Recognizing and Managing Life-Threatening Electrolyte Abnormalities: A Pharmacist's Stepwise Approach

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Disclosure Statement

I have no conflicts of interest with ineligible companies to disclose.

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Dosing Disclaimer

The doses below are adult educational examples based on the cited references. Actual treatment should follow the patient's clinical status, renal/hepatic function, ECG, institutional protocols, and current guidelines.

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Learning Objectives

- Identify the normal laboratory ranges for common electrolytes
- Describe the common signs and symptoms associated with abnormal electrolyte values
- Outline treatment strategies for correcting electrolyte disturbances and understand the complications related to overly rapid corrections

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Pre-Test Question 1

Which of the following medications can cause hyperkalemia? SELECT ALL THAT APPLY

A. Lisinopril
B. Furosemide
C. Hydrochlorothiazide
D. Spironolactone
E. Sulfamethoxazole/Trimethoprim

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Pre-Test Question 2

Which of the following medications are used to shift potassium intracellularly?

A. Calcium Gluconate
B. Insulin Regular
C. Furosemide
D. Dialysis
E. Sodium Bicarbonate

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Pre-Test Question 3

Dr. Fitzgerald is taking care of a patient in the ICU who has a potassium level of 2.5 with multiple symptoms. He would like to give the patient a bolus dose of potassium chloride 100 mEq to increase the potassium level rapidly. The doctor would like reassurance from you on whether he should give the 100mEq or another dose. What dose do you recommend?

A. Recommend 100mEq IV bolus dose, there is no problem with the dose
B. Recommend giving 60mEq IV bolus dose
C. Recommend 10mEq every few hours
D. Recommend 40mEq oral x 1 dose
E. Patient does not need potassium!

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Pre-Test Question 4

Olivia Pope is rushed to the hospital after experiencing non-stop seizures for six minutes. Upon admission, labs were drawn and Olivia had a sodium level of 114. The physician wishes to correct the sodium level very quickly and wants her sodium level to be at 135 by the end of the day. What do you recommend?

A. Inform the physician the patient can receive Sodium Chloride 23.4% to make this correction.
B. Inform the physician the patient can receive Sodium Chloride 3% to make this correction.
C. Inform the physician the patient can receive Tolvaptan to make this correction.
D. Inform the physician that jumping from a sodium level of 114 to 135 in less than 24 hours is not recommended.
E. Inform the physician that sodium level is normal at 114 and no treatment is needed.

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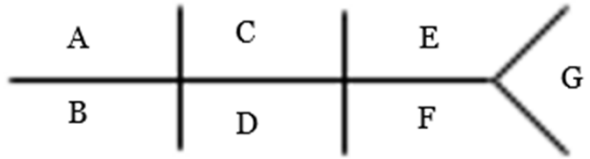
Fishbone



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Major Electrolytes – Life-Threatening

- Potassium
- Sodium
- Calcium
- Magnesium

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Potassium

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Potassium

Normal Range

- 3.5-5 mEq/L

Hyperkalemia Causes

- Impaired Renal Excretion
- Transcellular Shifts
- Increased Potassium Intake

Hypokalemia Causes

- Decreased Potassium Intake
- Renal Losses
- Gastrointestinal Losses
- Transcellular Shifts

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Potassium Complications

Hyperkalemia

- Ventricular Arrhythmias
- Conduction Abnormalities
- Cardiac Arrest

Hypokalemia

- Ventricular Arrhythmias
- Muscle Weakness/Paralysis
- Respiratory Failure

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Electrocardiography (ECG) Changes

