"In everything the middle course is best: all things in excess bring trouble."

Titus Maccius Plautus
Greek dramatist
~220 B.C.E.

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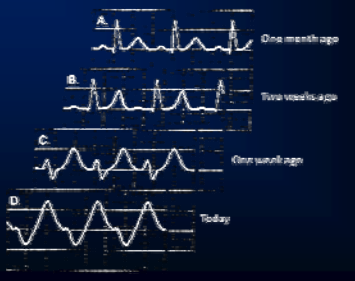
Too much potassium …

Kills people

True story

- 48 year old gentleman presents feeling weak and tired
- Has been eating large amounts of tomatoes, bananas and ice-tea
- Using Motrin for back pain
- Known to have CKD from a genetic condition, but GFR stable

An EKG is performed



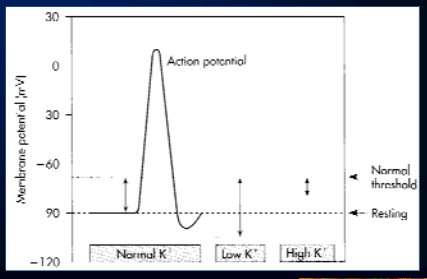
Too much potassium …

- Chronic metabolic acidosis
  - Hyperkalemia inhibits renal ammonia metabolism
    - Renal ammonia metabolism is the primary component of net acid excretion
  - Leads to
    - Skeletal demineralization
    - Muscle atrophy

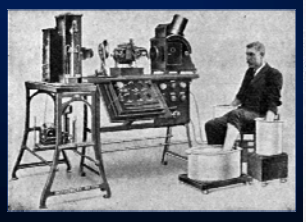
Too little potassium …

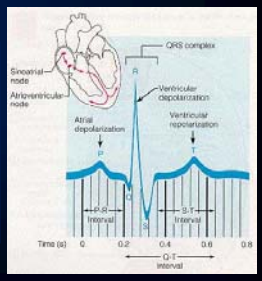
- Kills people
  - Increases likelihood of lethal ventricular arrhythmias
  - Worsens hypertension
  - Worsens diabetes
- Makes people “uncomfortable”
  - Weakness
  - Polyuria

Effects of K^+ on membrane potential

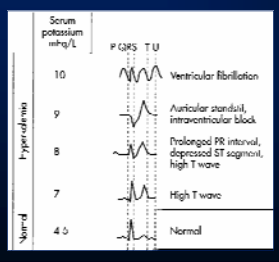


Basics of electrocardiography



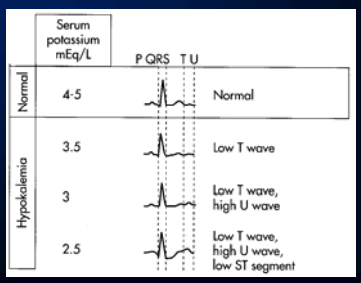


Effects of hyperkalemia on the EKG



- Repolarization increased
  - "Peaked" T waves
- Slowed conduction
  - Prolonged PR interval and QRS complex
- Progression is poorly predictable and not exactly correlated with serum K^+

Effects of hypokalemia on the EKG



Evaluating hyperkalemia

- True or spurious?
  - Cellular K^+ release
    - RBC – Hemolysis
    - Platelets - Thrombocytosis
    - WBC – Leukemia

Evaluating hyperkalemia

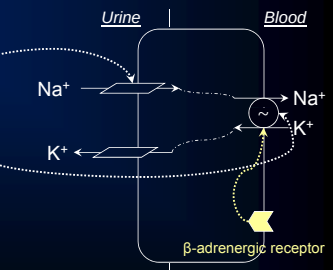
- True or spurious?
- Redistribution or excess total body K^+?
  - Redistribution
    - Acute organic acid metabolic acidosis
      - Diabetic ketoacidosis
    - Digoxin overdose
      - Blocks Na^+-K^+-ATPase

Evaluating hyperkalemia

- True or spurious?
- Redistribution or excess total body K^+?
  - Excess total body K^+
  - Too much in or too little out?
    - Excess dietary intake
      - Tomatoes
      - Chocolate
      - Ice tea
    - Inadequate renal excretion

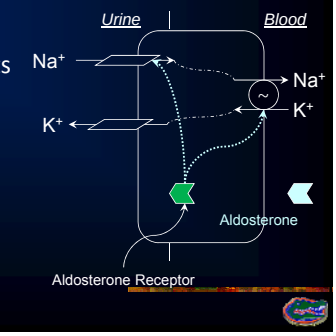
What determines renal K^+ excretion?

