in the acute phase.

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Introduction

Sodium and water imbalance are some of the most common conditions that present to the emergency department [1, 2]. However, it is hard to assess the overall percentages of those disorders. Nevertheless, it is of utmost importance to know the physiology of normal water and sodium balance and the pathologies that may change this equilibrium. Hypernatremia is mostly due to unreplaced lost water that leads to increased serum sodium concentration [1]. Meanwhile, hyponatremia is due to relative excess in water concerning sodium, which leads to reduced concentration [2]. In this review, we will look at the basic physiological mechanisms that regulate water and sodium balance, along with the etiologies of their disorders and management.

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Materials and Methods

PubMed database was used for articles selection, and the following keys were used in the mesh ((hypernatremia) OR (hyponatremia)) AND (management). Regarding the inclusion criteria, the articles were selected to include one of the following topics; Hypernatremia, Hyponatremia, Management. Exclusion criteria were all other articles that did not have one of these topics as their primary endpoint.

Review

Regulation of Water and Sodium Balance

The kidneys are the organs that independently regulate water and sodium balance [2]. Kidneys maintain this balance by regulating plasma tonicity. Tonicity, also called effective plasma osmolality, is the parameter sensed by osmoreceptors and determines the transcellular distribution of water [3, 4]. Plasma tonicity and osmolality are different because tonicity reflects the concentration of solutes that do not cross the cell membrane easily. Meanwhile, osmolality measures all solutes regardless of their ability to cross the cell membrane [3]. For instance, In hyponatremia, which causes a fall in tonicity, water moves from the extracellular fluid (ECT) into the cells, including brain cells, leading to an increase in the size of cells. Meanwhile, as is the case in kidney failure, an increase in urea leads to a rise in serum osmolality. However, because urea can cross the cell membrane effectively, this does not change the overall tonicity of the plasma and, thus, no shift in the water volume occurs [3].

Osmoreceptors sense is changed in the plasma tonicity in the hypothalamus [3]. These receptors sense the change in plasma tonicity and affect water intake and excretion by inducing thirst and the release of anti-diuretic hormone (ADH), respectively [5]. ADH is a particularly powerful tool because it allows the kidneys to reabsorb more water from the collecting tubules leading to a net loss of sodium more than water, thereby regulating the water and sodium balance in the bloodstream [3, 6]. Thirst is another mechanism to regulate water and sodium balance, especially in areas with higher temperatures, since it allows for extra exogenous water and thus regulates the plasma volume [3].

Other than plasma tonicity, effective arterial blood volume is also important to regulate. In cases where plasma tonicity is reduced, water is shifted from the ECF into the cells, leading to a reduced effective arterial blood volume and, as a result, decreased perfusion. Various baroreceptors regulate [3] Effective arterial blood volume in the body, the juxtaglomerular cells that activate the Renin-Angiotensin-Aldosterone System (RAAS), the carotid sinus, and aortic receptors that increase the sympathetic activity, and the cardiac receptors that release atrial natriuretic peptide and brain natriuretic peptide [7, 8]. These receptors sense the change in pressure rather than the tonicity of the plasma. However, in normal individuals, pressure and volume are usually linked, and, thus, changes in volume will lead to changes in pressure [3]. Angiotensin II and norepinephrine are vasoconstrictors, and they promote sodium reabsorption along with aldosterone. Meanwhile, the natriuretic peptides are vasodilators that increase sodium excretion [3, 7, 8]. If the arterial blood volume is increased, the natriuretic peptides will lead to net vasodilation and increased sodium excretion along with water excretion leading to a restoration of effective arterial blood volume. Meanwhile, suppose the blood volume is reduced. In that case, RAAS and norepinephrine will lead to net vasoconstriction and sodium retention, resulting in a net pressure increase and water retention, leading to the restoration of effective arterial blood volume.

