# Hyperkalemia

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### Key Words

**Hyperkalemia, potassium, electrolyte abnormalities**

## Common case presentation:

65 year old diabetic female with CKD stage 4 just underwent a 7 hour radical nephrectomy in flank position. During the case, she was transfused 6 units of pRBCs. Postoperatively, her hematocrit is stable, but her metabolic profile is significant for a serum potassium of 6.5 mEq/L.

## I. Receiving the phone call and initial thoughts

a. **What are the vitals?** Hyperkalemia can result in abnormalities in cardiac conduction which can predispose towards deadly arrhythmias.
b. **What were some of the specifics of her operation?** Long operations, especially those performed in flank position, can result in rhabdomyolysis and liberation of intracellular potassium.
c. **What is her baseline renal function?** There are two main mechanisms by which the body maintains potassium hemostasis: renal excretion and cellular shifts of potassium. Risk of hyperkalemia is inversely related to glomerular filtration rate, and increase perceptibly once the GFR is < 30 mL/min. [1]
d. **Was there a blood transfusion?** Acute hemolytic transfusion reactions can occur due to use of incompatible red blood cells or large volume of incompatible plasma.[2]
   These reactions are rare but can cause release of large amount of intracellular potassium, which can cause hyperkalemia, especially in the setting of impaired renal function.

## II. Differential Diagnosis

a. **Hyperkalemia**
   Hyperkalemia is a potentially life-threatening electrolyte disorder typically caused by shifting of intracellular potassium out of cells (typically transient) or by impaired renal potassium excretion (sustained). The major physiologic regulation of potassium concentration is renal excretion and

shifts of potassium into and out of cells. The vast majority of potassium is stored intracellularly, and even small shifts of potassium extracellularly can cause hyperkalemia. The main physiologic regulators of potassium shift into cells are insulin and catecholamines

1. **Causes**
    i. **Metabolic Acidosis**
    Mineral acidosis (NH4Cl or HCl) can directly result in potassium movement into extracellular fluid to maintain electroneutrality.[3] Organic metabolic acidosis (i.e. lactic acidosis or ketoacidosis) do not directly cause significant efflux of potassium, but are associated with other causes of acidosis (i.e. renal failure)
    ii. **Acute or Chronic Renal Failure**
    Renal failure is a significant risk factor for the development of hyperkalemia and can occur whether acute or chronic. Decreased renal function results in impairment of potassium excretion[4]
    iii. **Decompensated Heart failure**
    can exacerbate hyperkalemia due to decreased renal perfusion
    iv. **Medications**
        1. **Renin angiotensin aldosterone system (RAAS) inhibitors**
        angiotenisin-concerning enzyme inhibitors (ACEIs), angiotensin receptor blockers (ARBs), aldosterone receptor antagonists
        2. **Calcineurein inhibitors**
        decrease aldosterone synthesis and the activity of the sodium-potassium ATPase pump[5]
        3. **Nonsteroidal anti-inflammatory drugs**
        decrease prostaglandin-mediated renin release, renal blood flow, and glomerular filtration[6]
        4. **Heparin**
        blocks the biosynthesis of aldosterone in the adrenal gland[7]
        5. **Ketoconazole**
        Interferes with biosynthesis of adrenal steroids and can cause aldosterone deficiency[8]
        6. **Potassium-sparing diuretics**
        spironolactone, eplerenone, amiloride, triamterene[8]
        7. **Trimethoprim**
        blocks luminal sodium channels[9]
        8. **Pentamide**
        blocks luminal sodium channels[10]
        9. **Nonselective beta blockers**
        (i.e. propranolol, carvedilol, labetalol, nadolol)
    v. **High potassium diets**
    The body has several mechanisms to absorb excess dietary potassium, however

excess dietary potassium can overwhelm the body's ability to excrete or shift it intracellularly when there are other factors involved, especially in the setting of poor renal function. High potassium dietary sources include melons, citrus juice, salt substitutes, coconut juice, noni juice, and certain herbs

vi. **Tissue Injury**
rhabdomyolysis, hemolysis, tumor lysis

vii. **Insulin Deficiency: insulin promotes potassium entry into cells**

viii. **Diabetic Ketoacidosis or Hyperosmolar Hyperglycemic State**
Although patients generally have a potassium deficit in these conditions, some patients may develop hyperkalemia. The increased serum osmolality can result in water shift from intracellular into extracellular space, which results in potassium also following out of the cells by solvent drag and redistribution[11]

