Sodium Disorders

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Case presentation

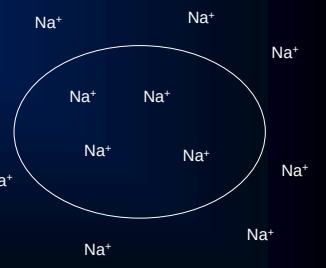
- A 28 year old woman undergoes elective abdominal surgery
- Pre-operatively, serum [Na^+] normal, 140 mmol/L
- Post-operatively, she awakens and appears normal.
- The following day, she developed seizures and acute respiratory failure.

What happened?

- Her serum Na^+ was 116 mmol/L.
- Why …
  - Do we care about her [Na^+]?
  - Did this happen?

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



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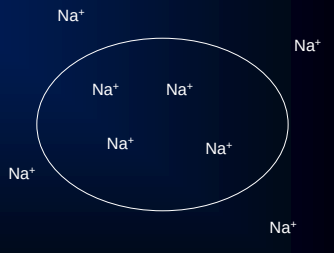

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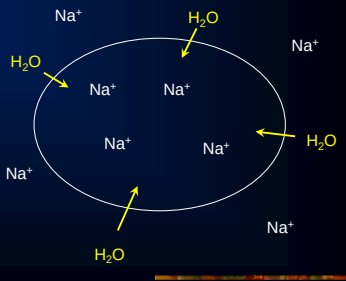

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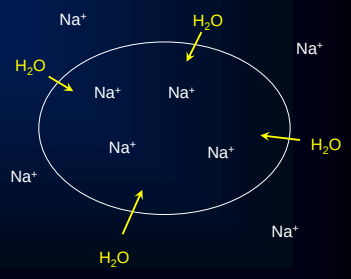


Acute hyponatremia leads to …

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

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^+)
- Continuation
  - Excessive ADH
    - Surgery, vomiting, pain, anxiety

Treating acute hyponatremia

- Emergent
  - Hypertonic NaCl
    - 3% NaCl vs "normal Saline" = 0.9% NaCl
- Sub-emergent
  - Loop diuretics combined with NS intravenous
    - Urine is hypotonic with loop diuretics
    - Infuse NS at rate = urine output

Another case

- 63 year old gentleman with history of chronic alcohol abuse, liver disease and ascites is admitted
- His $[Na^+]$ is 116 mmol/L
- He is treated with 3% NaCl (515 mmol/L)
- 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

What happened?

- Central pontine myelinolysis
- Cause:
  - Over-rapid correction of chronic hyponatremia
  - Particularly in those with histories of alcoholism, malnutrition and general ill health

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

Moral #2

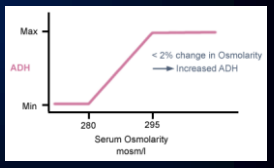
- Chronic hyponatremia only causes problems when corrected rapidly
- General principle:
  - Things that occurred quickly should be treated quickly, and
  - Things that occurred slowly should be treated slowly.

What caused it?

- $[Na^+] = (Na^+_{tb} + K^+_{tb}) / H_2O_{tb}$
  - *tb – total body*
- $\uparrow H_2O_{tb}$
- $\downarrow [Na^+]$

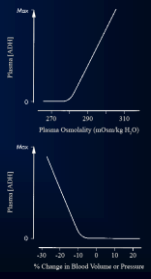
What caused it?

- ALL cases involve ADH
  - Excess ADH
    - Appropriate
    - Inappropriate
  - Inability to respond to ADH

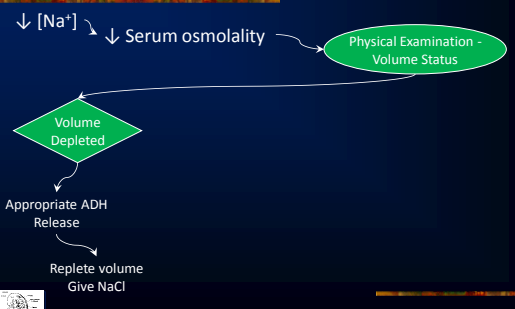


When is excess ADH *appropriate*?

