CRRT 2012
Acid-Base and Electrolyte Workshop
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Hyponatremia

• Hyponatremia is the most common electrolyte disorder seen in both in-patient and out-patient settings.

• In all settings, it is associated with an increased risk for mortality due to the disorder itself, the attendant co-morbidities and the treatment.

• Understanding the basic physiology of salt and water handling allows for rational diagnosis and proper therapy.
Case 1

- 28 yo male schizophrenic with a history of compulsive water drinking is admitted to the hospital with increasingly erratic behavior.
- On examination: he is thin (50 kg), with a normal examination.
- Labs: Sodium = 125 meq/L   BUN = 6 mg/dL
  Uosm = 150   Una = 10   Uk = 32
- Two days later he is found seizing in the shower. Emergent sodium was 108 meq/L.
Case 1

- *How would you treat this patient emergently?*
  - A. Water restriction
  - B. Normal Saline 1250 cc over 8 hours
  - C. 3% Sodium chloride: 295 ml over 3 hours
  - D. 3% Sodium chloride: 500 ml over 3 hours
  - E. Valium 10 mg and water restriction.
  - F. 3% Sodium chloride: 500 ml over 3 hours and tolvaptan 30 mg orally daily for 3 days
Calculation of IV Fluid Effect on Serum Sodium

• To determine the amount of sodium needed to raise the serum sodium by any amount:

\[
\text{Change in serum Na} = \frac{\text{infusate Na} - \text{serum Na}}{\text{Tot body water} + 1}
\]

• Note: if significant amounts of K+ are given in the infusion this amount MUST be added to the infusate Na to calculate the change in serum Na.
Solution

- We would like to increase the Na+ by 4-5 meq/L in the next few hours.

- Giving 3% NaCl (513 meq/L):

- Change in serum Na = 513 – 108/30 + 1 = 13 meq

- Since we want to increase Na by 4 meq then 4/13 x 1 L or 300 ml of 3% NaCl can be given over three hours with hourly monitoring of the serum Na.

- Note: this formula is an approximation and does not take into account urinary losses of solute which must be replaced or isoosmotic losses of water. Thus, frequent monitoring is required.
3% Sodium Chloride for Serum
Sodium Values < 120 meq/L

Δ Serum [Na] with 1 L infusate = \( \frac{\text{Infusate [Na]} - [\text{Na}]}{\text{Total Body Water} + 1} \)

Mohmand et al, CJASN 2:1110-1117, 2007
Lower Serum Na = Higher Risk of Overcorrection

Mohmand et al, CJASN 2:1110-1117, 2007
Case 2

- 68 yo female is brought to the ER with drowsiness and syncope. Two weeks ago she was started on hydrochlorothiazide and a low salt diet for hypertension. Over the past three days she has had diarrhea. Examination reveals a BP of 90/50 mm Hg, pulse of 110, flat jugular veins, and dry mucous membranes. Weight is 60kg.

- Serum Na = 106
- BUN = 46
- Uosm = 650
- Serum K = 2.2
- Creatinine = 2.0
- Sosm = 232
Therapy

Appropriate treatment should include the following:

- a. Fluid restriction
- b. 3% NaCl 250 cc over three hours
- c. Normal saline 1 liter over two hours
- d. Normal saline with 30 meq/L KCl 1 L over two hours
- e. 3% NaCl with 30 meq/L KCL 250 cc/3hours
Answer

• Diagnosis: hypotonic hyponatremia from thiazide, gastrointestinal losses and potassium depletion.

• Initial treatment: 0.9% normal saline with 30 meq/L KCL given.

• From the formula, retention of 1 liter of this fluid will increase the serum sodium 2.8 meq/L.

• \( \{(154 + 30) - 106 / 27 + 1\} = 2.8 \)
Continued therapy…

She receives 2 L of fluid and after this her BP is 128/72, mental status is improved and her sodium is now 112 meq/L and potassium is 3.0 meq/L.

