PedsCases Podcast Scripts

This is a text version of a podcast from Pedscases.com on "**Disorders of Sodium Balance.**" These podcasts are designed to give medical students an overview of key topics in pediatrics. The audio versions are accessible on iTunes or at www.pedcases.com/podcasts.

Disorders of Sodium Balance

Developed by Dr. Laura Betcherman, Dr. Talia Lenton-Brym and Dr. Rachel Pearl for PedsCases.com.
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Introduction:

Hello, my name is Laura, **and my name is Talia,** and we are second year pediatrics residents at the Hospital for Sick Children in Toronto, Canada. This podcast was developed under the guidance of Dr. Rachel Pearl, a pediatric nephrologist at the Hospital for Sick Children. Today we will be discussing disorders of sodium balance: hypernatremia and hyponatremia.

The **objectives** of this podcast are to:

1) Describe the common etiology of disorders of sodium balance
2) Review the common clinical presentations of hyper- and hyponatremia
3) Review a basic approach to sodium imbalance, and
4) Discuss the inpatient management of patients with sodium disturbances

Let's get started!

How do you define hypo and hypernatremia?

Hypernatremia is a serum sodium concentration of greater than 145 mmol/L and hyponatremia refers to a serum sodium concentration of less than 135 mmol/L.

How is water balance regulated in the body?

Water regulation is controlled by two important mechanisms: thirst and anti-diuretic hormone, or ADH. Thirst is regulated in the hypothalamus through osmoreceptors. When the amount of osmoles is high in the blood, including salt, then the brain senses the higher osmoles and increases the thirst drive. ADH, which is also called vasopressin, is a hormone produced by the posterior pituitary in response to low water content or low blood water volume. It acts on the renal cortical collecting duct to stimulate water reabsorption in the kidney through special channels called aquaporins.

How is salt regulated in the body?
Salt is regulated through the renin-angiotensin-aldosterone system, also called RAAS. When blood volume is low, or salt content is low, renin is released from the juxtaglomerular apparatus in the kidney, which causes the adrenal glands to produce aldosterone. Aldosterone acts on the kidneys to reabsorb salt and on the blood vessels as a vasoconstrictor, both of which help to increase blood pressure. These two concepts – water regulation by ADH and salt regulation by aldosterone are important in understanding an approach to disorders of sodium balance.

Let's talk about a case of hyponatremia.
Imagine you are seeing a previously healthy 18-month-old male in the emergency department with a two-day history of fever, diarrhea and decreased oral intake. His parents tell you that he has been less playful and has had fewer wet diapers than usual. He has a fever of 38.7 degrees Celsius, a heart rate of 160 beats per minutes and a blood pressure of 95/65. His weight is 10 kg. Initial bloodwork shows a sodium of 126 mmol/L.

What is the cause of hyponatremia?
Usually, hyponatremia occurs because there is too much water relative to salt, or because the kidney is excreting too much salt. The first thing to do is to rule out something called factitious hyponatremia, or pseudohyponatremia. This happens in cases where there are other molecules in the blood that falsely decrease the concentration of sodium – this is a lab artifact! Things that may lead to pseudohyponatremia include hyperlipidemia, hyperglycemia or hyperproteinemia. This happens because these substances displace water and alter the relative concentration of sodium, but remember, they do not change to total amount of sodium.

Is there an approach to the etiology of hyponatremia?
There is – once you have established that this is not pseudohyponatremia, a straight-forward way to classify the cause of hyponatremia is based on the patient's volume status, and can be divided into three categories: hypovolemic, euvolemic or hypervolemic hyponatremia.

Hypovolemic hyponatremia is usually caused by a net loss of sodium that is greater than the loss of free water. In our case example of viral gastroenteritis, the child has signs of dehydration with vomiting. The natural instinct of most families is to try to keep the child hydrated by encouraging them to drink free water. In addition, because of the patient's low volume status, the pituitary is triggered to produce ADH, which leads to free water retention in the kidneys, exacerbating the hyponatremia..

In cases of hypovolemic hyponatremia, the urinary sodium can help you determine the cause. Inappropriately high urine sodium, with levels of >20mmol/L, suggest a renal cause, such as salt-wasting in renal dysplasia, proximal tubule dysfunction or diuretic use. Low urine sodium levels, <20mmol/L, suggest an extra-renal cause, such as a viral

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gastroenteritis, because it demonstrates that the kidneys are acting appropriately by retaining sodium through the RAAS system.