- Life-saving
  - 15-20% ↓ BP/plasma volume
- Choice – osmolality vs blood volume
  - Small changes – osmolality
  - Large changes – blood volume



Hyponatremia evaluation



What causes inappropriate ADH release?

- Body inappropriately producing ADH
  - Nausea, pain, anxiety, surgery
  - Cancers
- Body fooled – thinks its volume depleted but isn't
  - Cardiac failure
  - Liver failure
  - Nephrotic syndrome
- Differentiate by evidence of volume overload
  - Body NOT fooled
    - ↑ADH → H_2O retention
    - H_2O retention → ↑ plasma volume
    - ↑ plasma volume → activation volume sensors
    - Volume sensors → ↑ renal Na^+ excretion

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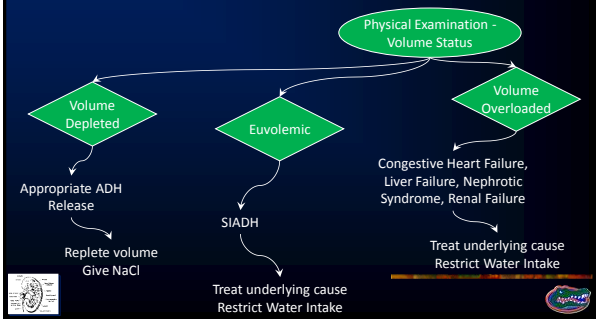
  - Cardiac failure
  - Liver failure
  - Nephrotic syndrome
- Differentiate by evidence of volume overload
  - Body fooled
    - Stimulation of BOTH ADH and volume sensors
    - Stimulation of both H_2O and Na^+ retention
    - Volume overload

Hyponatremia evaluation



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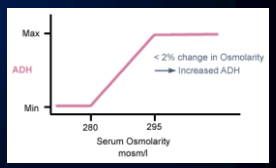


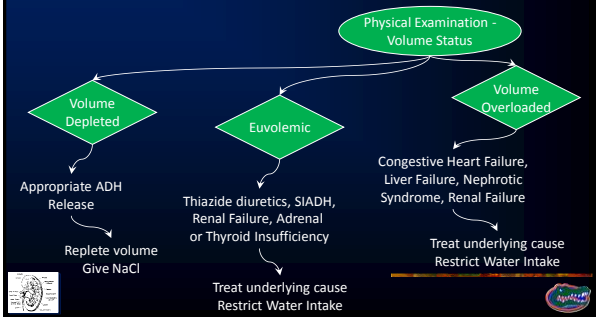
Inability to excrete free water by kidneys

- Kidneys generate dilute urine by NaCl reabsorption without H_2O transport in the connecting segment
- Amount, ~10% GFR
  - Normal GFR, 120 ml/min ≈ 180 L/d
    - 18 L/d
  - Abnormal GFR, 20 ml/min ≈ 28 L/d
    - 2.8 L/d

Inability to excrete free water by kidneys

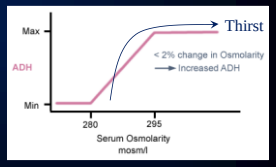
- Kidneys generate dilute urine by NaCl reabsorption without H_2O transport in the connecting segment
- Thiazide diuretics inhibit NaCl transporter
  - Inhibit ability to generate "free" water
- Glucocorticoids and thyroid hormone needed for normal function of NaCl transporter

Hyponatremia evaluation



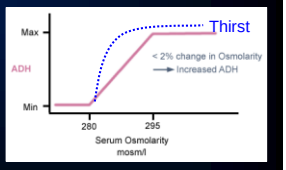
Hypernatremia

- $[Na^+] = (Na^+_{tb}+K^+_{tb})/H_2O_{tb}$
- Hypernatremia results from
  - Inadequate water intake
    - Altered Mental Status



Hypernatremia

- $[Na^+] \approx (Na^+_{tb}+ K^+_{tb})/H_2O_{tb}$
- Hypernatremia results from
  - Laboratory error
  - Inadequate water intake
    - Altered Mental Status
  - Excessive pure ("free") water loss in urine
    - Diabetes insipidus – inability to respond to ADH
      - Lithium
      - Brain injury
      - Genetic



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

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

Sodium disorders

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