

A Treatment Approach to Hypernatremia

1. Determine the chronicity and severity of hypernatremia and evaluate patient's stability

General guidelines to this step:

- **Patients with mild hypernatremia (e.g. 155-165)** may not need specific treatment if they are stable otherwise; however, it will be important to diagnose the most likely cause of hypernatremia and address it; correction of this problem will likely resolve hypernatremia; also, plasma sodium should be rechecked in this patient in 12-24h to make sure it is improving;
- **Unstable hypernatremic patients** are those that show signs of hypernatremia (usually neurologic signs such as tremors, severe depression/stupor/coma, seizures)
- **Any hypernatremia that occurred more than 24 hours ago or its onset is unknown is considered chronic;**
- **General rule of thumb to correct chronic hypernatremia** is to decrease sodium level by no more than 10-12 mmol/l per 24 hours (the total decrement per 24 hours is more important than per hour change);
- **It is advised to place a sampling venous line in patients with moderate to severe hypernatremia** if the patient is getting hospitalized; Na levels are usually rechecked every 4-6 hours;

2. Outpatient vs. inpatient treatment

- It is recommended to hospitalize any patient with acute or chronic hypernatremia that is moderate to severe;
- Stable patients with mild hypernatremia may be treated as outpatient as long as they can be rechecked within 12-24 hours, they have intact thirst mechanism and they are able to consume water (i.e. they are not vomiting, ambulatory, have normal mentation);

3. Approach to a stable hypernatremic patient that has intact thirst mechanism and is eating/drinking well

- These are usually patients with hypervolemic or normovolemic hypernatremia; clinical examples: a cat that was closed in the house for 5

days without access to water; an overheated dog that did not drink enough while was working out; a healthy puppy who got 3 doses of activated charcoal without IV fluids due to grape ingestion

- These patients have likely developed hypernatremia due to inadequate access to fresh water and/or increased losses of pure water
- They will likely correct their sodium levels by drinking water, however if they are moderately to severely hypernatremic, we may need to control their water consumption in the hospital environment to prevent an acute drop in Na concentration leading to cerebral edema;

- To calculate how fast they can consume water, a free water deficit formula can be used:

- **Deficit = [(patient Na/desired Na) – 1] x 0.6 x weight (kg) = liters of fresh water**
- Divide the desired decrement in plasma Na⁺ by 10-12 mmol/l to calculate the number of days over which this water should be consumed to ensure safe rate of Na correction
- This formula does not take into account ongoing losses of free water; it is especially important in patients with diabetes insipidus who cannot conserve their free water;
- It will be important to monitor Na every 4-6 hours and adjust volume of consumed water as needed to ensure appropriate rate of Na decrement per 24 hours
- **Clinical example: 10 kg dog with Na = 175 mmol/l; eating and drinking well; cause of hyperNa – 3 doses of activated charcoal with inadequate access to fresh water**
 - Step 1 – address an underlying condition – stop activated charcoal administration
 - Step 2 – calculate free water deficit: $[(175/150) - 1] \times 0.6 \times 10 \text{ kg} = 1 \text{ liter or } 1000 \text{ ml of free water deficit}$
 - Step 3 – calculate the number of hours this amount of water should be consumed over: $(175-150)/12 \text{ mmol/l} = 2.08 \text{ days} = 50 \text{ hours} = 1000 \text{ ml}/50 \text{ hours} = 20 \text{ ml/hr}$
 - Step 4 – If the dog is drinking well and stable, you can correct this free water deficit by giving fresh water by mouth every 4-6 hours according to your hourly calculated rate (e.g. $20 \text{ ml/hr} \times 4 \text{ hours} = 80 \text{ ml of water every } 4 \text{ hours}$)
 - Step 5 – you may also need to account for maintenance requirements in addition to your calculated free water deficit (maintenance requirement: 40-60 ml/kg/day); for example, $60 \text{ ml/kg/day} = 600 \text{ ml/day}$ for a 10 kg dog

= 600 ml divided by 6 (every 4 hours water consumption) = **100 ml every 4 hours**;

- Step 6 – sum up your maintenance requirements + water deficit replacement = **80 ml + 100 ml given every 4 hours**
- Step 7 – recheck plasma Na in 4 hours and adjust this amount as needed + monitor for signs of cerebral edema; reduce free water consumption if Na is dropping to fast; if this acute drop resulted in neurologic signs and suspected cerebral edema, give hypertonic saline to treat the cerebral edema, and bring the plasma Na concentration back up to a safe range.

