Evidence-Based Management Of Potassium Disorders In The Emergency Department

Abstract

Hypokalemia and hyperkalemia are the most common electrolyte disorders managed in the emergency department. The diagnosis of these potentially life-threatening disorders is challenging due to the often vague symptomatology a patient may express, and treatment options may be based upon very little data due to the time it may take for laboratory values to return. This review examines the most current evidence with regard to the pathophysiology, diagnosis, and management of potassium disorders. In this review, classic paradigms, such as the use of sodium polystyrene and the routine measurement of serum magnesium, are tested, and an algorithm for the treatment of potassium disorders is discussed.

November 2016 Volume 18, Number 11

Authors

John Ashurst, DO, MSc
Director of Emergency Medicine Residency Research, Duke Lifepoint Conemaugh Memorial Medical Center, Johnstown, PA

Shane R. Sargent, DO
Department of Emergency Medicine, Conemaugh Memorial Hospital, Johnstown, PA

Benjamin J. Wagner, DO
Department of Emergency Medicine, Conemaugh Memorial Hospital, Johnstown, PA

Peer Reviewers

Cameron L. Pfennig, MD, MHPE
Associate Professor of Emergency Medicine, University of South Carolina School of Medicine, Emergency Medicine Residency Program Director, Greenville Health System, Greenville, SC

Corey M. Slovis, MD, FACP, FACEP
Professor and Chair, Department of Emergency Medicine, Vanderbilt University Medical Center, Nashville, TN

CME Objectives

Upon completion of this article, you should be able to:
1. Identify the etiology of the depletion of potassium in patients with hypokalemia.
2. Identify and manage the etiology and underlying causes of hyperkalemia.
3. Describe the algorithmic management of hypokalemia and hyperkalemia.

Prior to beginning this activity, see “Physician CME Information” on the back page.

Editor-in-Chief

Andy Jagoda, MD, FACEP
Professor and Chair, Department of Emergency Medicine, Icahn School of Medicine at Mount Sinai, New York, NY

Associate Editor-in-Chief

Kaushal Shah, MD, FACEP
Assistant Professor, Department of Emergency Medicine, Icahn School of Medicine at Mount Sinai, New York, NY

Editorial Board

Saadia Akhtar, MD
Associate Professor, Department of Emergency Medicine, Associate Dean for Graduate Medical Education, Program Director, Emergency Medicine Residency, Mount Sinai Beth Israel, New York, NY

William J. Brady, MD
Professor of Emergency Medicine and Medicine; Chair, Medical Emergency Response Committee; Medical Director, Emergency Management, University of Virginia Medical Center, Charlottesville, VA

Calvin A. Brown III, MD
Director of Physician Compliance, Credentialing and Urgent Care Services, Department of Emergency Medicine, Brigham and Women’s Hospital, Boston, MA

Peter Delliaux, MD
Professor of Clinical Medicine, Interim Public Hospital Director of Emergency Medicine Services, Louisiana State University Health Science Center, New Orleans, LA

Daniel J. Egan, MD
Associate Professor, Department of Emergency Medicine, Program Director, Emergency Medicine Residency, Mount Sinai St. Luke’s Roosevelt, New York, NY

Nicholas Genes, MD, PhD
Assistant Professor, Department of Emergency Medicine, Icahn School of Medicine at Mount Sinai, New York, NY

Michael A. Gibbs, MD, FACEP
Professor and Chair, Department of Emergency Medicine, Carolinas Medical Center, University of North Carolina School of Medicine, Chapel Hill, NC

Steven A. Godwin, MD, FACEP
Professor and Chair, Department of Emergency Medicine, Assistant Dean, Simulation Education, University of Florida COM-Jacksonville, Jacksonville, FL

Gregory L. Henry, MD, FACEP
Clinical Professor, Department of Emergency Medicine, Assistant Dean, Simulation Education, University of Florida COM-Jacksonville, Jacksonville, FL

John M. Howell, MD, FACEP
Clinical Professor of Emergency Medicine, George Washington University, Washington, DC, Director of Academic Affairs, Best Practices, Inc, Inova Fairfax Hospital, Falls Church, VA

Shkelzen Hoxhaj, MD, MPH, MBA
Chief of Emergency Medicine, Baylor College of Medicine, Houston, TX

Eric Legome, MD
Chief of Emergency Medicine, King’s County Hospital; Professor of Clinical Emergency Medicine, SUNY Downstate College of Medicine, Brooklyn, NY

Keith A. Marill, MD
Research Faculty, Department of Emergency Medicine, University of Pittsburgh Medical Center, Pittsburgh, PA

Charles V. Prollack Jr., MA, MD, FACEP
Professor and Senior Advisor for Interdisciplinary Research and Clinical Trials, Department of Emergency Medicine, Sidney Kimmel Medical College of Thomas Jefferson University, Philadelphia, PA

Michael S. Radeos, MD, MPH
Associate Professor of Emergency Medicine, Well Medical College of Cornell University, New York; Research Director, Department of Emergency Medicine, New York Hospital Queens, Flushing, NY

Ali S. Raja, MD, MBA, MPH
Vice-Chair, Emergency Medicine, Massachusetts General Hospital, Boston, MA