Euvolemic hyponatremia usually occurs in the setting of the syndrome of inappropriate diuretic hormone, or SIADH. As suggested by the name, SIADH is an inappropriate over-secretion of ADH. This means that ADH is present even in cases where the body is not in a state of dehydration or low blood volume. SIADH occurs in certain cancers, lung or CNS infections, in the post-operative setting and secondary to pain or acute infections such as meningitis and pneumonia, especially in hospitalized patients. Many medications including chemotherapy can also cause it. In SIADH, the body is retaining a lot of water. It tries to excrete the water in urine, but because water follows salt, it is excreting salt too. Urine sodium is high, usually greater than 20mmol/L. Unfortunately, the body can't keep up with the high body water volume, so the body's naturesis is futile in correcting the primary pathophysiology of SIADH. Some chemotherapy agents also cause proximal tubule defects with salt wasting.

Euvolemic hyponatremia can also be caused by primary polydipsia, which is usually seen in psychiatric patients. In this case, patients have excessive thirst and are taking in a lot of free water. The body sees this and turns off ADH, because it needs to diurese due to the high water consumption. The body's salt and water regulation in these patients is normal. To make it simple: the patient is taking in more free water, so the body compensates by excreting more free water. The urine will be dilute, with a low urine osmolarity, usually less than 100mOsm. The plasma osmolarity in these patients is usually low for a few reasons: poor nutritional intake is common and sodium concentration is low relative to high body water. This activates the RAAS, which increases salt retention in the kidneys. Thus, the urine sodium will be low. This is a key differentiating factor between psychogenic polydipsia and SIADH. The urine sodium and urine osmolarity are **low** in primary polydipsia, but are **high** in SIADH. Primary polydipsia can sometimes be confused with diabetes, and urine and serum glucose can help you distinguish the two.

The last category of hyponatremia is **hypervolemic hyponatremia.** This one is a little more tricky to conceptualize. In this case, there is a relative gain of free water in relation to sodium. In pediatrics, this is seen in cases of edema such as nephrotic syndrome, acute liver failure, or heart failure. The body has a lot of excess fluid, but the intravascular volume – the volume of fluid in the blood vessels - is low because all that fluid is shifting into other areas in the body. In response to low intravascular volume, the body increases ADH release from the pituitary in order to retain fluid. It also tries to hold on to salt, by activating RAAS. The issue is that there is relatively more water in the vasculature, resulting in hyponatremia. Remember that hyponatremia relates to sodium concentration, not content!

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What are the signs and symptoms of a patient with hyponatremia?
This depends on the severity of hyponatremia. Symptoms arise because of the influx of water into the intracellular space, leading to cerebral edema and encephalopathy. Severe symptoms include vomiting, lethargy, seizure, or cardio-respiratory distress. Moderate symptoms include nausea, confusion or headache. Chronic or mild hyponatremia is often asymptomatic.

In evaluating a patient, make sure to pay attention to their volume status and neurological exam. This will help you determine the etiology, but also the degree of severity and management.

How do you treat hyponatremia?
The treatment depends on the etiology and severity of hyponatremia. For severe cases, or if the patient is symptomatic, a bolus of 3% saline may be used. The usual strategy is to give 2mL/kg of 3% saline over 20 minutes. This can be repeated twice until symptoms resolve OR until there is a 5 mmol/L rise in the serum sodium concentration. Remember that if a patient is having a seizure secondary to hyponatremia, you must treat the seizure as well!

Once you have stabilized their symptoms, or if the degree of hyponatremia is mild, there are various formula available on-line to calculate the change in serum sodium that will occur with one litre of any given solution. Then you need to carefully select the type of fluid and rate of infusion that will be used to correct the hyponatremia. We will not discuss the formulae here or get into the calculations, but please refer to PedsCases.com for a case description and for example calculations.

The most important concept is that you do not want to increase the concentration of sodium by more than 8-10mmol/L in the first 24 hours, because of the risk of central pontine demyelination, which we'll talk about in a moment.

Other considerations in the management of disorders of sodium include the following:
1. Strictly monitor the oral/IV intake and urine output
2. Repeat the labs every 2-4 hours until they stabilize
3. Measure the urine sodium to help determine the etiology

What are some issues that may arise in the treatment of hyponatremia?
Clinicians must monitor for a sudden rise in urinary output. This occurs when ADH becomes suppressed as the patient's intravascular volume becomes restored with increases in free water. When it is suppressed, you get rapid diuresis.

Another concern with hyponatremia management is something called the central pontine or osmotic demyelination syndrome. This happens when a patient is more chronically hyponatremic and there is rapid correction. In this case, the serum sodium rises too quickly, which draws fluid out of the brain cells because of the relative rise in

salt concentration outside of the cells. This can cause confusion, pseudocoma and even quadriplegia, and occurs several days following the correction of hyponatremia.