ix. **Hyperkalemic Periodic Paralysis**[12]

x. **Exercise**
potassium increases during exercise, but rarely important clinically

xi. **Use of jejunum as urinary diversion**[13]

xii. **Reduced aldosterone secretion**
hyporeninemic aldosteronism (e.g. diabetic nephropathy, medications), primary adrenal insufficiency, severe illness, congenital hypoaldosteronism, pseudohypoaldosteronism type 2

xiii. **Aldosterone resistance**
medications, pseudohypoaldosteronism type 1, reduced sodium delivery to distal tubule, defects in the sodium resorptive capacity of distal tubule (i.e. obstructive uropathy)

b. **'Pseudohyperkalemia'**
Spurious elevations in measured serum potassium levels can occur with hemolysis during venipuncture (fist clenching during phlebotomy, application of tourniquets, use of small-bore needles) or handling/processing of blood, thrombocytosis, familial pseudohyperkalemia, or polyctemia[14]

# III. Evaluation

a. **Physical Exam - Key Points**

i. **Vitals**
Hyperkalemia can result in cardiac conduction abnormalities and arrhythmias

ii. **General**
when serum potassium concentration rises above 7.0 mEq/L, patients may experience muscle weakness or paralysis

iii. **Heart**
cardiac conduction abnormalities and cardiac arrhythmias

iv. **Intake/Output:** evaluate color of urine, as a dark, cola, or tea-colored color can be an indicator of myoglobinuria and a sign of rhabdomyolysis

b. **Laboratory Data**

i. **Serum electrolytes**

1. **Serum potassium**

- Ensure this is not pseudohyperkalemia. If the patient is stable, without predisposing risk factors, and has had normal potassium and renal function in the past, consider repeating a serum electrolyte profile urgently
- If elevated above 6.5 mEq/L this constituted a 'hyperkalemic emergency'
- If elevated above 5.5 mEq/L but < 6.5 mEq/L in the setting of renal failure, this should still prompt you to lower the potassium level quickly
- If elevated but less than 5.5 mEq/L – this can be managed more conservatively, with changes in diet, use of diuretics, discontinuation of medications associated with hyperkalemia, bicarbonate therapy, or reversal of the causes of hyperkalemia

2. **Serum creatinine**

- Will allow for a calculation of glomerular filtration rate and estimation of current renal function
- Understanding the patient's current and baseline renal function may provide the understanding of the cause of hyperkalemia, the patient's susceptibility to developing hyperkalemia, the urgency of treatment, and potential methods of treatment

ii. **Arterial Blood Gas**

assessment of pH, bicarbonate, and lactate

iii. **Glucose**

uncontrolled hyperglycemia (diabetic ketoacidosis, hyperosmolar hyperglycemic state) can cause a redistributive hyperkalemia

iv. **Lactic acid**

lactic acidosis can be associated with hyperkalemia due to cellular ischemia (not direct cause like organic metabolic acidosis)

v. **Creatinine Kinase**

most reliable and sensitive indicator of muscle injury[15]

c. **EKG**

An EKG is of paramount importance. Classic signs of hyperkalemia include peaking of T-waves, ST-segment depression, widening of the PR interval, widening of the QRS interval, loss of P wave, development of a sine-wave pattern that is a harbinger of ventricular fibrillation. Importantly, the correlation between potassium elevation and EKG changes is poor. Patients with severe hyperkalemia can have minimal EKG changes, while those with moderate hyperkalemia can have life-threatening changes. Patients who suffer from chronic hyperkalemia (e.g. dialysis patients) may have minimal EKG changes despite high serum

potassium levels. Therapeutic strategies should be guided by EKG changes rather than serum levels alone.[16]

d. **Imaging**

1. **Renal bladder ultrasound**

   If serum creatinine is elevated, it is important to evaluate for possible obstruction of the urinary tract

# IV. Management

a. **Initial management/problem to solve**

i. **Hyperkalemic Emergency: serum potassium above 6.5 mEq/L or with EKG changes**

1. **Cardiac Monitor**

   Place patient on a continuous cardiac monitor to correlate treatment effect. Repeat EKC every 1-2 hours to assess response to therapy.