Serum potassium (mEq per L)*	Electrocardiograph waveform	Serum potassium (mEq per L)*	Electrocardiograph waveform	Serum potassium (mEq per L)*	Electrocardiograph waveform
> 9.0	Sinusoidal wave pattern	> 5.5	Peaked T wave	< 3.5 to ≥ 2.0	ST segment depression, T-wave inversion, prominent U wave
> 5.5 to ≤ 9.0	Wide QRS duration**	3.5 to 5.0	Normal sinus rhythm	< 3.5 to ≥ 2.0	T- and U-wave fusion
> 5.5 to ≤ 9.0	Bradyarrhythmias**	< 3.5 to ≥ 2.0	Decreased amplitude of T wave	< 3.5 to ≥ 2.0	Prolonged QT
> 5.5 to ≤ 9.0	Loss of P wave; junctional rhythms**	< 3.5 to ≥ 2.0	U waves, best seen in leads V2 and V3	< 2.0	Ventricular tachycardia, torsades de points
> 5.5 to ≤ 9.0	Prolonged PR interval				

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What medications can cause hypokalemia?

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Hypokalemia – Medication Causes

Renal losses	Gastrointestinal losses	Intracellular shifts	Inadequate intake
Medical condition			
• Mineralocorticoid excess • Types 1 and 2 renal tubular acidosis • Hypomagnesemia • Intrinsic renal transport defects: ◦ Bartter syndrome ◦ Gitelman syndrome ◦ Fanconi syndrome ◦ Liddle syndrome	• Chronic diarrhea • Acute diarrhea • Bowel preparation for colonoscopy • Vomiting	• Refeeding syndrome • Alkalosis • Thyrotoxicosis • Familial periodic paralysis • Hypothermia	• Anorexia • Starvation • Total parenteral nutrition
Medications			
• Thiazide diuretics • Loop diuretics • Mineralocorticoids • Exogenous corticosteroids • Drugs that cause magnesium depletion: ◦ Amphotericin B ◦ Cisplatin ◦ Foscarnet ◦ Aminoglycosides	• Laxatives/enemas • Sodium polystyrene sulfonate	• Insulin • Beta agonists (e.g., epinephrine, bronchodilators) • Caffeine • Theophylline	• —

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What medications can cause hyperkalemia?

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Hyperkalemia – Medication Causes

Impaired excretion	Transcellular shift	Increased intake
Medications: • Angiotensin-converting enzyme inhibitors • Angiotensin-II receptor blockers • Aldosterone antagonists and other potassium-sparing diuretics • Digoxin • Beta blockers • Heparin • Trimethoprim/sulfamethoxazole • Calcineurin inhibitors • Nonsteroidal anti-inflammatory drugs **Reduced effective plasma volume** **Renal failure:** • Acute renal failure • End-stage renal disease • Type 4 renal tubular acidosis	**Ongoing release:** • Tumor lysis syndrome • Rhabdomyolysis • Severe hemolytic anemia • Extensive burn injury **Other transcellular shifts:** • Metabolic acidosis • Hyperglycemia • Pseudohyperkalemia caused by hemolysis during venipuncture, small needle, sustained tourniquet, transport on pneumatic tube system, thrombocytosis (> 500,000 per mm³), or leukocytosis (> 70,000 per mm³) due to potassium released during clotting	• Blood transfusions • Commercially available salt substitutes and potassium-enriched foods • Enteral feeding • High-potassium diet* • Intravenous fluids • Parenteral nutrition

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Hyperkalemia – Foods

Food group	Food item	Food group	Food item
Seasonings/ condiments	Low-sodium salt (contains potassium chloride) Sea salt	Vegetables	Seaweed Spinach Tomatoes Broccoli Potatoes
Desserts	Molasses Chocolate	Meats	Beef Chicken Pork Lamb
Nuts, seeds, and legumes	Lima beans Sunflower seeds Pistachios Pumpkin seeds	Fruit	Bananas Cantaloupes Oranges Avocados Dried fruits (dates, prunes)
Grains	Wheat germ Bran Oats		

Highest content (> 1,000 mg per serving)
Very-high content (> 600 mg per serving)
High content (> 250 mg per serving)