Robert L. Rogers, MD, FACEP, FAEM, FACP
Assistant Professor of Emergency Medicine, The University of Maryland School of Medicine, Baltimore, MD

Alfred Sacchetti, MD, FACEP
Assistant Clinical Professor, Department of Emergency Medicine, Thomas Jefferson University, Philadelphia, PA

Robert Schiller, MD
Chair, Department of Family Medicine, Beth Israel Medical Center; Senior Faculty, Family Medicine and Community Health, Icahn School of Medicine at Mount Sinai, New York, NY

Scott Silvers, MD, FACEP
Chair, Department of Emergency Medicine, Mayo Clinic, Jacksonville, FL

Corey M. Slovis, MD, FACP, FACEP
Professor and Chair, Department of Emergency Medicine, Vanderbilt University Medical Center, Nashville, TN

Ron M. Walls, MD
Professor and Chair, Department of Emergency Medicine, Brigham and Women’s Hospital, Harvard Medical School, Boston, MA

Critical Care Editors

William A. Knight IV, MD, FACEP
Associate Professor of Emergency Medicine and Neurosurgery, Medical Director, EM Medium Provider Program, Associate Medical Director, Neuroscience ICU, University of Cincinnati, Cincinnati, OH

Scott D. Weingart, MD, FCCM
Associate Professor of Emergency Medicine, Director, Division of ED Critical Care, Icahn School of Medicine at Mount Sinai, New York, NY

Senior Research Editors

James Damilini, PharmD, BCPS
Clinical Pharmacist, Emergency Room, St. Joseph’s Hospital and Medical Center, Phoenix, AZ

Joseph D. Toscano, MD
Chairman, Department of Emergency Medicine, San Ramon Regional Medical Center, San Ramon, CA

International Editors

Peter Cameron, MD
Academic Director, The Alfred Emergency and Trauma Centre, Monash University, Melbourne, Australia

Giorgio Carbone, MD
Chair, Department of Emergency Medicine Ospedale Gradenigo, Torino, Italy

Suzanne Y.G. Peeters, MD
Emergency Medicine Resident, Haga Teaching Hospital, The Hague, The Netherlands

Hugo Peralta, MD
Chair of Emergency Services, Hospital Italiano, Buenos Aires, Argentina

Dhanadul Royjansarttikul, MD
Attending Physician, Emergency Medicine, King Chulalongkorn Memorial Hospital, Thai Red Cross, Thailand; Faculty of Medicine, Chulalongkorn University, Thailand

Stephen H. Thomas, MD, MPH
Professor & Chair, Emergency Medicine, Hamad Medical Corp., Well Cornell Medical College, Qatar; Emergency Physician-in-Chief, Hamad General Hospital, Doha, Qatar

Edin Zeilic, MD
Head, Department of Emergency Medicine, Leopoldina Hospital, Schwentorf, Germany
Case Presentations

An elderly woman presents with 4 days of generalized weakness and fatigue secondary to diarrhea. On examination, she appears dehydrated. During your workup, you find that she is in acute renal failure and is suffering from hyperkalemia, with a serum potassium of 6.5 mEq/L. Her ECG shows mild peaked T waves. During discussion with the admitting physician, you are asked to give the patient sodium polystyrene. You seem to recall some controversy regarding this treatment and wonder if it is really indicated for this patient.

Your next patient is a 24-year-old woman with diarrhea and vomiting. During your workup, you find that she has hypokalemia, with a potassium level of 2.2 mEq/L, an ECG with a prolonged QT interval, and a serum magnesium of 1.9 mEq/L. The patient’s internist recommends treatment with an antiemetic, oral potassium, and discharge home. You wonder if this is the best management plan.

Your third patient is a dialysis-dependent 56-year-old man who presents with shortness of breath and weakness. His serum potassium is 6.9 mEq/L, and there is evidence of fluid overload on the chest radiograph. You contact renal to arrange emergent dialysis and they recommend that you administer a “new” potassium-binding agent and discharge the patient for his regularly scheduled dialysis appointment later in the day. You wonder what these new agents are and whether best practice has recently changed without your being aware of it.

Introduction

Potassium disorders are common and potentially deadly, which makes early recognition and treatment fundamental to quality emergency care. The symptoms that a patient may experience with these disorders are typically vague and difficult to distinguish. The emergency clinician must have a heightened index of suspicion and a low threshold for testing and treating. Recent literature has questioned several age-old practices and has challenged the emergency clinician to assess new practice paradigms, including the routine ordering of serum magnesium levels in patients with hypokalemia, redrawing potassium levels in a hemolyzed sample, proper blood-drawing techniques, and the utility of sodium polystyrene sulfonate and bicarbonate in the treatment of acute hyperkalemia. This issue of Emergency Medicine Practice provides a systematic review of the newest evidence regarding the pathophysiology, diagnosis, and management of potassium-related emergencies.

Critical Appraisal Of The Literature

A MEDLINE® search for randomized controlled trials since 2010 was conducted using the search terms hyperkalemia and hypokalemia. MEDLINE® was also queried using the terms hyperkalemia and hypokalemia and therapy or treatment in order to identify studies that have not yet reached the randomized controlled trial phase. A total of 281 articles were identified and reviewed, with 118 being for hyperkalemia and 163 articles for hypokalemia. The literature reviewed had numerous large retrospective studies but very few randomized controlled trials for either hyperkalemia or hypokalemia. Moreover, very few articles reviewed dealt with new management strategies of these disease processes. The National Guideline Clearinghouse (www.guideline.gov) was searched and no recommendations for the treatment of hyperkalemia or hypokalemia were found. The Cochrane Database of Systematic Reviews was also queried. No reviews have been published for hypokalemia; a review was published in 2009 for hyperkalemia, but it has not been updated.