4. Approach to unstable hypernatremic patient or a patient that is unable to drink/eat/needs IV fluids

4.1 If the patient is hypovolemic and needs a bolus of fluids based on your physical examination, this fluid should have a sodium content that is similar to the patient's plasma sodium (+/- 5 mmol/l) in order to avoid rapid correction of hypernatremia

4.1.1 An addition of hypertonic saline to a regular balanced solution will increase its sodium concentration; the following formula can be used to calculate the amount of hypertonic saline to be added to a bag of a regular balance crystalloid solution:

$$V_x = [(C_1 - C_2) \times V_1] / C_3$$

C₁ – Desired Na⁺ concentration in a final solution

C₂ – Current Na⁺ concentration in a crystalloid solution

V₁ – Desired volume of a final solution

C₃ – Current Na⁺ concentration in a hypertonic saline (1283 mmol/l in 7.2-7.5% solution)

V_x – Volume of the hypertonic saline to be added to the bag of a regular crystalloid

Example: You have a 10 kg dog with plasma Na = 185 mmol/l; the dog is hypovolemic and you want to bolus 20 ml/kg of isotonic solution (isotonic to patient's plasma osmolality); You have a 500 ml LRS bag (that has Na = 130 mmol/l) and hypertonic saline 7.2% that can be mixed together in order to get a bag of fluid with Na=180-185 mmol/l;

$$V_x = [(185 - 130) \times 500] / 1283 = 21.4 \text{ ml}$$

That means you will need to withdraw 21.4 ml of fluid from 500 ml LRS bag and add 21.4 ml of 7.2% hypertonic saline instead. This will provide you with 500 ml of a final solution with Na = 185 that can be given safely to a dog with hypernatremia;

4.2 Once the hypovolemia is corrected, a free water deficit can be calculated as previously discussed:

- **Free water deficit = [(patient Na/desired Na) - 1] x 0.6 x weight (kg)**
 - Divide the desired decrement in plasma Na⁺ by 10-12 mmol/l to calculate the number of days over which this water should be consumed to ensure safe rate of Na correction
 - This formula does not take into account ongoing losses of free water;
 - It will be important to monitor Na every 4-6 hours and adjust volume of administered fluid as needed to ensure appropriate rate of Na decrement per 24 hours

Case example: 10 kg dog with vomiting, diarrhea and ileus due to severe non-specific gastroenteritis; plasma Na = 185; the dog has already received a bolus of isotonic fluids and now is euvoletic, however it is still dehydrated (5-7%) and is unable to eat or drink due to persistent vomiting;

1. Free water deficit in this dog: $[(185/150) - 1] \times 0.6 \times 10 \text{ kg} = 1400 \text{ ml}$
2. Next, calculate how fast you can give it to decrease Na by 10-12 mmol/l per day: $(185 - 150)/12 = 2.9 \text{ days} = 70 \text{ hours}$; $1400 \text{ ml}/70 \text{ hours} = 20 \text{ ml/hr}$ of free water (Na free) – this can be 5% dextrose solution IV or fresh water via NG tube
3. Next, calculate how much fluids should be given in addition to this free water deficit replacement to account for dehydration, ongoing losses and maintenance:

Treatment of hypernatremia

- Dehydration = $10 \text{ kg} \times 6\% \times 10 = 600 \text{ ml}$ to be replaced over 12 hours = 50 ml/hr
- Maintenance requirement = $(60 \text{ ml} \times 10 \text{ kg}) / 24 \text{ hours} = 25 \text{ ml/hr}$
- Ongoing losses (vomiting/diarrhea/ileus) = 25 ml/hr (arbitrary, based off the fact that the dog produces 200 ml puddles of liquid stool every 8 hours)
- That means that you will need to add 100 ml/hr ($50 + 25 + 25$) of fluids in addition to 20 ml/hr free water deficit replacement;
 1. It is hard to determine what is the tonicity (or sodium content) of fluids that the dog is losing, therefore the choice of replacement solution to be given at 100 ml/hr is somewhat arbitrary. You may start with NaCl 0.9% that has a highest sodium content to be on the safe side
 2. Your final fluid plan: 20 ml/hr of 5% dextrose IV + 100 ml/hr of NaCl 0.9%
 3. It is important to recheck plasma Na in 4 hours and adjust your fluid rate or fluid composition based on the change in sodium concentration over this period of time
 4. If the plasma Na is the same or even went up, you may need to decrease tonicity of your replacement solution and/or increase 5% dextrose rate
 5. If the plasma Na went down too fast, you may increase tonicity of your replacement solution (i.e. add hypertonic saline to the bag of your normal saline) or decrease 5% dextrose rate.
- **Approach to a patient with sodium gain (salt poisoning, hypertonic saline overdose)**
 - These patients are typically hypervolemic and don't need IV fluid boluses
 - Free water deficit formula can be used to calculate the safe rate of 5% dextrose IV or oral water administration (via NG tube or free consumption), however it is important to realize that these patients do not have free water deficit; they are hypernatremic due to solute gain;
 - If the patient is able to drink without vomiting, a controlled amount of water (as calculated by free water deficit formula) can be given to this patient to slowly correct hypernatremia



Treatment of hypernatremia

- If the amount of water for consumption is not limited, these patients will continue to drink ravenously until they start vomiting or develop cerebral edema
- Low doses of furosemide can be considered to facilitate natriuresis, however it should be given carefully with close monitoring of plasma Na every 4-6 hours

References

1. Ueda Y, Hopper K, Epstein SE. Incidence, severity and prognosis associated with hypernatremia in dogs and cats. *J Vet Intern Med.* 2015 May-Jun;29(3):794-800. doi: 10.1111/jvim.12582. PMID: 25996661; PMCID: PMC4895431.
2. Muhsin SA, Mount DB. Diagnosis and treatment of hypernatremia. *Best Pract Res Clin Endocrinol Metab.* 2016 Mar;30(2):189-203. doi: 10.1016/j.beem.2016.02.014. Epub 2016 Mar 4. PMID: 27156758.