Diagnosis and Management of Common Electrolyte Disorders

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Special Thanks to:
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Objectives

To discuss diagnostic and therapeutic strategies for:

- 1.Hyponatremia
- 2.Hypernatremia
- 3.Hyperkalemia
- 4.Hypokalemia
Case 1

• 60 year old man
• “Admit for weakness and hyponatremia”
• [Na+] 120 mg/dL
Case 1 (cont’d)

- Nausea, weak, confused x 1 week
- HTN, CHF
- JVD, crackles (rales), edema
  - Na⁺ 120 mEq/L
  - BUN 93 mg/dL
  - Cr 3 mg/dL
  - Glucose 135 mg/dL
  - Albumin 2.9 mg/dL
  - Plasma osm 252 mOsm/kg
  - Urine osm 690 mOsm/kg
Hyponatremia usually reflects excessive H₂O
How did this happen?

Differential diagnosis
COMMON CAUSES of HYponatremia

1. History: predisposing features
2. Exam: volume status (including orthostatics supine/standing)
3. BMP; Urinalysis; Serum Osmolality; (Urine Sodium; Urine Osmolality)
4. Head C.T. (if symptomatic)
5. Other imaging/labs to evaluate CV, Renal, Endocrine systems as needed
Clinical Evaluation

- **History**
  - Symptomatic?
  - Predisposed?
  - Medications? IVF’s?

- **Physical**
  - Volume status?

- **Labs**
  - Confirm (if unusually abnormal)
  - Context
  - Additional diagnostic tests
Complications of Treating Hyponatremia

- Delayed treatment
  - Cerebral edema
  - Permanent neurological injury
  - Death

- Inappropriately rapid treatment
  - Cerebral dehydration/demyelination
  - Permanent neurological injury
  - Death

- Inappropriate treatment
  - Failure to improve $\rightarrow$ morbidity
  - Delayed improvement $\rightarrow$ morbidity
  - Further deterioration
Common Treatment Options

- Water restriction
- Diuresis (with loop diuretic)
- Volume infusion (with crystalloid)
- Hypertonic saline
- Demeclocycline
- ADH antagonists
What if he had cerebral edema?

1. Correct $[\text{Na}^+]$ to 125-130 mEq/L to temporarily relieve edema
2. $[\text{Na}^+]$ should NOT increase by more than 8-12 mEq/L in 1st 24 hours $\sim .33$ mEq/L/hr
3. Slow/Stop infusion as soon as symptoms improve
3% NaCl Calculation

\[ [\text{Na}^+] = 116 \text{ mEq/L} \]

Goal \( [\text{Na}^+] = 125 \text{ mEq/L at 24 hours} \)

Amount of \( \text{Na}^+ \) to be given as 3% infusion:

\[
\begin{align*}
\text{Amount} &= [\text{Serum Na}^+_{\text{(desired)}} - \text{Serum Na}^+_{\text{(measured)}}] \times (\text{TBW}) \\
&= [125 - 116] \times [(0.5)(60\text{kg})] \\
&= 270 \text{ mEq Na}^+ \\
\end{align*}
\]

3% saline = 513 mEq sodium/L

\[
\frac{270}{513} = 0.5 \text{ L} = \textbf{500 ml} \text{ over 24 hrs.}
\]
Hyponatremia: Key Points

- Serum sodium concentration < 135 meq/L
- Excess free water
- If symptomatic, treat more rapidly
- Slowly correct [Na⁺] towards normal
- Find the underlying cause
Case 2

- 40 y/o woman s/p hypertensive brain hemorrhage 2 weeks ago.
- This morning she’s less responsive.
- Stuporous
- BP 150/70, HR 94
- Dry mouth, poor turgor
- Na 160 mEq/L; K 2.8 mEq/L; HCO3: 18 mEq/L; Cl 137 mEq/L
Hypernatremia usually reflects insufficient H$_2$O
Hypernatremia represents a relative deficit of water in relation to solute
• What may have caused this problem?
• If you have access to water, why would you get hypernatremic?