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Dietary Recommendations

Stage	Dietary potassium recommendations	Comments
1 eGFR ≥ 90 mL per minute per 1.73 m² Albuminuria < 30 mg per g	Same as general population; 3,510 mg per day	Safe for potassium-rich foods (e.g., avocado, banana, spinach, leafy greens, potatoes, citrus juices, fish)
2 eGFR 60 to 89 mL per minute per 1.73 m² Albuminuria < 30 mg per g	Same as general population; 3,510 mg per day	Safe for potassium-rich foods (e.g., avocado, banana, spinach, leafy greens, potatoes, citrus juices, fish)
3a eGFR 45 to 59 mL per minute per 1.73 m² Albuminuria < 30 mg per g 3b eGFR 30 to 44 mL per minute per 1.73 m² Albuminuria < 30 mg per g	Same as general population unless episodes of severe hyperkalemia occur	Recommend fresh fruits and vegetables; limit milk and dairy products; avoid salt substitutes due to potassium chloride content; encourage a high-fiber diet*
4 eGFR 15 to 29 mL per minute per 1.73 m² Any stage with A2 (albuminuria 30 to 300 mg per day) or A3 (albuminuria > 300 mg per day)	< 3,000 mg per day if hyperkalemia occurs frequently	Recommend low-potassium foods (e.g., apples, berries, carrots, green beans, chicken, eggs, white grain breads, white rice); limit serving sizes; avoid salt substitutes and sea salt
5 eGFR < 15 mL per minute per 1.73 m²	< 3,000 mg per day	Recommend low-potassium foods (e.g., apples, berries, carrots, green beans, chicken, eggs, white grain breads, white rice); limit serving sizes; avoid salt substitutes and sea salt

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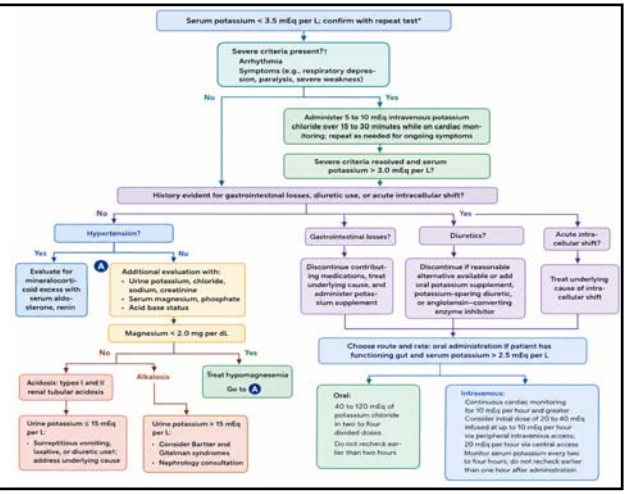
Hypokalemia Treatment



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Hypokalemia – Treatment – Medications

Medication	Initial dosage	Effectiveness	Comments
Potassium chloride	Oral: 10 to 40 mEq two to four times per day Intravenous*: • Up to 10 mEq per hour (peripheral line) • Up to 20 mEq per hour (central line) Emergent treatment*: 5 to 10 mEq intravenously over 15 to 20 minutes	• Expect increase in serum potassium by 0.1 mEq for every 10 mEq administered; may be less if the patient is experiencing ongoing losses	• Most effective formulation; up to 40% improved absorption compared with other formulations • Intravenous treatment should be reserved for patients with electrocardiographic changes, paralysis, respiratory failure, rhabdomyolysis, or inability to take treatment orally • Continuous cardiac monitoring is recommended for rates of 10 mEq per hour and greater
Potassium bicarbonate (potassium citrate, acetate, gluconate)†	Oral: Bicarbonate • 20 to 40 mEq per day in one to two divided doses (prevention) • 40 to 100 mEq per day in two to four divided doses (treatment) Citrate • 10 to 20 mEq two to four times per day Gluconate • 10 to 20 mEq two to four times per day Intravenous: Acetate • Up to 10 mEq per hour (peripheral line) • Up to 40 mEq per hour (central line)	• Intravenous treatment should increase serum potassium levels by 0.1 mEq per L for every 10 mEq administered	• Preferred for patients with metabolic acidosis • Potassium gluconate is commonly found in over-the-counter formulations • Continuous cardiac monitoring recommended for intravenous infusions
Potassium phosphate	Primarily used for the treatment of hypophosphatemia • For every 1 mmol of phosphate, there is 1.5 mEq of potassium	Not established	• Typically found in dietary potassium • Reserve for patients with hypokalemia and hypophosphatemia (e.g., refeeding syndrome, type 2 renal tubular acidosis, Fanconi syndrome) • Avoid oral supplementation due to phosphate-induced diarrhea

