Disorders of Potassium and Acid-Base Balance

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ACID-BASE DISORDERS

Physiology of Acid-Base Balance

Definitions of acid-base disorders

- Metabolic acidosis: fall in $\text{HCO}_3^-$ concentration with fall in $\text{pH}$
- Metabolic alkalosis: rise in $\text{HCO}_3^-$ concentration with rise in $\text{pH}$
- Respiratory acidosis: rise in $\text{CO}_2$ concentration with fall in $\text{pH}$
- Respiratory alkalosis: fall in $\text{CO}_2$ concentration with rise in $\text{pH}$

Compensatory response to acid-base disorders

- Metabolic acidosis: fall in $\text{pH}$ causes increased respiration, reducing $\text{CO}_2$
- Metabolic alkalosis: rise in $\text{pH}$ causes decreased respiration, increasing $\text{CO}_2$
- Respiratory acidosis: fall in $\text{pH}$ causes increased renal $\text{H}^+$ secretion, raising $\text{HCO}_3^-$ concentration
- Respiratory alkalosis: rise in $\text{pH}$ causes diminished renal $\text{H}^+$ secretion, lowering $\text{HCO}_3^-$ concentration

Response to acid generation

Average 1 mEq/kg/d for typical Western diet.
- Blood buffering of newly formed acid by bicarbonate, creation of $\text{CO}_2$
- Less efficient buffering of acid by hemoglobin in red blood cells, $\text{Ca}^{2+}$ exchange in bone
- Renal handling of acid:
  - Hydrogen excretion by proximal tubule (PT) into lumen leads to reclamation and reabsorption of $\text{HCO}_3^-$
  - $\text{H}^+$ then combines with either $\text{HPO}_4^{2-}$ or $\text{HSO}_4^-$ (“titratable acids”) or $\text{NH}_3$ in tubular lumen; 10 to 40 mEq of $\text{H}^+$ excreted each day as titratable acidity, 30 to 60 mEq/d by $\text{NH}_4^+$
  - Reclamation of filtered bicarbonate occurs primarily in PT
  - Under conditions of excessive acid generation (metabolic acidosis), ammoniagenesis is required to enhance acid secretion:
    - $\text{NH}_4^+$ produced by renal tubular cells from metabolism of amino acids (primarily glutamine)
    - $\text{NH}_4^+$ reabsorbed in thick ascending loop and recycled as $\text{NH}_3$ in renal medulla
    - $\text{NH}_3$ diffuses into tubular lumen, trapped as $\text{NH}_4^+$ by secreted $\text{H}^+$
    - Glutamine metabolism enhanced by hypokalemia, inhibited by hyperkalemia

Cellular mechanisms of renal adaptation

- To respiratory acidosis:
  - Increased PT cell secretion of hydrogen ion due to decreased cell $\text{pH}$
  - Increased PT cell secretion of $\text{H}^+$ via $\text{Na}^+/\text{H}^+$ exchanger, and increased reabsorption of $\text{HCO}_3^-$ via $\text{Na}^+/3\text{HCO}_3^-$ cotransporter on basolateral surface
- To respiratory alkalosis:
  - Decreased PT cell activity of carbonic anhydrase
  - Decreased PT cell secretion of $\text{H}^+$ and decreased reabsorption of $\text{HCO}_3^-$

Metabolic Acidosis

Causes

- Increased acid load:
  - Lactic acidosis
  - Ketoacidosis

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Ingestions:
- Salicylates
- Methanol
- Ethylene glycol
- Paraldehyde
- Sulfur
- Toluene
- Ammonium chloride
- Hyperalimentation fluids

Extrarenal acidosis:
- $\text{HCO}_3^-$ losses via gastrointestinal loss:
  - Diarrhea
  - Intestinal fistula
  - Ureterosigmoidostomy

Renal acidosis:
- Defect in $\text{HCO}_3^-$ reclamation:
  - Type 2 “proximal” renal tubular acidosis (RTA)
- Defect in $\text{HCO}_3^-$ regeneration:
  - Diminished $\text{NH}_4^+$ production (renal failure, hypaldosteronism-type IV RTA)
  - Diminished $\text{H}^+$ secretion (type I RTA)

