Sodium Disorders

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Case presentation

- A 28 year old woman undergoes elective abdominal surgery
- Pre-operatively, serum [Na^+] normal, 140 mmol/L
- Post-operatively, she awakens and appears normal.
- The following day, she developed seizures, acute respiratory failure and dies.

What happened?

- Her serum Na^+ was 116 mmol/L.
- Autopsy reveals cerebral herniation

The next day …

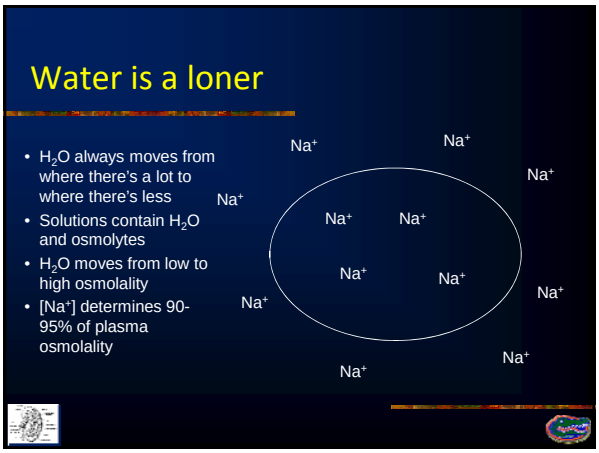
- 63 year old gentleman with history of chronic alcohol abuse, liver disease and ascites is admitted
- His [Na^+] is 116 mmol/L
- His physicians remember the previous case
- They treat him with hypertonic Na^+, 3% NaCl (515 mmol/L)

The next day …

- The next day his [Na^+] is 136 mmol/L
- On examination he has spastic quadriplegia of all four arms and legs. Eye examination shows loss of control of eye muscles, particularly cranial nerve VI
- One week later he dies

What happened?

- Central pontine myelinolysis


Water is a loner
• H_2O always moves from where there's a lot to where there's less
• Solutions contain H_2O and osmolytes
• H_2O moves from low to high osmolality
• [Na^+] determines 90-95% of plasma osmolality
Na^+
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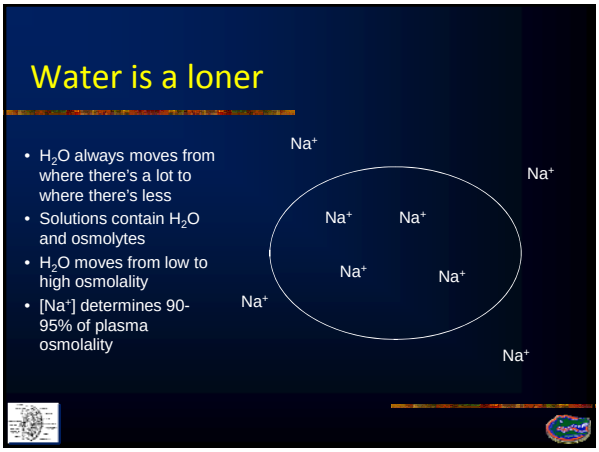
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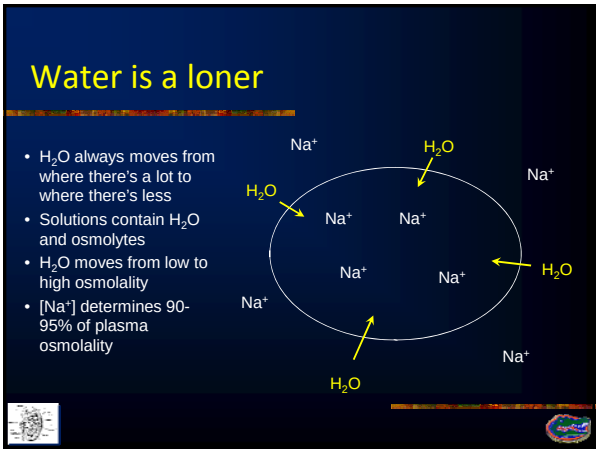
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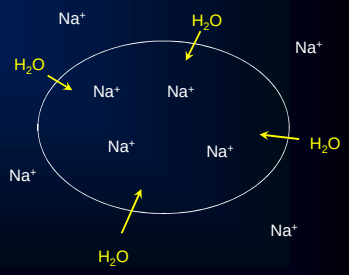
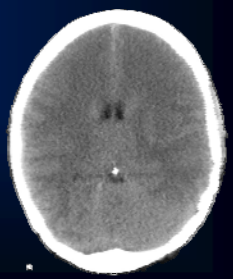


Acute hyponatremia leads to …

- Acute cellular swelling
  - Better looking biceps

Acute hyponatremia leads to …

- Acute cellular swelling
  - Increased intracranial pressure
    - Decreased cerebral perfusion pressure
    - Cerebral anoxia
    - Cerebral herniation
    - Death of respiratory centers



Serum Na^+ measurements …

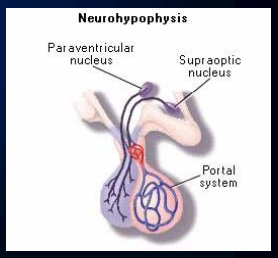
- Do NOT measure the amount of Na^+ in the body
- DO measure the relative ratio of Na^+ to H_2O
  - $[Na^+] = Na^+ / H_2O$
- Hyponatremia
  - Excessive H_2O relative to amount of Na^+