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Hyperkalemia Treatment Goals

- Immediately assess severity
- Stabilize the myocardium
- Shift K^+ intracellularly
- Remove K^+ from the body

Long B, Warix JR, Koyfman A. Controversies in management of hyperkalemia. *J Emerg Med.* 2018;55(2):192-205.
Palmer BF, Carrero JJ, Clegg DJ, et al. Clinical management of hyperkalemia. *Mayo Clin Proc.* 2021;96(3):744-762.
Viera AJ, Wouk N. Potassium disorders: hypokalemia and hyperkalemia. *Am Fam Physician.* 2015;92(6):487-495.
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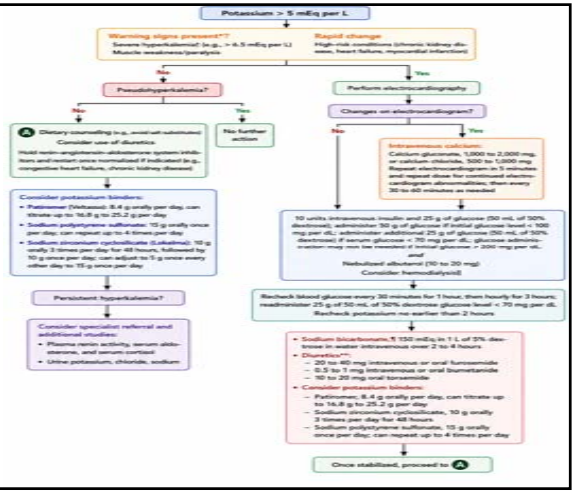
Hyperkalemia Treatment



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Hyperkalemia – Treatment – Medications

Treatment	Mechanism of action	Dose	Comments
Intravenous calcium	Stabilizes cardiac membrane by rapid reduction of excitatory effects of potassium in cardiac tissue membrane	• 1,000 to 2,000 mg calcium gluconate over two to five minutes • 500 to 1,000 mg calcium chloride over two to five minutes • May repeat dose after five minutes if electrocardiography changes persist or recur; then every 30 to 60 minutes as needed	• No effect on serum potassium levels • Continuous cardiac monitoring required • Adverse effects of calcium chloride include phlebitis and tissue necrosis • Adverse effects of calcium chloride and calcium gluconate include hypercalcemia, arrhythmia, bradycardia, hypotension, and cardiac arrest
Regular insulin	Drives extracellular potassium into the cells	• 10 units intravenous bolus *and* • 25 g of glucose (50 mL of 50% dextrose); administer 50 g (100 mL of 50% dextrose) of glucose if initial glucose level < 100 mg per dL (5.55 mmol per L); administer additional 25 g of glucose (50 mL of 50% dextrose) if serum glucose < 70 mg per dL (3.89 mmol per L) • Glucose administration may not be needed if initial glucose > 200 mg per dL (11.10 mmol per L) • Monitor glucose hourly for at least three hours	• 0.6 to 1.2 mEq per L at one hour • Onset of action: < 15 minutes • Duration of effect: two hours • Synergistic effect if administered with beta agonists • Adverse effects include hypoglycemia; monitor every 30 minutes in the first hour, then hourly, and treat with dextrose if serum glucose < 70 mg per dL
Beta$_2$-adrenergic agonists	Drive extracellular potassium into the cells	• 10 to 20 mg via nebulizer	• 0.6 mEq per L within 30 minutes after 10-mg inhaled dose • 1.0 mEq per L one hour after 20-mg inhaled dose • Duration of effect: two hours • Synergistic effect if given with insulin • Adverse effects include tachycardia