Pathophysiology Of Potassium Regulation

Potassium is the most abundant ion in the body, with about 98% of it located intracellularly. Cellular potassium levels range between 140 and 150 mmol/L, while the extracellular fluid potassium concentration ranges between 3.5 and 5 mmol/L. The cellular gradient of potassium is maintained by the sodium-potassium adenosine triphosphatase (Na+/K+-ATPase) pump in the cell membrane, which actively transports potassium into and sodium out of the cell. The large potassium gradient between the intracellular and extracellular compartments is fundamental to several vital cellular functions, including the excitability of nerves and muscle, cardiac pacemaker activity, and the resting cell membrane potential. Various mechanisms promote the movement of potassium both into and out of the cell. The body’s primary mechanism of transcellular potassium shift is through the upregulation or downregulation of Na+/K+-ATPase activity. A postprandial release of insulin stimulates the insertion of the glucose transporter protein 4 (GLUT 4), which causes an upregulation of the Na+/K+-ATPase activity. This increased activity allows potassium from the extracellular space to enter the intracellular space. Magnesium also plays a crucial role in the management of potassium regulation. Homeostasis is managed primarily by intestinal diet absorption, renal reabsorption, and excretion. A total of 60% of all magnesium is stored in bone, with only 2% available in the extracellular fluid. A magnesium deficiency causes impairment of the Na+/K+-ATPase pump and thus decreases cellular uptake of potassium. The increase in extracellular potassium signals the kidney to excrete an increased amount of potassium through aldosterone secretion, which can lead to refractory hypokalemia. A second mechanism for the role of magnesium in the regulation of potassium...
lies within activation of the renal outer medullary potassium (ROMK) channel. Magnesium binds to the ROMK channel and prevents the efflux of potassium out of the cell and prevents hypokalemia.1

Catecholamines can also cause changes in potassium uptake and removal from the cell. Alpha adrenergic receptors impair the transport of potassium intracellularly while an upregulation of beta receptors stimulates Na+/K+-ATPase activity. Additional acute potassium shifts occur most often secondary to disruption of the acid/base state. As pH changes (eg, secondary to hyperventilation or a decrease in partial pressure of carbon dioxide [PCO₂]), potassium will adjust at about 0.1 to 0.3 mEq/L for each 0.1 pH unit change. Sudden changes in potassium homeostasis secondary to acid-base changes are very complicated and dependent on the underlying cause.

Homeostasis of potassium is mainly regulated through excretion by the kidney, which accounts for 80% of the daily potassium loss. A total of 15% of potassium excretion occurs through the gastrointestinal system, except for patients with end-stage renal disease, and the remaining is excreted through sweat loss. In patients with end-stage renal disease, up to 25% of daily potassium excretion can occur through the gut secondary to an upregulation of high-conductance calcium-sensitive potassium channels.

**Etiologies Of Hypokalemia**

Hypokalemia is a condition referring to the depletion of serum potassium < 3.5 mEq/L, and is characterized as being either mild, moderate, or severe.2 (See Table 1.) Hypokalemia is one of the most common electrolyte abnormalities, with a prevalence of up to 21% in hospitalized patients.3,5 In an observational cohort study of almost 12,000 patients, hypokalemia was associated with increased mortality in patients admitted without severe heart or renal disease.6 Although excessive loss is the most common etiology for hypokalemia, inadequate potassium intake and transcellular shifts of potassium can also be causes of hypokalemia. (See Table 2.)

**Inadequate Intake**

Inadequate potassium intake is defined as intake of < 1 gram of potassium per day.2 The condition is rare, because in otherwise healthy patients, the kidneys are able to compensate for decreased intake by decreasing potassium excretion to < 15 mEq/L per day. This response sustains total body stores for 2 to 3 weeks before levels fall < 3 mEq/L. However, alcoholics and patients in a chronically malnourished state are most likely to have inadequate intake and develop symptomatic hypokalemia.

**Renal Loss**

The most common site of potassium loss occurs in the renal system, which can account for a 5 to 10 mEq loss per day.7 The renal tubules are able to reabsorb about 90% of the potassium that is excreted. Most losses are secondary to increased urinary flow or increased sodium delivery to the distal nephron. This phenomenon commonly occurs from drug-related involvement, as seen with diuretics. Diuretic-induced hypokalemia is usually mild, and it is dose-dependent. Thiazide and loop diuretics increase sodium and chloride to the distal collecting duct, and this influx increases potassium excretion. A recent study of over 33,000 patients demonstrated that 13% of patients taking low-to-moderate doses of diuretics had hypokalemia.8

While any medication or substance that affects renal function can induce hypokalemia, there are several that the emergency clinician should be particularly aware of. Antibiotics (such as penicillin or penicillin derivatives) increase sodium activity and, thus, potassium excretion.9 Antineoplastic medications can cause acute and chronic renal insufficiency, resulting in potassium wasting and a wide spectrum of associated electrolyte disturbances. Cisplatin, an antineoplastic agent used to treat solid tumors, is known to cause hypokalemia, hypomagnesemia, hypercalcemia, and metabolic acidosis through the mutation of the thiazide-sensitive Na-Cl cotransporter gene in the distal convoluted tubule.10 Genetic disorders are another important cause of hypokalemia secondary to abnormal renal losses. Bartter syndrome is classified as a dysfunction of the sodium reabsorption in the ascending limb of the loop of Henle that causes a hypokalemic metabolic balance.

