Case study

- 4 year old child in the PICU following multi-organ trauma [was skateboarding and hit by a car]
- TBI, pulmonary contusions, liver and spleen laceration
- 5 days after injury, ICP begins to rise>20. Responds to 2ml/kg boluses of 3% Saline.
- Remains in the PICU for an additional 7 days. ICPs gradually improve.
- Extubated on day 15
- **WHAT IS THE BASIS OF 3% SALINE BEING EFFECTIVE?**
Serum Osmolality

• S. Osmolality = 2x Na + BUN/2.8 + Glucose/16
• Sodium level is by far the most important determinant of Osmolality
• Increasing the Osmolality, helps improve rheology of blood flow and also helps draw fluid from interstitial compartment to the intravascular therefore decreasing CBF and ICP
• Goal in TBI is to maintain S. Osm > 310

• Ref: Pediatric TBI Guidelines 2003

Serum Osmolality

• **Calculated**
• **Measured**
  – Most accurate method is freezing point depression
• **Osmolar gap** = Osm$_{\text{meas}}$ – Osm$_{\text{calc}}$
  – **Causes of increased osmolar gap**
    • Methanol/Ethanol/Isopropanol
    • Mannitol
    • Ethylene glycol
    • Glycerol/Sorbitol/Propylene glycol
    • Radio contrast agents
    • Lipemia
Sodium homeostasis

- Sodium is most prevalent extracellular cation and exerts significant influence
- Sodium levels controlled by vasopressin/ADH system and also by osmoreceptors
- Renal excretion and GI absorption account for main mechanisms for sodium levels to be maintained

AVP: Synthesis, Transport and Secretion

http://www.biosbce.net/barron/physiology/endo/hypopit.htm
Case study - continued

- 4 year old skateboard vs car. Multiple trauma
- 8 days into hospital stay, patient’s ICP in mid-20s. Sodium is 130 mEq/L despite being on a 1ml/kg/hr of 3% Saline
- CPP is being maintained by Dopamine at 5mcg/kg/min
- Urine output is 0.8 ml/kg/hr
- Hyponatremia persists

What is your diagnosis?

SIADH

- By definition, implies that there is “inappropriate” ADH secretion
- Most common cause of hyponatremia in hospitalized patients
- Appropriate ADH secretion occurs in response to hypovolemia, hypotension where body is holding on to fluid
- SIADH is characterized by FeNA>2 and relatively high urine sodium levels
- Distinction has to be made clinically but can be assisted by lab results
- FeNA helps distinguish between appropriate and SIADH states.
SIADH Risk Factors

- Meningitis
- Encephalitis
- TBI
- Neurosurgical patients
- Prematurity
- Positive pressure ventilation
- Stress

- Dehydration
- Heart Failure
- Diuretics
- Medications
  - Morphine

SIADH

- Bartter and Schwartz, 1967

- Definition:
  - Serum hypoosmolality (hyponatremia)*
  - Urine osmolality > maximally dilute (>50-100 mOsm/L), and usually Na_U > 30mEq/L
  - Euvolemia

- “Dilute serum, non-dilute urine”

* = in the absence of pseudohyponatremia
SIADH: Diagnosis

<table>
<thead>
<tr>
<th>SIADH</th>
<th>CSW</th>
<th>DI (central)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body water</td>
<td>Increased</td>
<td>Decreased</td>
</tr>
<tr>
<td>Sodium</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Serum osmolality</td>
<td>&lt;280 mOsm/L</td>
<td>Decreased</td>
</tr>
<tr>
<td>Urine osmolality</td>
<td>&gt;500 mOsm/L</td>
<td>Increased</td>
</tr>
<tr>
<td>Urine to serum osmolality ratio</td>
<td>&gt;1</td>
<td>&gt;1</td>
</tr>
<tr>
<td>Urine output</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Urine sodium concentration</td>
<td>Increased</td>
<td>Increased</td>
</tr>
</tbody>
</table>

SIADH, Syndrome of inappropriate antidiuretic hormone secretion; CSW, cerebral salt wasting; DI, diabetes insipidus


SIADH - Management

- Fluid restriction 50-60 % of maintenance
- Hypertonic saline for symptomatic patients: coma, convulsions
  - $\text{Na}^+$ deficit (mEq) = $\text{Na}^+$ desired-$\text{Na}^+$ actual x 0.6
  - 4-6 ml/kg initially of 3% Saline to correct to about 120 and stop seizures
  - Rapid correction to $\text{Na}^+ > 120$ mEq/L then slow 5-10 mEq/L/day
Case study

- 8 days into hospital stay, patient’s ICP in mid-20s. Sodium is 132 mEq/L despite being on a 1ml/kg/hr of 3% Saline
- CPP being maintained by Dopamine at 5mcg/kg/min
- Urine output is 1.6 ml/kg/hr
- Hyponatremia persists

- **What is your diagnosis?**

Cerebral Salt Wasting

- Important in TBI and other neurosurgical states
- Precise etiology is unclear
- Characterized by hyponatremia
- Distinguished from SIADH by higher urine output and degree of increase in urinary sodium
- Diagnosis is often missed
CSW - Diagnosis

