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Objectives:

1. Practice a framework for the approach to managing hyperkalemia in the hospital
2. Recognize cardiac complications of hyperkalemia
3. Distinguish between temporizing measures and interventions that eliminate potassium

Plan to spend 30 minutes preparing for this talk by using the Interactive Board and clicking through the graphics/ animations to become familiar with the flow and content of the talk. Print out copies of the Learner’s Handout so learners can take notes as you expand on the pathophysiology and management. The first page of the handout is a blank schematic that learners can fill in as you go through the presentation.

The anticipated time to deliver the entire talk is about **15 min without cases and 20 min with cases**.

The talk can be presented in one of two ways:

1. Project the "Interactive Board" OR
2. Reproduce your own drawing of the presentation on a whiteboard/ Chalkboard

All clickable elements are denoted by a shaded rounded rectangle and a mouse cursor.

**Introduction:**This talks walks through the acute management of hyperkalemia in the hospital. The primary inpatient goals include myocardial stabilization, minimization of the consequences of severe hyperkalemia.

Start by introducing a common scenario on the medical wards. You may use a real clinical case or the one provided. Ask your learners what they would do if they were called for a critical lab of K of 6.7.

Introduce the framework of 5 steps when approaching all patients with hyperkalemia:

1. Confirm the lab abnormality
2. Check for ECG changes
3. Cardiac stabilization
4. Temporizing measures (intracellular shift)
5. Potassium elimination

**Step 1: Confirm hyperkalemia**

The first step is to confirm the lab abnormality. Was this result expected? Are there other concurrent lab abnormalities that would make hyperkalemia probable (such as AKI)? If the lab abnormality is unexpected, check for the presence of hemolysis, which can falsely elevate a measured serum potassium. Other factors such as fist clenching, poor specimen collection or processing can result in falsely elevated potassium.2 Confirming hyperkalemia should not significantly delay treatment.

Assess for symptoms of hyperkalemia such as myalgias, muscle weakness, and symptoms of cardiac arrhythmias.

**Step 2: Obtain an ECG**

The most life-threatening complications of severe hyperkalemia are cardiac arrhythmias - sinus bradycardia, AV block, ventricular arrhythmias, or cardiac arrest. The first step in evaluation of hyperkalemia is obtaining an ECG.

ECG changes:

* The earliest sign of hyperkalemia is tall, peaked T waves, best seen in hyperkalemia
* Next, there is P wave flattening
* Then widening of QRS
* Lastly, ventricular arrhythmia, asystole or sine wave
* Other ECG changes include pseudo-RBBB pattern or pseudo-ST elevation pattern in leads V1 and V2³

While the presence of ECG changes is more strongly linked to poor outcomes than actual serum potassium level2, ECG changes do not correlate well with serum potassium. A rapid rise in K is more likely to result in cardiac arrhythmias than a slow increase over several months². Patients with chronic kidney disease are more able to tolerate high potassium levels1,2.

**Step 3: Cardiac Membrane Stabilization**

For patients with ECG changes or a K > 6.5, IV calcium should be given to stabilize the cardiac membrane. This rapidly reduces the excitatory effects of hyperkalemia on the cardiac membrane. Its onset of action is within 5 min (some reports 1-3 min)2,3. If changes in ECG are observed within 5-10 min, a repeat dose of IV calcium should be given. The two formulations of IV calcium include:

* IV calcium gluconate 1-2 g - preferred, can be given peripherally
* IV calcium chloride 0.5-1 g - can be caustic to vessels, preferably given via a central line

**Step 4: Shift Potassium Intracellularly**

In addition to stabilization of the cardiac membrane, measures should be taken to decrease the serum potassium level by 1) shifting potassium intracellularly and 2) eliminating potassium. Measures to eliminate potassium from the body take several hours to have effect. Thus, temporizing measures to shift potassium intracellularly are needed to reduce serum potassium quickly. There are three main medications to shift potassium intracellularly. *Click on each of the buttons and ask your learners what dose to give, how much they anticipate this will lower the serum potassium, and the onset/duration of action.*

* Insulin + D50W *-*Insulin enhances the activity of Na-K-ATPase on skeletal muscles and shifts potassium intracellularly4. Typically, 10U of regular insulin is given intravenously with D50W to prevent hypoglycemia. The onset of action is within 30 min and effects last 4-6 h.
	+ Patients with renal dysfunction should receive 5U regular insulin, and patients with blood glucose > 250 do not need D50W.
	+ In general, it can lower the potassium level by 0.5 - 1.2 mEq/L4
* Beta-agonists - beta-2 adrenergic agonists like albuterol drive potassium intracellularly by activating Na-K-2Cl cotransporter and Na-K-ATPase on skeletal muscles. It can be given as 10-20 mg albuterol in 4 mL of saline by nebulization. Note that this is significantly higher than the typical dose given for bronchodilation. Other beta-agonists include 10 mg of salbutamol nebulizer. Onset of action is within 5 min of use and peaks at 90-120 min1,2,5. Duration of action is 3-6 hours.5
	+ Beta-agonists lower serum potassium by 0.5 - 1.5 mEq/L but is most effective when given in addition to insulin/D50W4.
	+ Should be avoided in patients with active coronary disease since it can cause tachycardia and induce angina in some patients4.
* Sodium Bicarbonate - This is the least effective strategy for shifting potassium intracellularly. Sodium bicarbonate increases plasma pH which in turn draws out H+ ions from inside cells, resulting in potassium shift into cells via a H+/K+ transporter. It can also promote potassium elimination in patients with metabolic acidosis.2 Bicarbonate can be given as bolus ampules, isotonic infusion, or oral tablet. IV formulations have a rapid onset of action and lasts 8-10 min.6 In some studies, sodium bicarbonate infusion lowered potassium by 0.6-0.7 mEq/L at 4-6 hours in patients with HCO3 < 18 mEq/L.4
	+ Bicarbonate therapy should not be used in patients who have ESRD as this has not been shown to be effective at lowering potassium.4
	+ Bicarbonate therapy should only be considered in patients with metabolic acidosis.