**Table 1. Severity Classifications Of Hypokalemia And Hyperkalemia**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Mild (mEq/L)</th>
<th>Moderate (mEq/L)</th>
<th>Severe (mEq/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypokalemia</td>
<td>3.0-3.5</td>
<td>2.5-2.9</td>
<td>&lt; 2.5</td>
</tr>
<tr>
<td>Hyperkalemia</td>
<td>5.5-6.4</td>
<td>6.5-7.5</td>
<td>&gt; 7.5</td>
</tr>
</tbody>
</table>

**Table 2. Common Causes Of Hypokalemia**

<table>
<thead>
<tr>
<th>Inadequate Intake</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Eating disorders</td>
</tr>
<tr>
<td>• Alcoholism</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Renal Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Diuretics</td>
</tr>
<tr>
<td>• Increased mineralocorticoid activity</td>
</tr>
<tr>
<td>• Hypomagnesemia</td>
</tr>
<tr>
<td>• Genetic</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gastrointestinal Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Vomiting</td>
</tr>
<tr>
<td>• Diarrhea</td>
</tr>
<tr>
<td>• Increased output from an ostomy</td>
</tr>
<tr>
<td>• Nasogastric drainage</td>
</tr>
</tbody>
</table>
acidosis with renal salt wasting. Gitelman syndrome also causes hypokalemia, but through a defect in the distal convoluted tubule.

**Gastrointestinal Loss**
Gastrointestinal loss is another common cause of potassium loss, accounting for about 15% of potassium that is excreted via stool. Normal excretion from stool is a fraction of normal total loss, at about 10 mEq daily.7 In pathologically induced states (such as in diarrhea and vomiting), this loss occurs at an accelerated rate. After a prolonged period of diarrhea and vomiting, dehydration further induces hypokalemia, either through secondary hyperaldosteronism or an alkalosis-related increase in the filtered bicarbonate load. This increased load of bicarbonate exceeds the reabsorptive capacity of the proximal tubule and allows increased distal nephron potassium excretion.

**Sweat Loss**
Sweat accounts for 5% of total daily loss of potassium, and contains a potassium concentration of 5 to 8 mmol/L.11

**Etiologies Of Hyperkalemia**

Hyperkalemia is classified as mild, moderate, or severe, depending on the serum potassium level.12 (See Table 1, page 3.) In the general population, hyperkalemia has been found in 2.6% to 3.2% of patients studied, but in patients with chronic kidney disease, its occurrence is between 7.7% and 73%.13-15 A retrospective chart review of almost 250,000 patients with chronic kidney disease found that a single episode of hyperkalemia increased the risk of mortality within 1 day of the event being found.16 Based upon this risk, the emergency clinician should prioritize diagnostic testing, intervene at an early stage of the patient’s workup, and maintain a low threshold for admission.

**Pseudohyperkalemia**
Approximately 70% of clinical decisions are based upon laboratory values, with potassium being one of the 10 most tested analytes in the United States.17 Although laboratory errors can occur during the analysis of a substance, the majority of errors occur before the sample is analyzed. Pseudohyperkalemia or factitious hyperkalemia is a false elevation in the serum potassium levels. Mechanical factors are some of the most common causes of pseudohyperkalemia. A tourniquet applied for periods greater than 1 minute causes an altered water balance that results in hemoconcentration and hemolysis of cells. Patients should be discouraged from fist clenching during the collection phase due to a local release of potassium from the forearm muscle. In a quality improvement study of almost 245,000 patients, there was a reduction of serum potassium levels by up to 26% after the cessation of fist clenching.18 In another study, after implementation of proper phlebotomy techniques, there was a reduction of unexplained hyperkalemia by 13%.19 (See Table 3.) Other mechanical factors that can cause pseudohyperkalemia include vigorous mixing, transport in pneumatic tubes or unpadded canisters, traumatic phlebotomy, and inappropriate needle diameter.

Mechanical factors are the most common causes of pseudohyperkalemia, but patient factors can also influence potassium levels. Patient fear can result in hyperventilation, with an associated hyperkalemic response. Familial pseudohyperkalemia is an autosomal dominant disorder that causes leakage of potassium across the cell membrane when blood is stored at room temperature.20 Both leukocytosis and thrombocytosis have been linked to pseudohyperkalemia as well, though the exact mechanism is not clearly understood at this time.

When pseudohyperkalemia is encountered, it may be important to redraw the specimen. However, new data from a study of 45 patients with suspected pseudohyperkalemia show a negative predictive value of 100% for hyperkalemia when there is a glomerular filtration rate (GFR) > 60 mL/min/1.73 m² and a normal electrocardiogram (ECG).21 Though larger studies are needed to validate practice, we do not recommend redrawing specimens in patients who have a normal ECG and renal function and who do not have extenuating circumstances, such as being on multiple medications known to increase potassium.