Let's re-cap the key points of hyponatremia:

1. Hyponatremia can be defined in the context of volume status: hypovolemia, euvolemia or hypervolemia
2. Tests such as serum and urine osmolarity, and urine sodium can help you determine the etiology
3. Management of hyponatremia depends on the severity of symptoms
4. Always treat symptomatic hyponatremia, and remember to go slow, especially in chronic cases, and to watch for signs of osmotic demyelination syndrome

Let's now switch gears and talk about a case of hypernatremia. Imagine you are seeing another 18 month old previously healthy toddler. His parents brought him into the emergency department because of a 2 month history of increased diuresis and thirst. The baby is afebrile, with slightly elevated heart rate of 150 beats per minute and anormal blood pressure and respiratory rate. Although the baby looks well, you are concerned for an underlying pathology given the prolonged history of increased urine output and order routine bloodwork and a urinalysis with urine and serum osmolarity. The patient's vital signs are stable, and this time, you find a serum sodium of 154mmol/L with a serum osmolarity of 320mOsm and a urine osmolarity of 185mOsm with no glycosuria.

So what do you do?

The first step in any case is to assess the ABCs and stabilize the patient. This patient is clinically stable, so no immediate intervention needs to be taken and we can focus on our approach to the patient's hypernatremia.

What is the etiology of hypernatremia?

Hypernatremia is caused by a relative deficiency of total body water. This can be due to increased losses (for example by excessive sweating, vomiting, or diarrhea) or decreased water intake. Rarely, hypernatremia is the result of excessive sodium intake.

Who is at risk of hypernatremia?

Any patient with excess output is at risk of hypernatremia, for example patients with vomiting or diarrhea. Specific patient populations who cannot easily access water are at higher risk, including infants, patients with neurological deficits, or those who are acutely ill. Disorders of mineralocorticoid excess, although rare, can cause elevated sodium levels.

What are the signs and symptoms of a patient with hypernatremia?

Most of the signs and symptoms are nonspecific, including irritability, altered level of consciousness, and lethargy. Clinical signs and symptoms of dehydration may also be present. One important clinical clue is doughy-skin that feels like bread dough!

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How do you treat hypernatremia?
The first thing to consider when treating hypernatremia is to determine the underlying etiology. Next you would assess for and correct the patient's dehydration, if present.

Once you have stabilized the patient, one of the key principles in the treatment of hypernatremia is to replace the **free water deficit**. There are a few formulas that can be used to calculate this, which are easy to look up online. We will not go through the calculations in this podcast –please refer to PedsCases.com for a case example. The general principles after determinine the free water deficit are to

1. Determine your ideal sodium concentration, which is usually 140mmol/L
2. Choose an appropriate IV solution - the volume of fluid to give to correct the sodium depends on the composition of the IV solution
3. Run your solution at a rate that will correct your sodium slowly, again aiming to correct no more than 8-10mmol/day

Aim to correct hypernatremia slowly because in patients with chronic hypernatremia, the brain creates idiogenic osmoles as a means to adapt. This means that the brain cells have these "new" osmoles present so that they can hold on to water and don't continually shrink in a state of hypernatremia. If you correct too quickly, and give too much free water, water moves from the vessels, where we have infused it, into the brain where the sodium is more concentrated because of these new osmoles. This can cause swelling, or cerebral edema.

Coming back to our case, an important clue can help point towards a diagnosis. The patient is not dehydrated, and there is no indication of increased sodium intake. This patient has a lower urine osmolarity to serum osmolarity, indicating water wasting, or diabetes insipidus, which is also called DI. This is a disease state where the body either does not have ADH, or cannot respond appropriately to ADH. There are two causes of DI: central and nephrogenic. Central DI is a problem with production of ADH, whereas nephrogenic DI occurs when the kidneys do not respond to ADH. In either case, the body is diuresing water in excess, leading to hypernatremia.

Let's recap the key points about hypernatremia.

1. Hypernatremia is usually caused by a relative free water deficit
2. The signs and symptoms may be subtle, especially in young children, but include altered level of consciousness, lethargy and dehydration
3. The first step in management is to calculate and correct the free water deficit
4. Correcting the serum sodium must be done slowly, so as to prevent cerebral edema

That concludes our podcast on hyponatremia and hypernatremia in children. Thanks for listening and thank you to Dr. Rachel Pearl for her help in developing this podcast. For more resources, and more podcasts, please refer to PedsCases.com

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Resources:

1. Moritz ML and Ayus JC. Disorders of water metabolism in children: hyponatremia and hypernatremia. Pediatrics in Review. 2002;23(11):371-80.
2. Goff DA and Higinio V. Hypernatremia. Pediatrics in Review. 2009;30(10):412-3.
3. Reid-Adam J. Hyponatremia. Pediatrics in Review. 2013;34(9):417-9.

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