


Sodium Disorders

I. David Weiner, M.D.
Professor of Medicine and Physiology
University of Florida College of Medicine

374-6102
David.Weiner@medicine.ufl.edu
RenalLectures.com


Case presentation

- A 28 year old woman undergoes elective abdominal surgery
- Pre-operatively, serum $[\text{Na}^+]$ 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)



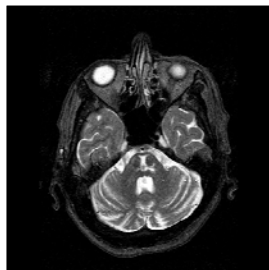
The next day ...

- 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





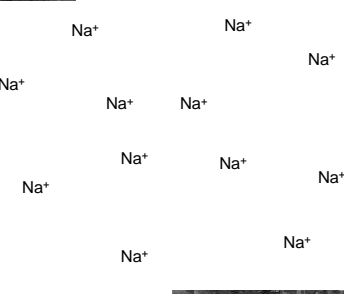
What happened?

- Central pontine myelinolysis





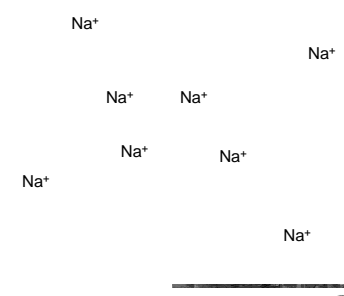
Water is a loner

- H₂O always moves from where there's a lot to where there's less
- Solutions contain H₂O and osmolytes
- H₂O moves from low to high osmolality
- [Na⁺] determines 90-95% of plasma osmolality





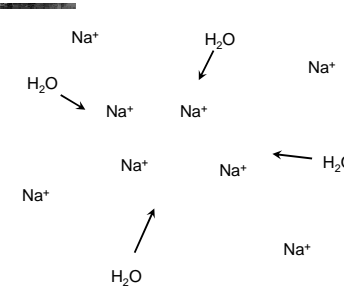
Water is a loner

- H₂O always moves from where there's a lot to where there's less
- Solutions contain H₂O and osmolytes
- H₂O moves from low to high osmolality
- [Na⁺] determines 90-95% of plasma osmolality



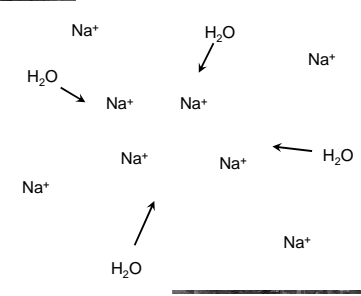
Water is a loner

- H₂O always moves from where there's a lot to where there's less
- Solutions contain H₂O and osmolytes
- H₂O moves from low to high osmolality
- [Na⁺] determines 90-95% of plasma osmolality



Water is a loner


- H₂O always moves from where there's a lot to where there's less
- Solutions contain H₂O and osmolytes
- H₂O moves from low to high osmolality
- [Na⁺] determines 90-95% of plasma osmolality



The diagram illustrates osmosis. It shows two compartments separated by a semi-permeable membrane. The left compartment contains a higher concentration of Na⁺ ions (represented by 'Na+' symbols) and a lower concentration of H₂O molecules. The right compartment contains a lower concentration of Na⁺ ions and a higher concentration of H₂O molecules. Arrows indicate the direction of movement: H₂O molecules move from the right compartment (higher water concentration) to the left compartment (lower water concentration) through the membrane. Na⁺ ions do not move across the membrane.

Acute hyponatremia leads to ...


- Acute cellular swelling
 - Better looking biceps



A black and white photograph of a person's right arm flexed at the elbow, showing a very muscular and well-defined bicep.

Acute hyponatremia leads to ...



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



An axial CT scan of the brain. The image shows a cross-section of the brain with a noticeable shift of the midline structures towards the right side, which is a sign of increased intracranial pressure.




Serum Na⁺ measurements ...

- Do NOT measure the amount of Na⁺ in the body
- DO measure the relative ratio of Na⁺ to H₂O
 - $[Na^+] = Na^+ / H_2O$
- Hyponatremia
 - Excessive H₂O relative to amount of Na⁺





Causes of acute hyponatremia

- Initiation
 - Excessive “free” water administration
 - Dilute intravenous fluids (D₂W, D₅½NS, D₅¼NS, ½ NS)
 - Lots of oral intake (Gatorade ~19 mmol/L Na⁺)
 - Prostate irrigation fluids



Causes of acute hyponatremia

- Continuation
 - Inability to excrete H₂O
 - 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



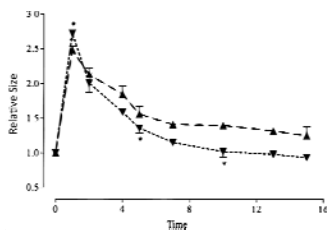
What happened?

- 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 ...

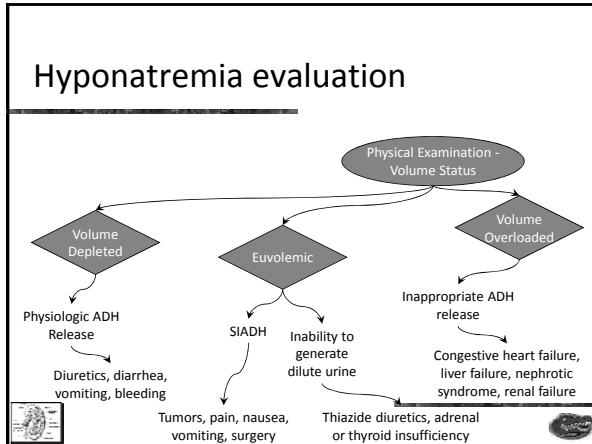
- Do NOT measure the amount of Na⁺ in the body
- DO measure the relative ratio of Na⁺ to H₂O
 - $[Na^+] = Na^+ / H_2O$
- Hyponatremia
 - Excessive H₂O relative to amount of Na⁺



Regulation of total body H₂O

- ADH – stimulates renal H₂O 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





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



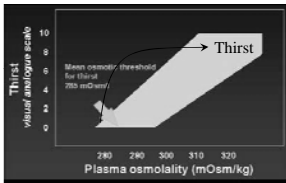
Hypernatremia and serum Na⁺ measurements ...

- Do NOT measure the amount of Na⁺ in the body
- DO measure the relative ratio of Na⁺ to H₂O
 - $[Na^+] = Na^+ / H_2O$
- Hypernatremia
 - Inadequate H₂O 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

$$H_2O = \frac{[Na^+] - 140}{140} \times 0.6 \times LBW_{kg}$$


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