Utility of plasma and urine anion gap:
- Plasma anion gap:
  - $[\text{Na}^+] - ([\text{Cl}^-] + [\text{HCO}_3^-])$; normally 8 to 11 mEq/L (mmol/L)
  - Buffering of HA (proton-anion) by $\text{HCO}_3^-$ in setting of increased acid load leads to increased unmeasured anions (A$^-$) and increased anion gap

- Urine anion gap:
  - $([\text{Na}^+] + [\text{K}^+]) - [\text{Cl}^-]$
  - In setting of metabolic acidosis with normal plasma anion gap (“hyperchloremic metabolic acidosis”), urine anion gap is useful to distinguish between extrarenal and renal acidosis

  - Urine anion gap greater than 0 suggests failure to excrete acid load (eg, RTA)
  - Urine anion gap less than 0 suggests extrarenal bicarbonate loss (eg, diarrhea)

Renal tubular acidosis

Hyperchloremic metabolic acidosis, normal serum anion gap, urine anion gap greater than 0.

Type I RTA (defect in $\text{H}^+$ secretion in distal tubule).
- Physiology:
  - $\text{H}^+$-adenosine triphosphatase (ATPase) located in cortical collecting tubule (intercalated cells only), where $\text{H}^+$ secretion influenced by $\text{Na}^+$ reabsorption in principal cells, and in medullary collecting duct

Pathophysiology:
- Defect in distal $\text{H}^+$-ATPase pump (Sjögren syndrome), increased collecting duct membrane permeability with back-diffusion of $\text{H}^+$ (amphotericin B), decreased distal delivery of $\text{Na}^+$ with failure to exchange for $\text{H}^+$ and $\text{K}^+$ (volume depletion), or decreased cortical reabsorption of $\text{Na}^+$ with net increase in luminal charges and inhibition of $\text{H}^+$ and $\text{K}^+$ secretion (“hyperkalemic type I RTA,” as in urinary tract obstruction or sickle cell disease)

- Calcium and phosphate release from bone to buffer acidemia leads to propensity for nephrocalcinosis in type I RTA

Diagnosis:
- Urine pH >5.3
- Plasma $\text{K}^+$ usually low or normal (except with voltage defect)

### Table 1. Formulae Quantifying the Degree of Compensation

<table>
<thead>
<tr>
<th>Disorder</th>
<th>Compensation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metabolic acidosis</td>
<td>CO$_2$ decreases by 1.0-1.5 × the decrease in arterial $\text{HCO}_3^-$</td>
</tr>
<tr>
<td>Metabolic alkalosis</td>
<td>$\text{CO}_2$ increases by 0.25-1.0 × the increase in arterial $\text{HCO}_3^-$</td>
</tr>
<tr>
<td>Respiratory acidosis</td>
<td></td>
</tr>
<tr>
<td>Acute</td>
<td>$\text{HCO}_3^-$ increases by about 1 for each 10–mm Hg increase in $\text{CO}_2$</td>
</tr>
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<td>Chronic</td>
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</table>
Plasma HCO$_3^-$ low (<14 mEq/L [mmol/L])

- Treatment:
  - HCO$_3^-$ 1-2 mEq/kg/d

**Type II RTA (defect in PT HCO$_3^-$ reclamation).**

- Physiology:
  - Filtered HCO$_3^-$ reabsorbed primarily in the PT after the addition of a proton in lumen (Na$^+$/H$^+$ antiporter), forming H$_2$CO$_3$, and conversion to CO$_2$ and H$_2$O facilitated by carbonic anhydrase
  - CO$_2$ diffuses across apical membrane and converted to HCO$_3^-$ again by carbonic anhydrase
  - HCO$_3^-$ then transported to blood by Na$^+$/3HCO$_3^-$ cotransporter
  - Distal nephron contributes a trivial amount of HCO$_3^-$ reabsorption via intercalated cell of collecting duct

- Pathophysiology:
  - Injury to luminal Na$^+$/H$^+$ antiporter or basolateral Na$^+$/K$^+$-ATPase pump (likely etiologies for type II RTA in multiple myeloma, Fanconi syndrome, ifosfamide therapy) or deficient/inhibited carbonic anhydrase (cystinosis, acetazolamide therapy)
  - Acidosis milder than type I RTA due to intact reabsorption of HCO$_3^-$ in distal nephron
  - Often evidence of generalized PT dysfunction is present, with glycosuria, aminoaciduria, and phosphaturia