Differential diagnosis
COMMON CAUSES of HYPERNATREMIA

- **Volume Status**
  - **Low**
    - Nonrenal losses:
      - Sweating
      - GI losses
      - Respiratory
  - **Renal Losses**
    - Diuretic
    - Glycosuria
    - Renal failure
  - **Renal losses**
    - Diabetes insipidus (central/nephrogenic)

- **Normal**
  - Nonrenal losses:
    - Skin or respiratory insensible losses
  - **Renal Losses**
    - Urine [Na] variable

- **High**
  - Iatrogenic hypertonic IVF
  - Exogenous salt
  - Mineralocorticoids (mild)
  - Aldosteronism
  - Cushing’s
  - Adrenal hyperplasia
  - Urine [Na] > 20 usually

Renal losses: Urine [Na] > 20
Non renal losses: Urine [Na] < 10
Differential Diagnosis

- Lack of water
- Severe diarrhea
- Severe burns
- \( \uparrow \text{H}_2\text{O} \) excretion
  - Osmotic diuresis
- \( \downarrow \text{H}_2\text{O} \) conservation
  - Diabetes insipidus
## Major causes of hypernatremia

<table>
<thead>
<tr>
<th>Category</th>
<th>Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unreplaced water loss</strong></td>
<td>(which requires an impairment in thirst or access to water)</td>
</tr>
<tr>
<td>Insensible and sweat losses</td>
<td></td>
</tr>
<tr>
<td>Gastrointestinal losses</td>
<td></td>
</tr>
<tr>
<td>Central or nephrogenic diabetes insipidus</td>
<td></td>
</tr>
<tr>
<td>Osmotic diuresis</td>
<td></td>
</tr>
<tr>
<td>Hypothalamic lesions impairing thirst or osmoreceptor function</td>
<td>Primary hypodipsia</td>
</tr>
<tr>
<td></td>
<td>Reset osmostat in mineralocorticoid excess</td>
</tr>
<tr>
<td><strong>Water loss into cells</strong></td>
<td>Severe exercise or seizures</td>
</tr>
<tr>
<td><strong>Sodium overload</strong></td>
<td>Intake or administration of hypertonic sodium solutions</td>
</tr>
</tbody>
</table>
Guidelines for Hypernatremia Rx

• Determine and treat likely cause(s)
• Most common error is “underestimation” of water deficit:
  \[ \text{TBW} \times \left( \left[ \text{Na}^+\text{ (measured)} \right] - \left[ \text{Na}^+\text{ (desired)} \right] \right)/\left[ \text{Na}^+\text{ (desired)} \right] \]
• Replace H\textsubscript{2}O enterally if possible
• Frequent monitoring
Sodium Content of IVF’s (mEq/L)

- 3% saline: 513
- 0.9% (normal) saline: 154
- Ringer’s Lactate: 130
- Half Normal (0.45%) saline: 77
- 5% Dextrose (D5W): 0
Hypernatremia: Key Points

- $[\text{Na}^+] > 145$ mEq/L
- Net water deficit
- Calculate the water deficit
- Usually seen in patients with impairment
Case 3

- 29 y/o man with severe muscle weakness.
- No vomiting or diarrhea.
- Normal physical exam.
- $\text{Na} = 141 \text{ mEq/L, } K = 1.4 \text{ mEq/L, } \text{Cl} = 116 \text{ mEq/L, } \text{HCO}_3^- = 11 \text{ mEq/L}$
- $\text{pH} = 7.25, \text{ pCO}_2 = 21 \text{ mmHg}$
Consequences of Hypokalemia [K] <3

• Neuromuscular manifestations
  – Weakness, fatigue, rhabdomyolysis, myonecrosis, respiratory failure

• GI symptoms
  – Constipation, ileus

• Nephrogenic Diabetes Insipidus

• Dysrhythmias (if heart disease)
Common Causes of Hypokalemia

• Malnutrition/NPO
• Diarrhea
• Vomiting (volume depletion)
• DRUGS
  – Thiazides (stimulate excretion)
  – Amphotericin B
  – Penicillins
  – Gentamicin
  – Foscarinet
“Choose the most likely diagnosis”

- Bartter’s syndrome
- Laxative use
- Primary aldosteronism
- Diuretic use
- Distal renal tubular acidosis
Less Common Causes

- **Hormonal**
  - Primary hyperaldosteronism
    - Adenomas, hyperplasia, ectopic ACTH, ectopic mineralocorticoid (licorice, chaw)
  - Secondary hyperaldosteronism
    - Renal hypoperfusion (CHF, RAS, severe HTN)
    - Renin-secreting tumor

- **Renal tubular disease**
  - Type 1 or 2 RTA
  - Bartter’s syndrome (metabolic alkalosis, polyuria)
  - Chronic magnesium depletion