**Impaired Excretion Of Potassium**
Renal excretion of potassium is dependent upon the rate of flow in the distal nephron, aldosterone, and the secretory pathways of potassium. Hyperkalemia occurs when one or more of these systems are impaired. Patients with renal failure, however, can maintain near-normal potassium levels unless their GFR decreases to < 15 mL/min/1.73 m².

<table>
<thead>
<tr>
<th>Table 3. Proper Phlebotomy Techniques To Reduce Pseudohyperkalemia</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Use the proper gauge of needle based upon the patient’s age</td>
</tr>
<tr>
<td>• Decrease tourniquet time</td>
</tr>
<tr>
<td>• Do not allow the patient to clench fist</td>
</tr>
<tr>
<td>• Draw the sample swiftly and gently</td>
</tr>
<tr>
<td>• Remove the tourniquet before withdrawing the needle from the patient</td>
</tr>
<tr>
<td>• Do not aggressively agitate the sample after collection</td>
</tr>
<tr>
<td>• Pack the samples safely for transport</td>
</tr>
</tbody>
</table>

Medication-Induced Hyperkalemia
Adverse drug reactions are common, with an estimated 50 adverse drug reactions occurring for every 1000 patient-years in the elderly. In hospitalized patients, medications were reported as the primary cause for hyperkalemia, with a rate of 35% to 75% of all cases, often the result of impaired potassium excretion. Medications that induce hyperkalemia are potassium-containing agents, drugs that affect aldosterone secretion, drugs that cause tubular resistance to the action of aldosterone, and drugs that cause transmembrane shifting of potassium. (See Table 4.)

Potassium-Containing Agents
Hyperkalemia caused by potassium supplementation is fairly rare in persons with normally functioning kidneys secondary to potassium adaptation. Blood transfusions have the potential to cause hyperkalemia, and even cardiac arrest, in some cases. The supernatant of packed red blood cells contains 60 mEq/L of potassium, and when it is stored, there is a decrease in ATP synthesis that causes potassium to leak out of the cells. A prospective study of 125 patients demonstrated that when blood is stored for more than 12 days, there is a more pronounced rise in potassium in the recipient as compared to patients who receive blood that is less than 12 days old.

Penicillin is another medication that contains potassium that may be unknown to the clinician. Penicillin G contains 0.33 mmol of sodium and 1.7 mmol of potassium per 1 million units. The administration of penicillin has also been linked to cardiac arrest secondary to hyperkalemia after the rapid infusion of the medication.

Table 4. Medications That Can Cause Hyperkalemia

<table>
<thead>
<tr>
<th>Medication</th>
<th>Mechanism Causing Hyperkalemia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packed red blood cells</td>
<td>Potassium infusion</td>
</tr>
<tr>
<td>Penicillin G</td>
<td>Potassium infusion</td>
</tr>
<tr>
<td>Beta blockers</td>
<td>Decrease beta 2-driven potassium uptake</td>
</tr>
<tr>
<td>Succinylcholine</td>
<td>Depolarizes cell membranes</td>
</tr>
<tr>
<td>Digoxin</td>
<td>Decreases Na+/K+-ATPase activity</td>
</tr>
<tr>
<td>Spironolactone</td>
<td>Aldosterone antagonism</td>
</tr>
<tr>
<td>ACE inhibitors, ARBs</td>
<td>Decrease aldosterone synthesis, renal blood flow, and glomerular filtration rate</td>
</tr>
<tr>
<td>Nonsteroidal anti-inflammatory drugs</td>
<td>Decrease renin release, renal blood flow, and glomerular filtration rate</td>
</tr>
<tr>
<td>Heparin</td>
<td>Decreases aldosterone synthesis</td>
</tr>
<tr>
<td>Trimethoprim</td>
<td>Blocks luminal sodium channels</td>
</tr>
<tr>
<td>Pentamidine</td>
<td>Blocks luminal sodium channels</td>
</tr>
</tbody>
</table>

Abbreviations: ACE, angiotensin-converting enzyme; ARBs, angiotensin II receptor blockers; Na+/K+-ATPase, sodium-potassium adenosine triphosphatase.

Medications That Affect Aldosterone Secretion
Angiotensin-converting enzyme (ACE) inhibitors block angiotensin II synthesis, which effectively decreases aldosterone secretion and impairs renal potassium secretion by reducing the GFR. Angiotensin II receptor blockers (ARBs) competitively bind to angiotensin II receptors, decreasing adrenal synthesis of aldosterone. These 2 medications contribute to 10% to 38% of all admissions secondary to hyperkalemia. In the outpatient setting, ACE inhibitors and ARBs contribute to up to 10% of all hyperkalemia cases and account for as much as 6% of all hyperkalemia in enrolled clinical trials.

Nonsteroidal anti-inflammatory drugs (NSAIDs) indirectly inhibit the synthesis of aldosterone by inhibiting the production of renal prostaglandin. Concurrent hyperkalemia was first related to indomethacin in 1985. Since then, several other studies have attempted to correlate NSAID use with hyperkalemia. Originally, COX-2 inhibitors were thought to cause more instances of hyperkalemia as compared to nonselective NSAIDs, but new literature fails to demonstrate this.