Hyponatremia

As stated earlier, hyponatremia is the relative excess of water concerning sodium in the plasma. This can manifest either by the increase in water intake or impaired water excretion [9]. Hyponatremia can be defined as a serum sodium concentration of less than 135 mEq/L [10]. However, different values are used based on different guidelines to a small degree [9, 10]. The causes of hyponatremia depend on the etiology and mechanism of how the sodium level in the plasma was reduced. Patients with increased water consumption, such as the case with primary polydipsia or low dietary sodium intake, will develop hyponatremia even with normal functioning kidneys [2]. Another major cause is organ failure. This includes renal failure, heart failure, and liver cirrhosis. Although patients with heart and liver failure present with edema rather than the usual presentation of hyponatremia [11, 12]. Another major cause is the syndrome of inappropriate ADH secretion (SIADH), in which the kidneys reabsorb more water into the circulation than is necessary, leading to hyponatremia via water retention [13]. The symptoms of hyponatremia are predominantly neurogenic; this is due to the development of cerebral edema as a mechanism to counteract the reduced tonicity of ECF [13]. As a general rule, the more severe the symptoms, the more severe the edema is [10]. The earliest symptoms are nausea and malaise, which may be seen when sodium levels fall below 130 mEq/L [10]. As serum sodium concentration drops below 120 mEq/L, headache, lethargy, obtundation, seizures, coma, and respiratory arrest shortly follow [10, 13]. Acute hyponatremic encephalopathy can be reversible. However, if the symptoms are prolonged with no treatment, this will lead to permanent damage, and death may occur [10, 13]. Overly rapid treatment may further worsen the patient's condition, especially in chronic hyponatremia. When the sodium levels are corrected rapidly, the rapid shift of water from the brain tissue into the bloodstream may lead to osmotic demyelination syndrome (ODS) [14]. This complication may lead to permanent damage and severe, long-lasting neurological symptoms. Furthermore, the symptoms may not appear for 2 or 6 days after the treatment, meaning that patients may improve and respond to cure for a while to deteriorate once more [14].

Management

Before starting the therapy, the duration of hyponatremia needs to be established. If the hyponatremia develops in a period of less than 48hr, then it is termed acute hyponatremia. If the duration is more than 48hr or is unknown, it is termed chronic hyponatremia [10, 13]. Acute hyponatremia patients are generally more severe and are at a greater risk of complications of hyponatremia, namely seizures and coma, and require more aggressive therapy. Acute hyponatremia typically results from overhydration, either in the hospital settings in postoperative patients or from self-induced water intoxication in marathon runners and extreme polydipsia [10, 13, 15]. On the other hand, chronic hyponatremia patients have a greater risk of developing osmotic demyelination if aggressive therapy is initiated and, thus, require more monitoring to avoid overcorrection [14]. Next, determine the severity of the symptoms. Severe symptoms include seizures, obtundation, coma, and respiratory arrest [9]. Other symptoms, such as nausea, vomiting, gait disturbance, and confusion, are mild to moderate symptoms [9]. Furthermore, especially in chronic hyponatremia patients, determining the risk factors for ODS is of utmost importance in the management. Risk factors include a presenting sodium concentration of ≤ 105 mEq/L, alcoholism, advanced liver disease, malnutrition, and hypokalemia [9]. There are four main goals in the therapy of hyponatremia. These prevent further reduction in serum sodium concentration, relieve hyponatremia symptoms, decrease intracranial pressure to avoid brain herniation, and avoid overcorrection, especially in those with risk for ODS [9, 10, 13]. The rate of correction is also of importance. If the patient is known to have acute hyponatremia, the rate should not be constrained as they carry no risk for ODS, and rapid correction may prevent cerebral herniation [9]. However, with chronic hyponatremia, the rate should be considered as they carry a risk for ODS development. The current guidelines for the rate of correction are specified to the risk of development of ODS [9, 10]. In high-risk patients, the goal is to increase sodium concentration by 4-6 mEq/L in 24hr with an upper limit of 8 mEq/L in any 24hr period. For intermediate-risk patients (those with no risk factors and a sodium concentration between 105-125 mEq/L), the goal is to increase sodium concentration by 4-8 mEq/L in 24hr with an upper limit of 10-12 mEq/L in any 24hr period. For low-risk patients (those with a sodium concentration of > 125 mEq/L), normalization rather than correction should be initiated [9, 10, 13].

Acute Hyponatremia

The main complication we fear in acute hyponatremia is cerebral herniation. Thus, it is imperative to treat all symptomatic patients that present with acute hyponatremia [16, 17]. The goal of the therapy is to increase serum sodium concentration by 4-6 mEq/L rapidly, which can be achieved by the infusion of 100 boluses of ml 3% hypertonic saline over 10 minutes [9, 10, 16, 17]. There is no need for other medications, such as mannitol or vasopressin antagonist, since the rapid elevation in serum sodium concentration will alleviate the symptoms and prevent cerebral herniation from occurring [10]. Once the level has risen to the goal of the therapy, a gradual increase in sodium concentration should follow until normal levels are restored [9]. Asymptomatic patients and those with serum sodium between 130-135 do not require aggressive therapy, and gradual normalization should treat their condition [9, 10, 14].