**Step 5: Eliminate Potassium From the Body**

Therapies to shift potassium intracellularly are fast acting but do not lower whole body potassium. Concurrent measures should be taken to eliminate potassium. Ninety percent of potassium is excreted through the kidneys and 10% is excreted in the GI tract. *Click on the kidney and GI tract icon to discuss therapies that augment elimination through the kidneys and GI tract, respectively.*

* Loop diuretics - Increases potassium excretion in patients without severe renal impairment. IV loop diuretics such as furosemide or bumetanide have an onset of action of ~ 30 min and duration of 2 hours.7 Oral formulations have a duration of action up to 6 hours. A reasonable starting dose for most patients is IV furosemide 40 mg.
	+ Loop diuretics should be used cautiously in isolation since they can cause dehydration in euvolemic or hypovolemic patients which can worsen kidney function and thus, hyperkalemia.
	+ It is the treatment of choice in patients who are hypervolemic.
* IV fluids -isotonic fluids with 0.9% NS or sodium bicarbonate infusion can be given to maintain euvolemia in patients given loop diuretics. As stated above, in some studies, sodium bicarbonate infusion lowered potassium by 0.6-0.7 mEq/L at 4-6 hours in patients with HCO3 < 18 mEq/L.4
* Hemodialysis - Urgent dialysis is indicated for patients with severe kidney dysfunction. Dialysis is the intervention most likely to achieve normokalemia within 4 h and should be considered for patients with reasonable vascular access.2,4
* Potassium binders - These medications increase fecal excretion of potassium by binding and "trapping" potassium in the gut. The mostly approved binders in the US include patiromer, sodium zirconium cyclosilicate (SZC) and Kayexelate (sodium polystyreme sulfonate, SPS). These should be considered in patients who have renal dysfunction but do not have access to urgent dialysis.1
	+ SZC - This act son both the small and large intestines. This is preferred over patiromer because of its fast onset of action (1 h). It is dosed 10 g TID for 48 h for initial correction of hyperkalemia. It is associated with some GI upset (nausea, vomiting, diarrhea). It is a large sodium load and can also cause edema. Its use is primarily limited by cost and availability.2
	+ Patiromer - This is not shown on the graph but can be mentioned along with SZC as one of the relatively newly approved potassium binders. This acts only on the colon but has slower onset of action (7 h) compared to SZC. Its use is also limited by cost and availability.2
	+ Kayexelate (SPS) - This acts on the colon. its onset of action is variable, but generally is considered to be several hours. It can be given orally (typically 15 g - 60 g q6h) or rectally, as an enema (30-50 g).2 In some studies it lowered potassium by a mean of 0.9 mEq/L at 24 h.4
		- Kayexelate has been associated with a risk of bowel necrosis and perforation. Contraindications include post-operative patients, patients with an ileus/ obstruction or are prone to such. It should also not be given to patients with IBD, infectious colitis, underlying bowel disease.4
		- Kayexelate should be separated from other mediations by 3 hours since it can impact absorption of other medications.4
		- While the potassium lowering effect of Kayexelate is unpredictable, but generally, K is lowered more with higher doses of Kayexelate.8

After performing these interventions, potassium should be monitored and rechecked at a short interval (e.g, 2-4 hours) with temporizing and elimination measures repeated until dialysis or potassium reaches a normal range.

**Cases:**Click through 2 sample cases to practice the concepts taught above.

**Take Home Points:**

1. Hyperkalemic crisis is a medical emergency! Primary complications include severe weakness and fatal cardiac arrhythmias.
2. ECG changes seen in hyperkalemia include peaked T waves, loss of P wave, widened QRS, conduction delays, and ventricular arrhythmias. Patients with ECG changes or severe hyperkalemia > 6.5 should receive IV calcium gluconate to stabilize the cardiac membrane.
3. Hyperkalemia should initially be treated with fast acting measures that shift potassium intracellularly. These include insulin, beta-agonists, and sodium bicarbonate (in patients with metabolic acidosis).
4. Loop diuretics with or without IV fluids and potassium binders eliminate potassium through kidney or fecal excretion. Patients with severe renal dysfunction or lack of response to loop diuretics should receive urgent dialysis.

**References:**

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