- Diagnosis:
  - Urine pH >5.3 if above reabsorptive threshold, <5.3 in steady state, plasma K$^+$ usually low, plasma HCO$_3^-$ 14 to 20 mEq/L (mmol/L)

- Treatment:
  - HCO$_3^-$ 10 to 15 mEq/kg/d

**Type IV RTA (aldosterone deficiency or resistance).**

- Physiology:
  - Aldosterone promotes distal Na$^+$ reabsorption, K$^+$ and H$^+$ secretion
  - Direct effects of aldosterone on Na and K channels in luminal membrane of principal cells in cortical collecting tubule, increased Na$^+$-K$^+$-ATPase pump activity in basolateral membrane, and H$^+$-ATPase pump activity in intercalated cells in cortical collecting duct, medullary collecting tubule cells
  - Indirect effects of aldosterone in H$^+$ secretion secondary to electrochemical gradient induced by Na$^+$ reabsorption

- Pathophysiology:
  - Decreased adrenal aldosterone production (heparin, tuberculosis, adrenal insufficiency)
  - Decreased activity of renin-angiotensin system (diabetes, renal insufficiency, angiotensin-converting enzyme inhibitors/angiotensin receptor blockers)
  - Resistance to aldosterone (potassium-sparing diuretics, trimethoprim, pseudohypoaldosteronism)
  - Acidosis exacerbated by hyperkalemia-induced inhibition of glutaminase with diminished ammoniagenesis

- Diagnosis:
  - Urine pH <5.3, plasma K$^+$ high, plasma HCO$_3^-$ 14 to 20 mEq/L (mmol/L)

- Treatment:
  - Correct hyperkalemia, HCO$_3^-$ 1 to 2 mEq/kg/d

**RTA of renal insufficiency (reduction in nephron mass).**

- Physiology:
  - Under normal conditions, ammonium excretion increases in response to an acid load, as described earlier in the Physiology/Response to Acid Generation subsection; this increase can be up to 3 to 4 times normal, but is limited by glomerular filtration rate (GFR)

- Pathophysiology:
  - Fibrosis that occurs with chronic kidney disease leads to diminished functional nephron number and diminished capacity for ammoniagenesis
  - At GFR less than 40 to 50 mL/min (0.67 to 0.83 mL/s), total ammonium excretion diminishes
  - H$^+$ is retained but a reduction in HCO$_3^-$ is stabilized at serum levels of 12 to 20 mEq/L by calcium buffering from bone

- Diagnosis:
  - Measurement of GFR
Treatment:

- NaHCO₃ therapy can be used to minimize bone buffering of acidemia and delay development of osteopenia, but this benefit must be weighed against risks of sodium retention.

- Indications for use of alkali include:
  - Dyspnea/inability to maintain respiratory compensation
  - Chronic kidney disease in children (at risk of growth retardation)
  - Severe acidosis with plasma HCO₃⁻ less than 12 mEq/L (mmol/L)

**Anion gap acidosis.**

- Treat underlying disease process
- With saline hydration, NaCl + HA → kidney excretes NaA rather than NH₄⁺
- Transition from “anion gap” to “nonanion gap” acidosis in the hydrated patient during treatment

**Lactic acidosis and ketoacidosis.**

- Treat underlying disease process
- Controversies surround use of bicarbonate-containing fluids in ketoacidosis and lactic acidosis due to potential risk of worsening intracellular acidosis and lack of clinical benefit

**Ingestions.**

- Competitive inhibition of alcohol dehydrogenase with ethanol or fomepizole for alcohol ingestions
- Indications for hemodialysis treatment under conditions of ethylene glycol, methanol, and salicylate ingestion

**Rhabdomyolysis.**

- Enhancement of myoglobin excretion with alkalinization of urine with bicarbonate-containing fluids, hemodialysis

**Renal tubular acidosis.**

- Identify type of RTA by urine pH, serum potassium
- Calculate bicarbonate deficits, replacement needs, and maintenance dosing of bicarbonate in cases of RTA types I, II, and IV

**Metabolic Alkalosis**

**Causes**

- Two phases of metabolic alkalosis:
  - **Generation phase.**
  - **Maintenance phase.**