- Distal (collecting duct) K^+ secretion
  - Na^+ channel blockers
    - Amiloride
    - Triamterene
    - Trimethoprim
  - Na-K-ATPase inhibitors
    - Digoxin
    - Calcineurin inhibitors
      - Cyclosporine, FK506
  - Prostaglandins
    - NSAIDs and COX-2's
  - β-blockers

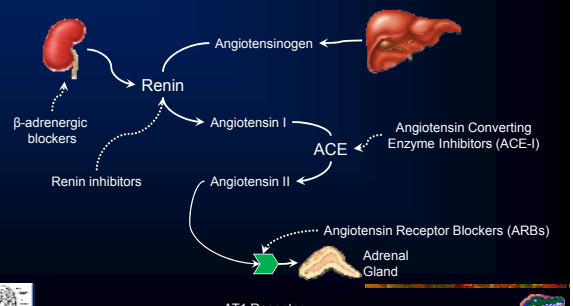


How does the collecting duct know to increase K^+ secretion?

- Aldosterone receptor antagonists
  - Spironolactone
  - Eplerenone



How is aldosterone production regulated?



What to do for hyperkalemia

- If acute lethality possible (see EKG), treat rapidly
  - IV calcium
    - Onset – 1-2 minutes
    - Duration 30-60 minutes
  - Drive K^+ into cells – activate Na-K-ATPase
    - Insulin
      - Give glucose to prevent hypoglycemia
    - β-agonists (high dose)

What to do for hyperkalemia

- Remove K^+ from the body
  - Kayexalate
    - Na^+-K^+ exchange resin
      - Onset – 1-2 hours
      - Acts in colon
  - Hemodialysis
    - Onset – depends on availability
  - Diuretics
    - Only if residual renal function
    - Best for long-term treatment of mild hyperkalemia

Another case

- 64 year woman presents to ER with sub-sternal chest pain for the past 2 hours
- Post-menopausal
- Is taking diuretics for high blood pressure with only fair BP control
- Has recent history of poorly controlled DM
- EKG consistent with acute myocardial ischemia
- While waiting to go to cardiac catheterization laboratory she dies

20 minutes later …

- $[K^+]$ is 2.8 mmol/L
- All other laboratory tests normal

Hypokalemia, why care

- Increases myocardial susceptibility to arrhythmias
- Causes hypertension
  - NaCl retention
  - Increases vasoconstriction
- Impairs blood glucose regulation

How to evaluate hypokalemia

- Real or spurious?
  - Leukemic WBC can take up K^+ after blood drawn
- Redistribution?
  - Insulin
  - Aldosterone
  - β-agonists
    - Bronchodilators
    - Pre-mature labor
    - Response to myocardial ischemia

How to evaluate hypokalemia

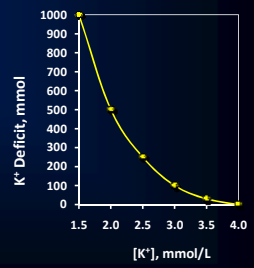
- Real or spurious?
- Redistribution?
- Total body K^+ deficiency
  - Renal K^+ loss
    - Diuretics
    - Hypomagnesemia
  - Non-renal K^+ loss
    - Diarrhea
    - Diaphoresis
  - Inadequate dietary intake

How to treat hypokalemia

- Treat underlying cause
- K^+ replacement
  - Oral is safer (KCl)
  - IV
    - 10 mEq per hr – safest
    - 20 mEq per hr – less safe
    - 40 mEq per hr – ICU with continuous EKG monitoring

How much K^+ to give?

- Replace deficit
- Problem – 98% of K^+ is intracellular
  - We measure extracellular K^+
  - Total body deficit is MUCH larger than appears from serum K^+



Basic principles of electrolyte management

- Do you believe the results?
- How fast did it develop?
- What caused it?
- Know your treatment options