Your next step should be:

• A. Continue current hydration with normal saline
• B. Change fluid to 0.45% saline with 30 meq/L KCl
• C. Begin fluid restriction to 800 cc per day
• D. Begin fluid restriction to 500 cc per day
• E. Begin demeclocycline 600 mg bid
Clinical Course

• It is important to anticipate that as fluid status improves, stimulus for ADH secretion rapidly disappears and the free water excretion increases.
• Thus, her IV fluid should be changed to .45% saline with potassium:
  • From the formula: \(\frac{(77 + 30) - 112}{27 + 1} = -0.2\)

• Again, it is important to remember that this formula does not account for urine losses of water and solute and thus, the anticipated production of a urine with a lower Na and K than the infusate will promote correction of the Na.
• In fact, the next am the serum Na was 114.
Avoiding over-rapid correction

- Recognize those situations associated with reversibly impaired water excretion
  - Volume depletion
  - DDAVP
  - Hypocortisolism
  - Thiazide diuretics
  - SSRI’s
  - Nausea & alcohol withdrawal

  **In these cases, the stimulus for impaired water excretion is corrected quickly, and a rapid water diuresis then ensues.**

- Maximally dilute urine increases the serum sodium concentration by > 2 mEq/L/hr
- Continued vigilance with frequent measurements of the serum sodium concentration and attention to urine output is essential in all patients with very low serum sodium concentrations
Reversing Overcorrection

Serum Sodium (mmol/l)

Urine Osmolality (mOsm/kg)

DDAVP 2 mcg q 6hrs

3% NaCl

D5W

3% NaCl

Sterns, R. Kidney Int August, 2009
Re-Induction of Hyponatremia Prevents Myelinoysis

<table>
<thead>
<tr>
<th></th>
<th>Rapid Correction</th>
<th>Rapid Correction Plus Re-Lowering</th>
</tr>
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<tbody>
<tr>
<td><strong>SNa Pre-Rx</strong></td>
<td>108 2 mmol/l</td>
<td>104 2 mmol/l</td>
</tr>
<tr>
<td><strong>ΔSNa at 12 hrs</strong></td>
<td>--</td>
<td>29 1 mmol/l</td>
</tr>
<tr>
<td><strong>ΔSNa at 24 hrs</strong></td>
<td>29 mmol/l</td>
<td>14 1 mmol/l</td>
</tr>
<tr>
<td><strong>Sx’s Day 5</strong></td>
<td>12/12</td>
<td>1/16</td>
</tr>
<tr>
<td><strong>Deaths Day 10</strong></td>
<td>12/12</td>
<td>1/16</td>
</tr>
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Case 3

- A 50 year-old man with cirrhosis and ascites undergoes surgery for repair of an incarcerated umbilical hernia. After surgery, he is treated with spironolactone 50 mg daily to control his ascites. During the next 2 weeks, he sustains large ascitic fluid losses through his abdominal incision and returns to the ED complaining of dizziness. His blood pressure is 86/50 mm Hg, he is deeply jaundiced and lethargic. He has only a small amount of ascites and no peripheral edema.
Laboratory Work

• Serum sodium: 103 meq/L
• Serum potassium: 6 meq/L
• Serum osmolality: 260 mOsm/kg
• Serum BUN: 140 mg/dL
• Serum creatinine: 2.5 mg/dL

He is treated with 250 ml of 3% saline and 3 L of 0.9% saline. Four hours later, BP is 110/60, urine output is 100 ml/hour. Repeat labs:
• Serum sodium: 115 meq/L
• Urine osmolality: 513 mOsm/kg
• Urine sodium: 2 meq/L
• Urine potassium: 14 meq/L
A resident calculates the patient’s free water clearance from the last serum and urine studies:

\[ \text{CH}_2\text{O} = \text{Vurine}(1 - \text{Uosm}/\text{Posm}) = -1.7 \text{ ml/min} \]

The calculated free water clearance is negative (positive free water absorption) suggesting that the patient’s kidney is returning free water to the circulation.

**Question 1:** Is this calculation helpful in predicting what will happen to the serum sodium?

**Question 2:** If so, assuming that the urine volume and composition continue unchanged during the next 8 hours and other fluid losses are negligible, what would be your IV solution of choice?

- a. 3% saline
- b. 0.9% saline
- c. Dextrose 5% in water
- d. Dextrose 5% in normal saline
Concept of free water clearance

• Urine flow can be divided into two components:
  • 1. The volume of urine needed to excrete solutes at the concentration of solutes in plasma (isotonic) and is referred to as the osmolar clearance (Cosm)
  • 2. The second component is any remaining urine volume (the solute free water cH₂O)

\[
V = \text{Cosm} + \text{cH}_2\text{O}
\]

\[
\text{Cosm} = U\text{osm} \times V\text{urine}/P\text{osm}
\]

• By substitution:
Free water clearance

• \( cH_2O = V\{1 - Uosm/Posm\} \)
• We are interested only in the \textit{effective osmoles:}
• \( cH_2Oe = V\{1 - (Una + Uk)/Pna\} \)
• Therefore if:
  – Una + Uk > Pna then \( cH_2O \) is negative (that is water is being absorbed) and the sodium will fall.
  – Una + Uk < Pna then \( cH_2O \) is positive and the sodium will rise.
Key Point