**Factors that generate a metabolic alkalosis:**

- Loss of hydrogen due to gastrointestinal losses:
  - Gastric suction
  - Vomiting
  - Antacid therapy
  - Chloride-losing diarrhea
- Renal losses:
  - Diuretics
  - Mineralocorticoid excess
  - Hypercalcemia/milk-alkali syndrome
  - Low chloride intake
- H⁺ shift into cells:
  - Hypokalemia
  - Refeeding
- Retention of bicarbonate:
  - Massive blood transfusions
  - NaHCO₃ administration
- Contracture alkalosis:
  - Diuretics
  - Sweat losses in cystic fibrosis

**Maintenance phase.**

- Decreased GFR (due to volume depletion or renal failure) or
- Increased tubular reabsorption of HCO₃⁻ (due to volume depletion, chloride depletion, hypokalemia, hyperaldosteronism)

**Urinary chloride measurement in diagnosis of metabolic alkalosis.**

- Urine Cl⁻ <10 mEq/L (mmol/L):
  - Vomiting
  - Nasogastric suction
  - Diuretics
- Urine Cl⁻ >20 mEq/L (mmol/L):
  - In hypertension:
    - Cushing syndrome
    - Primary hyperaldosteronism
    - Hypokalemia
    - Glucocorticoid remediable aldosteronism
    - Conditions of apparent mineralocorticoid excess
  - With normal/low blood pressure:
    - Bartter syndrome
    - Gitelman syndrome

**Treatment**

- Metabolic alkalosis with low urinary chloride:
Normal saline or ½ normal saline lowers plasma HCO₃⁻ by reversing the stimulus to renal Na⁺ retention, permitting NaHCO₃ excretion, and increasing distal Cl⁻ delivery, which promotes HCO₃⁻ secretion (“saline-responsive alkalosis”)

Metabolic alkalosis with high urinary chloride:
- Treatment of underlying disorder (eg, adrenal adenoma resection) and repletion of potassium

### Respiratory Acidosis

#### Causes
- Inhibition of respiratory drive:
  - Opiates
  - Anesthetics
  - Sedatives
  - Central sleep apnea
  - Obesity
  - Central nervous system lesions
- Disorders of respiratory muscles:
  - Muscle weakness:
    - Myasthenia gravis
    - Periodic paralysis
    - Aminoglycosides
    - Guillain-Barré syndrome
    - Spinal cord injury
    - Acute lateral sclerosis
    - Multiple sclerosis
  - Kyphoscoliosis
- Upper airway obstruction:
  - Obstructive sleep apnea
  - Laryngospasm
  - Aspiration
- Lung disease:
  - Pneumonia
  - Severe asthma
  - Pneumothorax
  - Acute respiratory distress syndrome
  - Chronic obstructive pulmonary disease
  - Interstitial lung disease

#### Renal adaptation
- Elevated PCO₂ in PT leads to decreased intracellular pH, enhances H⁺ secretion in PT, leading to increased HCO₃⁻ generation over 5 days (3 to 5 mEq/L [mmol/L] HCO₃⁻ for every 10–mm Hg increase in PCO₂)

### Treatment
- Ventilatory support
- NaHCO₃ therapy controversial in this disorder:
  - Perhaps beneficial in severely acidemic patient (eg, status asthmaticus) versus
  - Hazards of therapy in patients with reversible hypercapnea (eg, chronic obstructive pulmonary disease in which respiratory drive is depressed)

### Respiratory Alkalosis

#### Causes
- Hypoxemia
  - Pulmonary diseases:
    - Pneumonia
    - Interstitial fibrosis
    - Emboli
    - Edema
  - Congestive heart failure
  - Anemia
- Stimulation of the medullary respiratory center:
  - Hyperventilation
  - Hepatic failure
  - Septicemia
  - Salicylate intoxication
  - Pregnancy
  - Neurologic disorders
- Mechanical ventilation

#### Symptoms
- Lightheadedness
- Paresthesias
- Cramps
- Carpopedal spasm

#### Renal adaptation
- Decreased PCO₂ in PT leads to increased intracellular pH, inhibits H⁺ secretion in the PT, leading to decreased HCO₃⁻ generation over 5 days (reduces serum concentration of HCO₃⁻ 3 to 5 mEq/L [mmol/L] for every 10–mm Hg decrease in PCO₂)

#### Treatment
- Correction of underlying disorder
- Increasing PCO₂ in inspired air (breathing into paper bag) in setting of acute respiratory alkalosis
Mixed Acid-Base Disorders

