

## Volume and sodium disorders

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## Volume disorders

- Why care?
  - Breathing
  - Tissue perfusion
- Fundamental renal function is regulation of plasma volume


## Clinical manifestations of volume overload

- Intravascular
  - Hypertension
- Lungs
  - Pulmonary edema



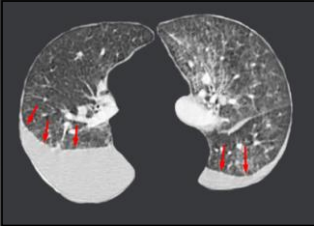
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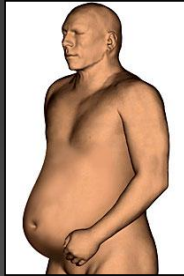
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- Extremities
  - Peripheral edema



## Clinical manifestations of volume overload

- Intravascular
  - Hypertension
- Lungs
  - Pulmonary edema
  - Pleural effusion
- Extremities
  - Peripheral edema
- Abdomen
  - Ascites



## Clinical manifestations of volume depletion

- Low blood volume
  - Hypotension
  - Tachycardia
  - Decreased skin turgor
  - Decreased jugular venous pressure
- Decreased tissue perfusion
  - Decreased mental status
  - Decreased renal function



## What causes volume overload?

- Intake > Excretion
- Intake:
  - Oral
  - Intravenous
- Excretion:
  - Kidneys
    - Capacity of ~20 L per day
- Volume overload indicates failure of the kidneys to adequately excrete NaCl and H<sub>2</sub>O
  - Unable – renal failure
  - Unwilling – inappropriate signal to retain NaCl and H<sub>2</sub>O



## Why would the kidneys be “unwilling” to excrete NaCl and H<sub>2</sub>O?

- Receiving “signal” that body has decreased “effective arterial blood volume”
  - Congestive heart failure
  - Liver failure
  - Nephrotic syndrome
  - Infections



## Volume overload is due to Na<sup>+</sup> excess

- “Signals” resulting from ↓ EABV stimulate renal NaCl retention
  - ↑ NaCl leads to ↑ plasma osmolality
  - ↑ osmolality leads to renal H<sub>2</sub>O retention
- Treatment
  - Treat underlying disease
  - Diuretics



## Causes of volume depletion

- Output > Intake
  - ↓ Intake
    - Decreased mental status → Not eating/being fed
  - ↑ Output
    - Diarrhea
    - Renal losses
      - Diuretics
    - Skin
      - Burns



## Treatment of volume depletion

- Treat underlying disease
- Give back NaCl and H<sub>2</sub>O
  - Chicken soup
  - NS, 0.9% NaCl



## Volume disorders

- Primary disorders of the amount of Na<sup>+</sup>
  - Lead to resultant (secondary) changes in amount of H<sub>2</sub>O
  - Lead to volume disorders
- Primary disorders of the amount of H<sub>2</sub>O
  - Lead to secondary changes in Na<sup>+</sup> ([Na<sup>+</sup>])



## Why care about [Na<sup>+</sup>] disorders?

- Do better on exams
- Bigger is better
  - Except in ...
    - Electronics
    - Cells in the cranium



## Case presentation

- A 28 year old woman undergoes elective abdominal surgery
- Pre-operatively, serum sodium was normal at 140 mmol/L
- Post-operatively, she awoke and appeared to be normal.
- The following day, she developed seizures and acute respiratory failure.



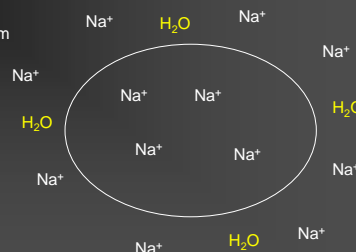
## What happened?

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



## Bigger is better, except in electronics and inside the skull

- H<sub>2</sub>O always moves from areas of high [H<sub>2</sub>O] to low [H<sub>2</sub>O]
- [H<sub>2</sub>O] ≈ 1 / Osmolality
- Corollary:  
H<sub>2</sub>O moves from low to high osmolality
- [Na<sup>+</sup>] determines 90-95% of plasma osmolality



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### Acute hyponatremia leads to ...

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

### Another case

- 63 year old gentleman with history of chronic alcohol abuse, liver disease and ascites is admitted
- His [Na<sup>+</sup>] is 116 mmol/L
- He is treated with 3% NaCl (515 mmol/L)
- The next day his [Na<sup>+</sup>] 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.

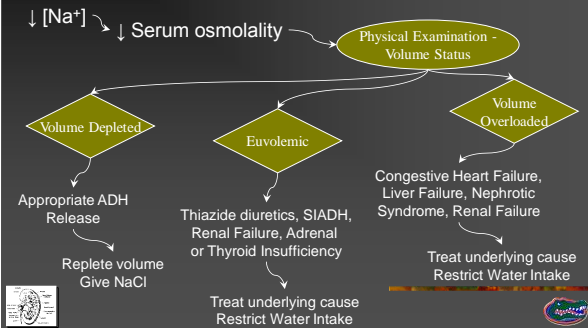


### Why does hyponatremia occur?

- $[Na^+] = (Na^+_{tb} + K^+_{tb}) / H_2O_{tb}$ 
  - *tb* – total body
- ↓ [Na<sup>+</sup>]
  - ↓↓ Na<sup>+</sup>, ↓ H<sub>2</sub>O
  - ↓Na<sup>+</sup>, ↔ H<sub>2</sub>O
  - ↑Na<sup>+</sup>, ↑↑ H<sub>2</sub>O



### Hyponatremia evaluation



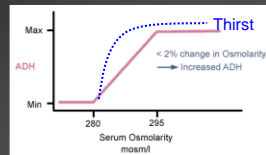
### Hyponatremia treatment

- Fluid restriction
  - ~1000 ml/d, starting
  - May need to decrease
  - All fluids count!
- Acute treatment for acute hyponatremia
  - 3% NaCl (515 mmol/L)
  - $Na^+ \text{ deficit} = (140 - [Na^+]) * 0.6 * LBW_{kg}$ 
    - Give 25% of deficit in 1<sup>st</sup> 8 hours,
    - Give another 25% in next 16 hours,
    - Reevaluate



### 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

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



## Sodium disorders

- Abnormal  $[\text{Na}^+]$  almost always means abnormal  $\text{H}_2\text{O}$  metabolism
  - Not abnormal  $\text{Na}^+$  metabolism
- Rapidity of treatment should parallel rapidity of onset
- Identify and treat underlying cause



## Sodium and water disorders

- Primary disorders of the amount of  $\text{Na}^+$ 
  - Lead to resultant (secondary) changes in amount of  $\text{H}_2\text{O}$
  - Lead to volume disorders
- Primary disorders of the amount of  $\text{H}_2\text{O}$ 
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