Hyperkalemia has also been described in patients who are being treated with heparin doses of ≥ 5000 units daily. The hyperkalemia from heparin is related to not only inhibition of adrenal aldosterone production in the zona glomerulosa, but also the final enzymatic step in aldosterone production.

Medications That Cause Tubular Resistance To The Action Of Aldosterone
Trimethoprim, an antibiotic similar to the potassium-sparing diuretic amiloride, competitively inhibits luminal sodium transport channels, causing a reduction in negative luminal charge and decreased potassium secretion. Patients who take both high-dose and low-dose antimicrobial therapies are at risk for developing hyperkalemia and renal failure, especially with concurrent use of an ACE inhibitor. When used in conjunction with spironolactone, there is a 12-fold increase in the risk of hyperkalemia and a 2-fold increase in the risk of sudden cardiac death as compared to amoxicillin.

Medications That Cause Transmembrane Shifting Of Potassium
Nonselective beta blockers can cause hyperkalemia by 2 separate pathways. Catecholamine-stimulated renin release is inhibited by beta blockade and causes a decrease in the amount of aldosterone synthesis. To a greater extent, however, beta blockers decrease the function of Na+/K+-ATPase by decreas-
ing the amount of cyclic adenosine monophosphate (cAMP) in the cells.

**Differential Diagnosis**

Both hypokalemia and hyperkalemia can present with vague complaints, making the differential diagnosis expansive. Hypokalemia and hyperkalemia should both be considered in the differential for any patient presenting with generalized fatigue, weakness, or even paralysis, along with other important diagnoses including diabetic emergencies, myocardial infarction, renal failure, viral illnesses, cerebrovascular accidents, seizures, spinal shock, and myasthenic crisis.

**Prehospital Care**

A potassium-related emergency is generally not known by the prehospital provider, so management defaults to stabilization and rapid transport. An exception is the patient with known end-stage renal disease, in which case hyperkalemia should be suspected and transport to an emergency department (ED) with access to onsite dialysis prioritized.

Intravenous access and cardiac monitoring should be obtained in patients with a suspected potassium derangement. An ECG should be obtained in order to assess for signs of hyperkalemia or hypokalemia. If signs of hyperkalemia or hypokalemia are present, medical direction should be obtained and Advanced Cardiac Life Support (ACLS) protocols followed.

**Emergency Department Evaluation**

**History**

Hypokalemia can present with generalized weakness, palpitations, or, rarely, paralysis. Data from a review of 43,805 patients have shown that patients with severe hypokalemia typically present with weakness and myalgias. Hyperkalemia can also present as generalized weakness, ascending paralysis, palpitations, and paresthesias. More importantly, the emergency clinician should ask questions targeted at the underlying cause that may have led to a potassium derangement, including history of kidney failure, gastrointestinal complaints, and thyroid disorders. A review of the patient’s medications should be performed to determine whether any drug interactions can be implicated. Previous records and laboratory values should also be reviewed to assess for a pattern of potassium derangement.

**Physical Examination**

Much like the vagueness that may be obtained during a history, the same is true for the physical examination of a patient with a potassium derangement. The general appearance of the patient could vary from a benign examination to a patient in extremis. Vital signs will typically be within normal limits. Intravascular volume status should be assessed in all patients to determine perfusion status. Cardiovascular examination may reveal bradycardia or pauses. Abdominal examination may reveal hypoactive bowel sounds. An in-depth neurologic evaluation should be conducted, which may reveal generalized weakness or decreased deep tendon reflexes. Lastly, the patient should be examined for the presence of an arteriovenous fistula.

**Diagnostic Studies**

The majority of patients who experience a derangement in potassium can be identified by a thorough history, but in certain cases, the diagnosis may not seem apparent. An ECG should be obtained immediately if an electrolyte disorder is suspected, and all patients should have a complete blood count and basic metabolic profile.

When the cause of hypokalemia is not apparent after a thorough history and physical examination, a diagnostic approach aimed at testing for the regulation of potassium excretion and the assessment of the patient’s acid/base status should be completed. A random urine potassium-to-creatinine ratio can be obtained to better aid the emergency clinician in diagnosing the cause of hypokalemia. When hypokalemia is caused by transcellular potassium shift, gastrointestinal loss, or use of diuretics, the urine potassium-to-creatinine ratio is usually < 13 mEq/g creatinine. If the ratio is higher than this, renal potassium wasting is a consideration. In a prospective study of 43 patients, the potassium-to-creatinine ratio method was able to correctly diagnosis patients with either hypokalemic periodic paralysis versus a renal potassium wasting disease. After the determination of a patient’s urinary potassium excretion, a blood gas level may be helpful for interpreting the results. (See Table 5, page 7.)