Diagnosis
- Identified by inappropriate or inadequate correction using the formulae for renal and respiratory compensation described in Table 1

Common scenarios
- Mixed respiratory acidosis and metabolic alkalosis (eg, chronic obstructive pulmonary disease and diuretic therapy)
- Mixed metabolic acidosis and metabolic alkalosis (eg, ketoacidosis and vomiting)
- Mixed respiratory alkalosis and metabolic acidosis (salicylate intoxication)

Change in serum anion gap (ΔAG)
- Use of ΔAG to determine if mixed acid-base disturbance is present
- The ΔAG = measured anion gap – expected anion gap
- The ΔAG is most useful to distinguish concomitant metabolic alkalosis and anion gap metabolic acidosis
- If ΔAG + measured bicarbonate is greater than physiologic bicarbonate concentrations (eg, 21 to 27 mEq/L [mmol/L]), an underlying metabolic alkalosis is present

ADDITIONAL READING

DISORDERS OF POTASSIUM (K)

Physiology of K Balance
Total body K determined by internal and external K balance:

Internal balance
Factors that regulate:
- Acid-base/metabolic acidosis: differences between organic (limited K shifts) and inorganic hyperchloremic acidosis
- Insulin: K moves from extracellular to intracellular sites
- Tonicity: hyperglycemia, mannitol moves K from intracellular to extracellular sites
B₂ adrenergic receptor: Catecholamines through B₂ adrenergic receptor move K into cells; α adrenergic receptor prevents K movement from extracellular to cellular compartments

Clinical correlate: “stress hypokalemia”

External balance
Renal K physiology:
- K freely filtered
- Filtered K reabsorbed in proximal convoluted tubule and proximal straight tubule
- K added to distal loop of Henle (at least in deep glomeruli) so that, at tip of loop, fractional excretion of K (FEₖ) 150% of filtered load
- K reabsorbed in ALH (Na, K₂Cl cotransporter) so that, at beginning of distal convoluted tubule, FEₖ 15% of filtered load
- K added to lumen of cortical collecting tubule so that, at end of this tubule, FEₖ 100% of filtered load
- K secretion mediated by Na reabsorption through Na channel followed by Na extrusion by basolateral Na, K ATPase, resulting in increases in cell K and K extrusion into the lumen through K channels
- K secretion regulated by aldosterone secretion (regulated by angiotensin II and total body K) and action (regulated by 11 B-OH steroid dehydrogenase and mineralocorticoid receptor) as well as distal nephron Na delivery and concentration
- K reabsorbed by collecting tubule, through K/H exchange (regulated by decreases in total body K)
- Urine K is independent of GFR above 30 mL/min (0.50 mL/s)
- Increases in urinary K are due to increases in K secretion or decreases in K reabsorption

Hypokalemia

Definition
- Serum K less than 3.5 mEq/L (mmol/L)

Causes

Normal total body K/transcellular shift.
- Alkalemia
- Insulin excess
- “Stress” (eg, asthma attack, acute coronary syndrome, drug intoxication [cocaine] or withdrawal [alcohol], B₂ adrenergic drugs)
- Hypokalemic periodic paralysis
- Thyrotoxicosis
- Refeeding syndromes
- Barium
- Cesium hypothermia

Decreased total body K.
- Decreased K intake, or
- Increased K losses:
  - Spurious.
  - Extreme leukocytosis

Spuriously.

Diagnostic approach
To decreases in total body K: use of urine K concentration, 24-hour urine K, transtubular K gradient:

Low 24-hour urine K (<20 mEq [mmol]/d):

extrarenal losses.
- Metabolic acidosis: gastrointestinal losses
- Normal pH: decreased intake, gastrointestinal losses
- Metabolic alkalosis: gastrointestinal losses

High 24-hour urine K (>20 mEq [mmol]/d): renal losses.
- Metabolic alkalosis:
  - Low urine chloride (<10 mEq [mmol]/d): vomiting, diuretics
  - High urine chloride (>20 mEq [mmol]/d): hypertension.