Chronic Hyponatremia

The treatment of chronic hyponatremia depends on the cause and severity [9]. In hypotonic hyponatremia, such is the case with diuretic-induced hyponatremia and primary polydipsia, electrolyte-free water must be restricted, and all drugs that may potentiate hyponatremia, such as thiazide diuretics, should be discontinued [9]. In hypovolemic hyponatremia, correction of the level of fluids with normal saline should resolve the condition. However, restoring the euvolemic state can be accompanied by suppressing the vasopressin release, which may lead to brisk water diuresis, further increasing serum sodium concentration [14]. In such patients, frequent U_{Osm} and hourly monitoring of urine output are useful. In the absence of shock, slow correction can prevent this complication [9, 14]. In euvolemic hyponatremia, such is the case of hypothyroid, glucocorticoid deficiency, and SIADH, eliminating the cause and water restriction is the cornerstone of the therapy. However, this is not always possible in SIADH. Increasing solute intake with protein or salt supplementation can be helpful [9, 10]. In all chronic hyponatremia symptomatic patients, the correction should follow the previously stated goals of therapy, especially if the symptoms are severe to avoid cerebral herniation [13].

If the treatment leads to overcorrection, correction of urine electrolyte-free water excretion can guide the therapy [9]. Once calculated from the hourly urine output and U_{Osm}, administration if IV 5% dextrose in water equal to the amount of lost water should prevent a further increase in serum sodium concentration [9, 10, 13]. If the urine output is very high, the addition of desmopressin to the 5% dextrose can mitigate the water loss [9].

Hypernatremia

The causes of hypernatremia can be grouped into 4 categories. The first category is dehydration or inadequate water intake. Those patients are either left stranded for a prolonged period before help came to rescue or those in chronic care facilities [18]. Those patients have altered sensorium, immobile, and the inadequate replacement of water loss causes their condition [1]. The next group is GI losses from diarrhea, febrile illnesses, or enteric fistulas [16]. Furthermore, excessive salt intake may develop hypernatremia, especially in those receiving hypertonic saline in resuscitation or over-concentrated baby formula for infants [9]. The largest group is those with renal concentrating defects, including patients on diuretics and central and nephrogenic diabetes insipidus [9]. The goal of the therapy in those patients is to replace ongoing water losses, prevent further water loss, and treatment of the cause, especially in those with diabetes insipidus. Acute hypernatremia presents with lethargy, weakness,

and irritability initially. If the condition is not corrected rapidly, it can progress to twitching, seizures, and coma [9, 19]. Chronic hypernatremia, on the other hand, is less likely to produce symptoms especially since most individuals suffer from an already preexisting neurological condition and the cerebral tissue can adapt to hypernatremia much more effectively when compared with hyponatremia [9, 18, 19]. The main danger of hypernatremia is the rapid shrinking of the brain causing rupture of cerebral veins. Thus, rapid deterioration of neurological functions in a patient known to suffer from hypernatremia is a dangerous sign [18].

Generally, there is no limit on the correction rate for hypernatremia, and most centers use opinion-based expert recommendations [9, 16]. Rapid correction to a normal level over a 24 hours period is generally accepted to avoid cerebral vein rupture in acute hypernatremia [9]. The main challenge in rapidly correcting hypernatremia is the avoidance of cerebral edema. However, evidence is still lacking regarding this point [1, 9]. For chronic hypernatremia, which develops over more than 48 hours, correction to normal levels over 48 hours is accepted [9]. The next step in management should focus on the cause of hypernatremia. For instance, if the cause is due to hyperglycemia, insulin infusion should be started. Furthermore, in the case of central diabetes insipidus, life-long administration of desmopressin is advised [9].

Conclusion

Multiple conditions cause sodium imbalances, and they result in neurological deficit if severe. The kidneys regulate the sodium concentration in the bloodstream and the help of numerous hormones and receptors. Both hypernatremia and hyponatremia present neurological symptoms, ranging from nausea, vomiting, lethargy to seizure, coma, and even death. Management of both conditions depends on the severity of the symptoms and the level of increased or decreased sodium concentration. As a general rule, if the symptoms are severe, especially in high-risk patients, rapid correction should be initiated to prevent further neurological damage. Furthermore, management should be tailored to the cause of both conditions.

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