- **Laxative abuse** (metabolic alkalosis)
Hypokalemia Rx

- Recognize likely total body depletion
  - 1 mEq/L decrease = 150-400mEq total deficiency
- Gradual oral replacement
- I.V. replacement if serum level less than 3 mEq/L
- Check & Replace magnesium
- Consider telemetry
Hypokalemia: Key Points

- $[K^+] < 3.5$: review medications, review health status
- $[K^+] < 3$: intervention
- Recognize Mg+ is cofactor
- Renal/CV monitoring
Case 4

• 59 y/o man with 3-days malaise, decreased mental acuity and responsiveness, slurred speech.
• ESRD on hemodialysis; HTN, DM, Hypothyroidism
• Disoriented and lethargic
• BP (supine) 148/79mmHg, HR 101/min (supine) RR 26/min, T 37.7°C.
• Mucous membranes are moist, neck veins are distended. Bilateral crackles and wheezes. Loud S4. 3+ peripheral edema.
What is the next most appropriate step in managing this patient?

- A. Give I.V. Calcium
- B. Administer 1 ampule dextrose and 10 units insulin I.V. for hyperkalemia
- C. Transfer to the ICU and perform emergent peritoneal dialysis
- D. Transfer to the ICU and perform emergent hemodialysis
Calcium raises the action potential threshold and reduces excitability without changing the resting membrane potential.
<table>
<thead>
<tr>
<th>Emergency</th>
<th>Response time</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac conduction abnormal</td>
<td>Immediate</td>
<td>15–30 min</td>
</tr>
<tr>
<td>Calcium gluconate or chloride a (10 mL of 10% solution)</td>
<td></td>
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<tr>
<td>[K\textsuperscript{+}] &gt; 6.5 serum/mEq/L or rising</td>
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<td></td>
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<tr>
<td>Glucose (50 mL of 50% solution) plus regular insulin 10 U</td>
<td>10–20 min</td>
<td>2–3 h</td>
</tr>
<tr>
<td>Albuterol 10–20 mg by inhaler over 10 min</td>
<td>20–30 min</td>
<td>2–3 h</td>
</tr>
<tr>
<td>NaHCO\textsubscript{3}, only if metabolic acidosis present</td>
<td>Delayed</td>
<td></td>
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<tr>
<td>Kayexalate 15–30 g with sorbitol</td>
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<td></td>
</tr>
<tr>
<td>By mouth</td>
<td>4–6 h</td>
<td></td>
</tr>
<tr>
<td>As retention enema</td>
<td>1 h</td>
<td></td>
</tr>
<tr>
<td>Loop diuretic (intravenous)</td>
<td>1 h</td>
<td></td>
</tr>
<tr>
<td>Hemodialysis</td>
<td>15–30 min</td>
<td></td>
</tr>
</tbody>
</table>

Long-term management

| Dietary K\textsuperscript{+} restriction 2–3 g/d | | |
| Discontinue supplemental K\textsuperscript{+} (salt substitutes) | | |
| Discontinue drugs that interfere with K\textsuperscript{+} homeostasis (see [Tables 4 and 5]) | | |
| Augment K\textsuperscript{+} excretion | | |
| Loop, thiazide diuretics | | |
| Fludrocortisone, if hypoaldosteronism present | | |
| Chronic kayexalate therapy | | |

\textsuperscript{a} Intravenous calcium should not be given in the setting of digoxin toxicity.
“Dialysis machine available in 20 minutes”
Emergency Treatment

$[K] \geq 6 \text{ mEq/L}$

- “STAT” ECG
- “STAT” repeat $[K^+]$
- Give IV Calcium
Additional Rx

- **More** IV Calcium
- Glucose and Insulin
- Bicarbonate
- Inhaled Beta-2 agonists
- Sodium polystyrene sulfonate (Kayexalate®)
Severe hyperkalemia is usually preceded by moderate, uncorrected hyperkalemia
Differential Dx

• Renal Failure (GFR < 10 ml/min)
• Extra Renal Causes
  – Metabolic acidosis
  – Cell lysis (chemotherapy, trauma)
  – Salt substitutes, ACE-I/ARB,
  – Addison’s Disease
  – Pseudo (coagulated RBC’s/platelets)
  – Drugs- digitalis, succinylcholine
  – Exercise
Hyperkalemia: Key Points

- K>4.5: caution with medications, & monitor
- K>5.5: intervene
- Calcium (not kayexalate) is 1st line in symptoms/ECG findings
- Check ECG!