ADDITIONAL READING
“Normal” aldosterone: Cushing syndrome, Liddle syndrome, apparent mineralocorticoid excess syndrome

High aldosterone: primary aldosteronism, glucocorticoid remediable aldosteronism

Normal or low blood pressure: diuretics (during therapy), severe K depletion, Bartter syndrome, Gitelman syndrome

Variable pH:
- Magnesium depletion
- Anionic drugs
- Metabolic acidosis

RTA types I and II

Clinical manifestations

Cardiovascular:
- Arrhythmias
- Digitalis toxicity

Neuromuscular:
- Smooth muscle:
  - Ileus
- Skeletal muscle:
  - Weakness
  - Paralysis
  - Rhabdomyolysis

Endocrine:
- Glucose intolerance

Renal/electrolyte:
- Vasopressin resistance
- Increased ammonia production
- Metabolic alkalosis

Structural changes:
- Renal cysts
- Interstitial changes
- PT dilation, vacuolization

Treatment

Estimate of K deficit: serum K may not reflect total body K

Reverse source of K loss

Symptomatic: intravenous K (rate, complications)

Asymptomatic:
- Metabolic acidosis:
  - K plus citrate, or
  - \( \text{HCO}_3^- \)
- Metabolic alkalosis:
  - K plus NaCl (chloride responsive)

Role of spironolactone, amiloride (chloride resistant)

Importance of magnesium therapy

ADDITIONAL READING


Hyperkalemia

Definition (mmol/L)

- Serum K ≥5.0 mEq/L (mmol/L)

Causes

Normal total body K: transcellular shift.

- Exercise, especially in setting of β adrenergic receptor blockade and mineral acidosis
- Hyperchloremic metabolic acidosis
- Insulin deficiency
- Hypertonicity
- α adrenergic receptor stimulation
- Tissue breakdown or ischemia, for example:
  - Rhabdomyolysis
  - Gastrointestinal
  - Brain

Increased total body K.

- Increased intake: rare as sole cause
- Decreased renal K excretion

Spurious.

- Thrombocytosis
- Leukocytosis
- Ischemic blood draw

Diagnostic approach

To increases in total body K: use of urine K concentration, 24-hour urine K, and/or transtubular K gradient (\( S_K/\text{Urine K} \div \text{Sosm/Uosm} \)):

Normal to high 24-hour urinary K (>40 to 60 mEq [mmol]/d):

- Relative increase in K intake

Low 24-hour urinary K (<20 to 40 mEq [mmol]/d):

- Decrease renal K excretion:
  - GFR >20 mL/min (0.33 mL/s):
Decreased distal nephron Na delivery
Decreased mineralocorticoid production or action
Decreased total body Na
Increased total body Na:
- heart failure
- cirrhosis
Decreased production:
- Addison disease
- Isolated hypoaldosteronism (hereditary, acquired, drugs [angiotensin-converting enzyme inhibitors, heparin, nonsteroidal anti-inflammatory drugs, COX2 inhibitors, infection [human immunodeficiency virus], chronic kidney disease [diabetes, tubular interstitial diseases, others])
Decreased action:
- Hereditary (pseudohypoaldosteronism types I and II)
- Acquired (drugs [angiotensin receptor blockers, amiloride, spironolactone, triamterene] and pseudohypoaldosteronism [hereditary, acquired: sickle cell disease, renal allograft disease, obstruction])

GFR <20 mL/min (0.33 mL/s):
- Endogenous or exogenous K
- Drugs that impair K excretion

Clinical manifestations
- May be disproportionately greater than level of serum K
- Cardiovascular:
  - T-wave abnormalities
  - Lengthened segments
  - Bradyarrhythmias
- Neuromuscular:
  - Ileus
  - Paresthesias
  - Weakness
  - Paralysis
- Renal/electrolyte:
  - Decreased ammonia production
  - Metabolic acidosis

Treatment
- Who requires emergent therapy:
  - Electrocardiogram abnormalities
  - Ileus
  - Paralysis
- Emergent therapies:
  - Doses, pharmacology
  - Stabilize cell membrane: Ca
  - Shift K from extra to intracellular compartments:
    - Insulin (± glucose)
    - HCO3
    - Albuterol (B2 adrenergic receptor agonist)
- Decrease total body K
  - K exchange resin (oral or rectal)
  - Hemodialysis
- Prevention of hyperkalemia:
  - Importance of diet
  - Recognition of drugs that decrease K secretion
  - Role of adequate distal Na delivery
  - K exchange resins

ADDITIONAL READING