For the hyperkalemic patient, a decrease in distal sodium delivery, mineralocorticoid deficiency, or abnormal cortical collecting tubule function may lead to the electrolyte abnormality. To determine the cause of the hyperkalemia, the emergency clinician should obtain urine sodium, potassium, and osmolality as well as a serum osmolality. If the urine sodium is > 25 mEq/L, then the transtubular potassium gradient (TTKG) can be used to aid in determining whether the hyperkalemia is due to a mineralocorticoid deficiency. However, if the urine sodium concentration is < 25 mEq/L, the hyperkalemia should be assumed to be a result of a decrease in distal flow, such as from acute kidney injury.
Potassium Wasting

When the TTKG is < 6, the hyperkalemia is most likely due to impaired aldosterone bioactivity in the distal nephron, but when the TTKG > 6, the hyperkalemia is most likely caused by potassium overload or cellular shifting of potassium. If the TTKG is < 6, the patient should be administered 0.05 mg of 9-α-fludrocortisone and have the TTKG repeated in 4 hours. An increase in the TTKG to > 6 would suggest an aldosterone deficiency.

Electrocardiogram Findings In Hypokalemia

As serum potassium levels decline, the transmembrane gradient is decreased, causing prolongation of the phase 3 repolarization and an increase in the relative refractory periods of cardiac myocytes. The ECG findings associated with hypokalemia can be broken down into repolarization changes and conduction abnormalities.

The earliest repolarization changes seen in patients with hypokalemia are a decrease in the T-wave amplitude, PR-interval prolongation, ST depression, T-wave inversions, and eventual U-wave formation. A U wave has been described as a positive deflection after the T wave that is best seen in the precordial leads of V2 and V3. Patients with hypokalemia also have an increased refractory period, an overall increase in the action potential, and are therefore at risk for cardiac dysrhythmias. Although there is no threshold of QT prolongation at which torsades de pointes is certain to occur, once the QT interval becomes longer than 500 milliseconds, the risk of torsades de pointes increases 2- to 3-fold.

In the Framingham Heart Study, potassium levels were inversely related to the occurrence of premature ventricular complexes (PVCs), and a decrease of 0.48 mEq/L of potassium was associated with a 27% greater chance of having PVCs. A more recent retrospective review with 671 patients found that even mild hypokalemia (mean 3.42, range 2.7-3.6 mmol/L) increases the risk of PVCs and death. Not only have ectopic ventricular beats been noted to occur in patients with hypokalemia, but also abnormal atrial rhythms. Recently, atrial fibrillation has also been linked to hypokalemia. The Rotterdam study showed that patients with hypokalemia (defined as < 3.5 mEq/L) were more likely to develop atrial fibrillation compared to patients with normokalemia, after adjustment for potential confounders, including serum magnesium concentrations.

Electrocardiogram Findings In Hyperkalemia

Increased extracellular potassium causes an increase in transmembrane permeability and influx of potassium into the cells. With this influx of potassium, there is a decrease in the magnitude of the resting potential, a decrease in the velocity of phase 0 of the action potential, and delayed conduction between the myocytes. The effects of these changes are dependent upon the tissue affected, with atrial myocardium being the most sensitive and the specialized tissue (SA node and HIS bundle) being the least sensitive.

Based upon theory and experimental settings, there is a correlation between potassium levels and ECG changes. As potassium increases to 6.5 to 7.5 mEq/L, prolongation of the QRS segment, loss of the P wave, and ectopic beats can be seen. When serum potassium reaches a level > 7.5 mEq/L, the QRS pattern may become a sine wave.

However, numerous studies have shown that an ECG alone is not sensitive for diagnosing hyperkalemia. A retrospective review demonstrated that only 55% of patients with a potassium level ≥ 6.8 mEq/L had signs of hyperkalemia. Although highly inaccurate, an ECG may be the only tool that an emergency clinician can use to make a rapid diagnosis. However, the lack of proficiency by some physicians to recognize ECG findings suggestive of hyperkalemia is concerning. In one study, residents in cardiology missed the findings of hyperkalemia in 81% of cases. In another study, attending physicians who practiced emergency medicine had a sensitivity of only 0.62 for diagnosing moderate to severe hyperkalemia.

Treatment Of Hypokalemia

The mainstay of treatment for hypokalemia is to prevent life-threatening arrhythmias and address the

<table>
<thead>
<tr>
<th>Cause of Hypokalemia</th>
<th>Acidosis</th>
<th>Alkalosis</th>
<th>Potassium Wasting</th>
<th>No Potassium Wasting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower gastrointestinal losses</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetic ketoacidosis</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Renal tubular acidosis</td>
<td>●</td>
<td></td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Sustenitious vomiting (bulimia)</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diuretic use</td>
<td>●</td>
<td></td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Vomiting</td>
<td>●</td>
<td></td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>Gitelman or Bartter syndrome</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Alternate treatment modalities, such as changing a patient from a potassium-wasting diuretic for hypertension to an ACE inhibitor or an ARB, should be explored.

When serum potassium decreases by 0.3 mEq/L, there is a 100 mEq/L reduction in total body potassium. For patients with borderline or low-normal potassium concentrations (3.5-4.0 mEq/L) an in-

**Figure 1. Electrocardiogram With Peaked T Waves And PR Depression In Hyperkalemia**

![Image of electrocardiogram with peaked T waves and PR depression in hyperkalemia](image1.png)

*Image courtesy of Rob Cooney, MD.*

**Figure 2. Electrocardiogram With A Widened QRS In Hyperkalemia**

![Image of electrocardiogram with widened QRS in hyperkalemia](image2.png)

*Image courtesy of Rob Cooney, MD.*
increase in dietary potassium should be encouraged. In patients with hypertension, recent myocardial infarction, or congestive heart failure, treatment with potassium supplementation should be considered to keep the serum potassium level at least 4.5 mEq/L. For patients with hypertension, Whelton et al found that potassium replacement was associated with a significant decrease in both systolic and diastolic blood pressure.