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Hyperkalemia – Treatment – Medications

Treatment	Mechanism of action	Dose	Comments
Sodium bicarbonate*	Drives extracellular potassium into the cells	• Intravenous, continuous: 150 mEq in 1 L of 5% dextrose in water over two to four hours; normal saline may increase serum potassium and should not be used • Intravenous, intermittent: 50 mEq over five minutes	• Only beneficial in patients with metabolic acidosis; do not use in patients with end-stage renal disease • Serum potassium decrease by 2 mEq per L for every 10 mEq per L increase in bicarbonate levels • Adverse effects: hypernatremia, cardiac failure
Diuretics	Remove potassium from the body	• No universally recommended dosage for acute or chronic hyperkalemia • Typical initial dosages for edema: – Furosemide: 20 to 40 mg once or twice per day (intravenous or orally) – Bumetanide: 0.5 to 1 mg once or twice per day (intravenous or orally) – Torsemide: 10 to 20 mg once per day orally	• Effect dependent on urine output; unpredictable kaliuretic effect • Use with caution in patients who are hypovolemic or with renal impairment; if needed for severe acute hyperkalemia, consider a crystalloid infusion before administration of dose • Adverse effects: hypovolemia, acute kidney injury
Gastrointestinal cation exchanger Sodium zirconium cyclosilicate (Lokelma)	Removes potassium from the body	• Acute: 10 g orally three times per day for 48 hours (total of six doses) • Chronic: 10 g orally three times per day for 48 hours, followed by 10 g once per day; can adjust to 5 g once every other day to 15 g once per day	• Decrease by 0.67 mEq per L at 48 hours • Administer other oral medications at least two hours before or after a dose • Adverse effect: urinary tract infection (1.1%), edema (0.9%)
Patiromer (Veltassa)	Removes potassium from the body	• Acute and chronic: 8.4 g orally per day; titrate up to 16.8 to 25.2 g per day	• Decrease serum potassium by 0.70 mEq per L after four weeks • Administer other oral medications three hours before or after a dose • Adverse effects include constipation (7.6%), diarrhea (4.5%), hypomagnesemia (7.1%)
Sodium polystyrene sulfonate	Removes potassium from the body	• 15 g orally one to four times per day • 30 to 50 g rectally every six hours in retention enema	• Serum potassium reduction from 0.8 to 1.4 mEq per L, based on dose and duration • Avoid concomitant administration with oral medications; significant drug interactions may occur • Adverse effects include ischemic colitis, intestinal necrosis, intestinal perforation

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Sodium

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Sodium

Normal Range

- 135-145 mEq/L

Hyponatremia Causes

- Hypovolemia
- SIADH
- Heart Failure
- Cirrhosis
- Medication-Induced Hyponatremia
- Endocrine Disease

Hypernatremia Causes

- Dehydration
- Vomiting
- Burns
- Infection
- Diabetes Insipidus

Nagler EV, Vanmassenhove J, van der Veer SN, Nistor I, Van Biesen W, Webster AC, Vanholder R. Diagnosis and treatment of hyponatraemia: a systematic review of clinical practice guidelines. Nephrology, Dialysis, Transplantation 2013 28 i385–i391.
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Walker SS, Mount DB, Curhan GC. Mortality after hospitalization with mild, moderate, and severe hyponatremia. American Journal of Medicine 2009 122 857–865.

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Sodium Complications

Hyponatremia

- Cerebral Edema
- Brain Herniation
- Death
- Muscle Complications
- Seizures
- Coma
- Respiratory Arrest

Hypernatremia

- Weakness
- Confusion
- Seizures
- Intracranial Hemorrhage
- Muscle Complications
- Coma
- Death

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When evaluating Sodium levels, what considerations should be taken to assess severity?