Causes of acute hyponatremia

- Initiation
  - Excessive "free" water administration
    - Dilute intravenous fluids (D_5W, $D_5¼NS$, $D_5½NS$, ½ NS)
    - Lots of oral intake (Gatorade ~19 mmol/L Na^+)
    - Prostate irrigation fluids

Causes of acute hyponatremia

- Continuation
  - Inability to excrete H_2O
    - Excessive ADH
      - Surgery, vomiting, pain, anxiety
      - Pituitary damage
    - Inhibition of dilute urine formation in distal convoluted tubule
      - Thiazide diuretics
    - Renal failure



Treating acute hyponatremia

- Emergent
  - Hypertonic NaCl
    - 3% NaCl, 515 mmol/L

Moral #1

- Acute hyponatremia acutely kills because of cell swelling in the CNS
- Treatment of acute hyponatremia is to acutely increase serum osmolality
  - Concentrated NaCl

Remember the 2nd case …

- 63 year old gentleman with history of chronic alcohol abuse, liver disease and ascites is admitted
- His [Na^+] is 116 mmol/L
- His physicians remember the 1st case
- They treat him with hypertonic Na^+, 3% NaCl (515 mmol/L)

The next day …

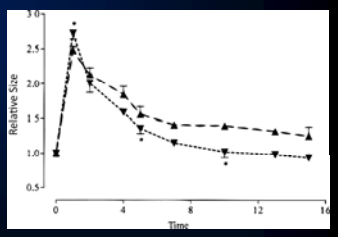
- The next day his [Na^+] is 136 mmol/L
- On examination he has spastic quadriplegia of all four arms and legs. Eye examination shows loss of control of eye muscles, particularly cranial nerve VI
- One week later he dies

What happened?

- Central pontine myelinolysis

Cells are, in general, smart

- Cells that swell in response to hyponatremia have altered intracellular concentrations
- Don't like that
- Will shrink back to baseline size with time



Moral #2

- Chronic hyponatremia only causes problems when corrected rapidly
- General principle:
  - Things that occurred quickly should be treated quickly, and
  - Things that occurred slowly should be treated slowly.

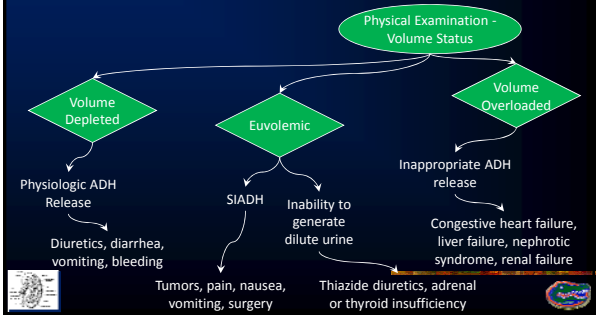
Serum Na^+ measurements …

- Do NOT measure the amount of Na^+ in the body
- DO measure the relative ratio of Na^+ to H_2O
  - $[Na^+] = Na^+ / H_2O$
- Hyponatremia
  - Excessive H_2O relative to amount of Na^+

Regulation of total body H_2O

- ADH – stimulates renal H_2O retention
  - Intravascular volume depletion
  - Hypotension
  - Pain
  - Nausea, vomiting
  - Some tumors
- Kidneys
  - Dilute urine generated in DCT
  - Sodium-chloride co-transporter
  - Glucocorticoids and thyroid hormone necessary

Hyponatremia evaluation



Caveats

- Have to exclude laboratory causes of hyponatremia
  - Severe hyperlipidemia
  - Massive increase in plasma proteins
- Severe hyperglycemia
  - 100 mg/dl increase in [glucose] decreases [Na^+] by ~1.6 mEq/L
  - [Glucose] = 1100 mg/dl → 16 mmol/L ↓[Na^+]

Moral #2

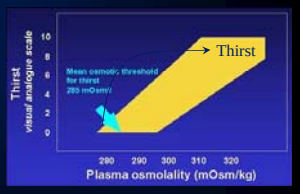
- Things that happen slowly should be treated slowly

Hypernatremia and serum Na^+ measurements …

- Do NOT measure the amount of Na^+ in the body
- DO measure the relative ratio of Na^+ to H_2O
  - $[Na^+] = Na^+ / H_2O$
- Hypernatremia
  - Inadequate H_2O relative to amount of Na^+

Hypernatremia

- What happens when you ingest NaCl?
- Hypernatremia results from
  - Inadequate water intake
    - Altered Mental Status
  - Inability to make or respond to ADH



Diabetes insipidus

- Central DI
  - Brain tumor, tuberculosis, a brain injury or surgery, and some forms of other diseases
  - Diagnosed by showing that replacing ADH corrects the problem
- Nephrogenic DI
  - Lithium
  - Congenital
  - Replacement ADH has no effect

Treatment

- Give water
- How much?
  - Amount of water needed to dilute current total body sodium to desired level
- How fast?
  - Half in the first 24 hrs
  - Half of that in the first 8 hrs
  - Frequent reassessments

$$H_2O = \frac{([Na^+] - 140) \times 0.6 \times LBW}{140}$$

Sodium disorders

- Abnormal [Na^+] almost always means abnormal H_2O metabolism
  - Not abnormal Na^+ metabolism
- Rapidity of treatment should parallel rapidity of onset
- Identify and treat underlying cause