• The urine sodium and potassium tell us the free water clearance NOT the urine osmolality.
• Thus, calculating the free water clearance as: \[ cH_2Oe = V\{1 - (Una + Uk)/Pna}\] the answer is: + 99 ml/hour or + 1.7 ml/min.
• This is critical as with hydration, the stimulus for ADH is decreased and a free water diuresis ensues.
• Thus, continuing either 3% or 0.9% saline will lead to a continued rapid rise in the serum sodium.
• Recognizing that a spontaneous water diuresis is occurring leads to the correct use of D5W.
Case #4

• A 60 yo female with ESRD secondary to polycystic kidney disease presents for her routine hemodialysis session. When she arrives it is noted that her right arm synthetic arteriovenous graft is thrombosed. She was told to return home, eat nothing after 10 pm and return to the hospital in the morning for an interventional radiology procedure. A plasma potassium level before being sent home was 4.6 meq/L
Case #4 Cont’d

- The next am, pre-op labs reveal:
  - Sodium 138 meq/L
  - Potassium 7.0 meq/L
  - Chloride 100 meq/L
  - Bicarbonate 17 meq/L
  - Blood urea nitrogen 70 mg/dL
  - Creatinine 8.0 mg/dL
  - Glucose 70 mg/dL
  - CBC normal
  - Electrocardiogram: normal except for left ventricular hypertrophy.
Question #1

Why did the patient become hyperkalemic?

- A. She missed dialysis
- B. She developed a metabolic acidosis
- C. She was NPO
- D. This was pseudohyperkalemia
Effect of fasting on hyperkalemia in ESRD

ESRD patients rely on transcellular shifts to regulate serum K+ to a greater degree than those with renal function

Allon et al. Kidney International 1993
Transcellular Shifts

**K+ shifts in:**
- Insulin
- Catecholamines
- Aldosterone
- (?) Alkalosis

**Blood**

**K+ shifts out:**
- Acidosis (non-organic)
- Exercise
- Increase ECF osmolality
Question #2

Which one of the following is an ineffective method for lowering the serum potassium in this patient?

- A. IV 2 amps (100 meq) sodium bicarbonate
- B. IV 10 units of insulin
- C. IV 100 ml of 10% dextrose in water
- D. Sodium polystyrene sulfonate 30 gm plus sorbitol 60 gm
# Change and timing in plasma K+ with various therapies

<table>
<thead>
<tr>
<th>Therapy</th>
<th>Maximal fall in [K+] mEq/L</th>
<th>Time to effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium bicarbonate (100 meq)</td>
<td>0.1</td>
<td>45 minutes (with prolonged infusion takes up to 4 hours to see effect)</td>
</tr>
<tr>
<td>Insulin/Glucose (10 u/1 amp D50)</td>
<td>1.0</td>
<td>Within 15 minutes and continued effect for 45 minutes</td>
</tr>
<tr>
<td>Albuterol (20 mg in 4ml saline over 10 minutes)</td>
<td>0.5</td>
<td>Within 30 minutes and continued effect for 60 minutes</td>
</tr>
<tr>
<td>Albuterol/Insulin/Glucose (as above)</td>
<td>1.5</td>
<td>Within 15 minutes and continued effect for 60 minutes</td>
</tr>
</tbody>
</table>

Allon et al. Kid Int 1990; 38: 869-872
Blumberg et al. Kid Int 1992; 41: 369
Sodium Polystrene Sulfonate (SPS)

- Recent debate about safety/risk/benefit
- Available in the US premixed in 33% sorbitol (FDA recommends against use of SPS with concomitant sorbitol due to risk of colonic necrosis)
- Along with dialysis, SPS represents one of the few methods of actually increasing net potassium excretion in the absence of renal function
- Effects are delayed for at least 2 hours (peak at 4-6 hours): requires colonic passage for efficacy and prolonged use tends to be much more effective
- While the capacity of SPS is 1 mEq of K+ per gram of resin in practice the efficiency is only about 33% and a 30 gram dose leads to binding and excretion of 10 mEq of K+. This amount is significantly increased with the use of a cathartic (sorbitol)
- Not all studies demonstrate a significant fall in [K+]

Dangers of SPS

• Colonic necrosis: thought to be secondary to the use of sorbitol (esp 70% formulation but described as well with current formulation)
  – High risk: post-operative, ileus, uremia
  – Incidence: 0.2-0.3%

• Other risks: mucosal injury to esophagus, stomach, duodenum; fatal aspiration pneumonitis

• Bottom line: use cautiously and judiciously