2. **Stabilize the heart**

   Intravenous calcium antagonizes the membrane action of hyperkalemia. Works rapidly but is short acting and needs to be repeated if hyperkalemic emergency persists. Typically given as IV calcium gluconate 1000mg over 2-3 minutes or IV calcium chloride 500-1000mg over 2-3 minutes. Patients should be on a cardiac monitor. Infusion can be repeated after 5 mins if EKG changes persist. The effect typically lasts 30-60 minutes. Calcium infusions can irritate veins and cause tissue necrosis. Ideally to use a small needle/catheter in large vein

3. **Drive potassium into the cells**

   - **Insulin with glucose**

     Insulin drives potassium intracellularly by Na-K-ATPase pump in muscle.[17] Glucose is given to prevent hypoglycemia (unless the patient has hyperglycemia). Typically given as 10-20 units of regular insulin in 500cc of 10% dextrose, given intravenously over 60 minutes. Works in 10-20 minutes and lasts 4-6 hours. Typically will drop the serum potassium concentration by 0.5-1.2 mEq/L. Patients receiving insulin infusions should have their serum glucose monitored hourly to assess for hypoglycemia.

   - **Beta-2-adrenergic agonists**

     Albuterol has been described as a means of transiently treating hyperkalemia, but should not be used alone. Typically given as 10-20mg in 4mL of saline by nebulation over 10 minutes. Works in 30 mins and lasts 1.5-2 hours. Typically will drop the serum potassium concentration by 0.6-1.0 mEq/L[18]

   - **Sodium Bicarbonate**

     Raises the pH, causing hydrogen ion release from cells, and driving of potassium intracellularly to maintain electroneutrality. Widely recommended in the past, but questionable efficacy, especially in patients with advanced renal

failure

4. **Get rid of potassium**
    - **Hemodialysis**
      If patient has severe renal impairment, it will be difficult for the body to clear the excess potassium load. Dialysis is the most rapid, effective, and definitive strategy [19]
    - **Loop Diuretics**
      Furosemide and bumetanide increase potassium loss in urine. Useful in patients with preserved renal function. Typical onset of action is 15-60 minutes and efficacy lasts hours. Should not be used as the only treatment modality in hyperkalemic emergency and caution is advised in patients who are volume depleted as diuretics can worsen this state resulting in decreased nephron flow and reduced potassium excretion
    - **Gastrointestinal Cation Exchangers:**
      (i.e. patiromer[20] or sodium polystyrene sulfonate [Kayxelate]). Bind potassium in the intestine and exchange of other cations. Typical dose patiromer 8.4g daily as needed.[21] Sodium polystyrene sulfonate is not preferred due to risk of intestinal necrosis, poor tolerance, unpredictable reductions in potassium, and high levels of sodium content [22]

ii. **Hyperkalemic Urgency**
serum potassium 5.5-6.5 mEq/L without EKG changes

1. Does not require rapidly acting agents but potassium should be lowered within 6-12 hours
2. Get rid of potassium
    - If severe renal impairment, options include dialysis or gastrointestinal cation exchanger
    - If no severe renal impairment, options include diuretics and gastrointestinal cation exchanger
3. Look for reversible causes of hyperkalemia

iii. **Non-urgent elevations in hyperkalemia**
serum potassium < 5.5 mEq/L without EKG changes

1. See long-term management

b. **Long-term management**

i. **Nephrology consultation**
ii. **Dietary modification: avoid foods high in potassium**
iii. **Review medications and discontinue those that impair potassium excretion[23]**
iv. **Loop and thiazide diuretics**
v. **Patiromer or Zirconium cyclosilicate (ZS-9)[24]**
vi. **Avoid fasting (nondiabetic patients with ESRD who are undergoing elective surgery should receive IV glucose containing solutions when fasting)**

**See also**:

AUA Update Series: Fluid, Electrolyte and Acid-Base Abnormalities in Urological Practice. Tanrikut C and McDougal WS, Vol. 25, Lesson 19, 2006

# Key Takeaways

- Hyperkalemia is a life threatening emergency that has a variety of causes including metabolic acidosis, renal failure, heart failure, and medications.
- Significant hyperkalemia (K > 6.5 mEq/L) can destabilize the heart and lead to conduction abnormalities that present with EKG changes and require rapid administration of IV calcium.
- Fast (but temporary) options to treat hyperkalemia include insulin (with glucose), beta-2 adrenergic agonists, and sodium bicarbonate, which all work to shift potassium intracellularly.
- Ultimately, treatment of acute hyperkalemia involves removing the potassium load via hemodialysis, loop diuretics or GI cation exchangers.

# Videos

Hyperkalemia

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