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	Hypervolemic Hyponatremia	Euvolemic Hyponatremia	Hypovolemic Hyponatremia
Description	Excess sodium and fluid but greater amount of fluid	Normal Sodium with excess fluid	Low sodium and low water but greater amount of fluid
Causes	Heart failure Cirrhosis Nephrotic syndrome	SIADH Medications (thiazide diuretics, SSRI, antiepileptics) Hyperglycemia	Fluid loss caused by emesis, diarrhea or medications
Treatment	Sodium and water restriction Treat underlying cause Vasopressin receptor antagonists	Stop offending agent Fluid restriction Demeclocycline Vasopressin receptor antagonists Control glucose	Fluid resuscitation

Nagler EV, Vanmassenhove J, van der Veer SN, Nistor I, Van Biesen W, Webster AC, Vanholder R. Diagnosis and treatment of hyponatraemia: a systematic review of clinical practice guidelines. Nephrology, Dialysis, Transplantation 2013 28 i385–i391.
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Walker SS, Mount DB, Curhan GC. Mortality after hospitalization with mild, moderate, and severe hyponatremia. American Journal of Medicine 2009 122 857–865.

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Sodium Correction

Maximum increase of 12 mEq in a 24 hour period

Central Pontine Myelinolysis/Osmotic Demyelination Syndrome

- Damages to nerve endings caused by rapid increase in sodium
- Symptoms – lethargy, neurologic damage, paralysis, dysphagia, coma

Nagler EV, Vanmassenhove J, van der Veer SN, Nistor I, Van Biesen W, Webster AC, Vanholder R. Diagnosis and treatment of hyponatraemia: a systematic review of clinical practice guidelines. Nephrology, Dialysis, Transplantation 2013 28 i385–i391.
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Hypernatremia Treatment

- Oral/enteral water if the patient can safely drink.
- IV **D5W** when IV free-water replacement is required.
- **0.45% saline** may be appropriate in selected euvolemic patients.

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Sodium

Usually a fluid an issue, resolve that prior to correcting sodium!

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Post-Test Question 1

Which of the following medications can cause hyperkalemia? SELECT ALL THAT APPLY

A. Lisinopril
B. Furosemide
C. Hydrochlorothiazide
D. Spironolactone
E. Sulfamethoxazole/Trimethoprim

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Post-Test Question 2

Which of the following medications are used to shift potassium intracellularly?

A. Calcium Gluconate
B. Insulin Regular
C. Furosemide
D. Dialysis
E. Sodium Bicarbonate

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Post-Test Question 3

Dr. Fitzgerald is taking care of a patient in the ICU who has a potassium level of 2.5 with multiple symptoms. He would like to give the patient a bolus dose of potassium chloride 100 mEq to increase the potassium level rapidly. The doctor would like reassurance from you on whether he should give the 100mEq or another dose. What dose do you recommend?

A. Recommend 100mEq IV bolus dose, there is no problem with the dose
B. Recommend giving 60mEq IV bolus dose
C. Recommend 10mEq every few hours
D. Recommend 40mEq oral x 1 dose
E. Patient does not need potassium!

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Post-Test Question 4

Olivia Pope is rushed to the hospital after experiencing non-stop seizures for six minutes. Upon admission, labs were drawn and Olivia had a sodium level of 114. The physician wishes to correct the sodium level very quickly and wants her sodium level to be at 135 by the end of the day. What do you recommend?

A. Inform the physician the patient can receive Sodium Chloride 23.4% to make this correction.
B. Inform the physician the patient can receive Sodium Chloride 3% to make this correction.
C. Inform the physician the patient can receive Tolvaptan to make this correction.
D. Inform the physician that jumping from a sodium level of 114 to 135 in less than 24 hours is not recommended.
E. Inform the physician that sodium level is normal at 114 and no treatment is needed.

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Recognizing and Managing Life-Threatening Electrolyte Abnormalities: A Pharmacist's Stepwise Approach

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