<table>
<thead>
<tr>
<th></th>
<th>SIADH</th>
<th>CSW</th>
<th>DI (central)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body water</td>
<td>Increased</td>
<td>Decreased</td>
<td>Decreased</td>
</tr>
<tr>
<td>Sodium</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Serum osmolality</td>
<td>&lt;260 mOsm/L</td>
<td>Decreased</td>
<td>&gt;300 mOsm/L</td>
</tr>
<tr>
<td>Urine osmolality</td>
<td>&gt;800 mOsm/L</td>
<td>Increased</td>
<td>Low</td>
</tr>
<tr>
<td>Urine to serum osmolality ratio</td>
<td>&gt;1</td>
<td>&gt;1</td>
<td>&lt;1.5</td>
</tr>
<tr>
<td>Urine output</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Urine sodium concentration</td>
<td>Increased</td>
<td>Increased</td>
<td>Decreased</td>
</tr>
</tbody>
</table>

SIADH, Syndrome of inappropriate antidiuretic hormone secretion; CSW, cerebral salt wasting; DI, diabetes insipidus


CSW - Management

- Isotonic intravenous fluids to correct the hypovolemia
- 3% Saline if symptomatic or if resultant increase in ICP
- Fludrocortisone: 0.05-0.2 mg/day
- Oral NaCl supplements
Case study

- Patient has undergone an intracranial tumor resection
- 24 hours postoperatively, urine output increases to 5ml/kg/hr
- Serum sodium is 155 mEq/L
- Urine specific gravity is 1.003

**Your diagnosis?**

- Image source: radpod.org

---

**DI**

- Due to inadequate secretion of ADH
- Appears in conjunction with severe TBI or other forms of intracranial injury
- Commonly encountered following craniopharyngioma surgery
- Results in hypernatremia and dehydration
Central DI - Management

- Main therapy is to replace ADH/Vasopressin with IV or intranasal DDAVP
- Keep up with urine output
- Monitor urine output and electrolytes closely and redose DDAVP when breakthrough occurs
Case study

2 month old child admitted to the pediatric ward with RSV bronchiolitis
Is NPO because of respiratory distress and increased work of breathing
Is receiving D5 0.25 NS with 20 mEq/L of KCl at “maintenance”
Urine output has been adequate [~1 ml/kg/hr]
36 hours after admission patient begins to seize

Hyponatremia

• Plasma Na⁺ < 130 mEq/L
• Most common metabolic problem in hospitalized patients (Gill,G. Clin End 2006; 65: 246–249)
• 30 % of patients admitted to ICU. 15 % hospitalized patients. Mortality 9-45% (Asadollahi. K. Q J Med 2006; 99:877–880)
• Usually iatrogenic
• Relatively asymptomatic until patient presents with seizures or coma. High morbidity and mortality.
• Preventable
Hyponatremia – Differential Diagnosis

- **Isotonic**
  Pseudohyponatremia (Osm 275-295)
  - Protein
  - Lipids

- **Hypertonic** Hyponatremia
  (Osm > 295)
  - Glucose
  - Mannitol
Hyponatremia – Differential Dx

**Hypotonic**

- Hypovolemic
  - Renal loss
  - GI loss
  - Sweat
  - Third space

- Euvolemic
  - SIADH
  - Glucocorticoid deficiency
  - Hypothyroidism
  - Water intoxication

**Hypervolemic**

- Edema forming states
- Renal failure

**Symptomatic Hyponatremia**

- Nausea, vomiting
- Decreased LOC
- Coma
- Seizures
- Respiratory arrest
- Death
Hypotonic Fluid – How did it start?


• The 1957 guidelines were derived from well children
• Hospitalized children today will likely have increased AVP (ADH) levels

Recommendation

• No routine use of hypotonic fluid in hospitalized children
  • 5% Dextrose 0.9% NaCl or 0.9% NaCl or at most 5% Dextrose 0.45% NaCl

• Does not apply to
  – Premies and neonates
  – High risk for fluid overload
  – Ongoing free water losses
Recommendations

- Applies to non-tropical or air conditioned health care facilities
- Children being nursed in non-air conditioned, warm or hot facilities may have much larger free water losses

Complications of DKA

- Cerebral swelling/edema
  - Old literature suggest that ~1% will have symptomatic cerebral edema
  - All patients with DKA will have some degree of cerebral swelling/edema
    - >50% will have narrowing of lateral ventricles
    - Lower pCO2 associated with increased chance of ventricle narrowing
  - Risk of significant swelling/edema minimized by slower correction of hyperosmolar state.
    - Decrease glucose by <100 per hour
- Sodium and osmolality play role in cerebral edema
Central pontine myelinolysis

- Rare neurologic syndrome associated with rapid treatment of longstanding hyponatremia


Pontine and extrapontine myelinolysis following rapid correction of hyponatraemia.

Laureno R, Karp BI.

Department of Neurology, George Washington University School of Medicine, Washington DC.

Central pontine and extrapontine myelinolysis is caused by the rapid correction of hyponatremia. Acceptance of this concept has been impeded by recent reports attributing myelinolysis to uncorrected hyponatremia, overcorrection of hyponatremia, or hypotonic fluid administration. Several new names have been proposed for this disease, but all are less specific than pontine and extrapontine myelinolysis. This proliferation of terminology is unnecessary and adds to the confusion surrounding the aetiology of myelinolysis.

Hyponatremia and CPM

- Vast majority of pts with CPM after hyponatremia suffered respiratory arrest, which often occurred before treatment of hyponatremia
- Prospectively studied pts with severe symptomatic hyponatremia undergoing rapid increase of serum Na using hypertonic NaCl have no morbidity


Summary

- Sodium homeostasis is essential from CV and neurologic standpoint
- Hyponatremia is increasingly recognized in the hospitalized population and is entirely preventable
- Hypotonic intravenous fluid should be avoided
- Keep in mind differential diagnosis

Suggested Reading


Courtesy Werner H: Hyponatremia in www.learnicu.org