In asymptomatic patients with mild to moderate hypokalemia, oral replacement therapy is recommended. Potassium bicarbonate is preferred in the patient with hypokalemia and metabolic acidosis, while potassium phosphate is recommended in patients with hypokalemia and hypophosphatemia. Potassium chloride is the preferred method of potassium replacement in all other patients. Patients should be treated with 60 to 80 mEq per day, but they may require up to 150 mEq per day if continued potassium loss occurs.

In patients with severe hypokalemia or ECG changes, an intravenous method of potassium replacement should be initiated. However, close cardiac monitoring must be used in order to monitor for any arrhythmia that may develop. Consensus guidelines recommend intravenous potassium chloride at a rate of 10 to 20 mEq/h as safe. Rates > 20 mEq/h are highly irritating to peripheral veins, and a central vein should be used. A replacement of 20 mEq of intravenous potassium would raise serum potassium by 0.2 mEq. After stabilization of the patient, oral potassium should be administered.

Approximately 50% of patients with hypokalemia also have concomitant magnesium deficiency, and routine magnesium replacement should be considered for patients with hypokalemia. A routine serum magnesium level may not adequately reflect the body’s total store of magnesium. Approximately 99% of the body’s total store of magnesium lies intracellularly within the bones and muscles and only 0.6% is ionized in the extracellular space. Thus, a normal serum magnesium may grossly underestimate a true body deficit of magnesium.

In symptomatic or severe hypomagnesemia (< 0.5 mmol/L), intravenous magnesium sulfate should be initiated at 0.5 g/h. Some patients may require maintenance therapy, which can be achieved with oral supplementation of magnesium oxide (400 mg 2 or 3 times daily) or magnesium gluconate (500 mg 2 or 3 times daily).

**Treatment Of Hyperkalemia**

Patients with suspected or known hyperkalemia need intravenous access, cardiac monitoring, and fluid resuscitation. Treatment should be initiated based upon the patient’s symptomatology, ECG findings, and laboratory values. However, the absolute potassium value for treatment should be seen as arbitrary, and used in conjunction with the emergency clinician’s clinical judgment. The overall goal for the treatment of hyperkalemia should be to stabilize the cardiac membrane to prevent life-threatening dysrhythmias, to shift potassium from the extracellular space into the cell, to enhance elimination, and to treat the underlying cause of hyperkalemia. A Cochrane review of the literature from 2005, updated in 2009, does not make specific recommendations for the level to begin treatment, but does note that beta agonists, insulin and glucose, and dialysis are all acceptable means of treatment for acute hyperkalemia. (See Table 6, page 12.)

For patients who have received treatment for hyperkalemia and who are boarding in the emergency department for a prolonged period of time, the emergency physician should continue to treat the underlying cause for the patient’s hyperkalemia. The emergency clinician should also be aware of the rebound effects of potassium once the initial treatment medications dissipate and should be cognizant that repeat dosing may be needed.

**Membrane Stabilization**

Calcium directly stabilizes the cardiac membrane by reducing the threshold potential of cardiac myocytes and should be given to any patient with concern for hyperkalemia with a wide QRS. Calcium recreates the electrical gradient, but does not decrease the amount of serum potassium. A Cochrane review...
Clinical Pathway For Management Of Hypokalemia In The Emergency Department

Patient presents with suspected hypokalemia

- Check serum potassium
- Perform emergent ECG

Serum potassium 3.0 to 3.4 mEq/L
• No symptoms
• Nondiagnostic ECG

• Administer potassium chloride orally
• Discharge with recommendation to increase dietary potassium and repeat potassium level (Class II)
• Consider oral magnesium sulfate

Cardiac dysrhythmia

• Administer potassium chloride IV 10-20 mEq/h (Class II)
• Administer magnesium sulfate 1-2 grams IV over 1 h (Class II)

Cardiac arrest

Commence Advanced Cardiac Life Support®

• Administer potassium chloride 10 mEq IV over 5 min; repeat once if needed (Class II)
• Administer magnesium sulfate 1-2 grams IV push over 2 min (Class II)

Abbreviations: ECG, electrocardiogram; IV, intravenous; K, potassium.

Class Of Evidence Definitions

Each action in the clinical pathways section of Emergency Medicine Practice receives a score based on the following definitions.

**Class I**
- Always acceptable, safe
- Definitely useful
- Proven in both efficacy and effectiveness

Level of Evidence:
- One or more large prospective studies are present (with rare exceptions)
- High-quality meta-analyses
- Study results consistently positive and compelling

**Class II**
- Safe, acceptable
- Probably useful

Level of Evidence:
- Generally higher levels of evidence
- Nonrandomized or retrospective studies: historic, cohort, or case control studies
- Less robust randomized controlled trials
- Results consistently positive

**Class III**
- May be acceptable
- Possibly useful
- Considered optional or alternative treatments

Level of Evidence:
- Generally lower or intermediate levels of evidence
- Case series, animal studies, consensus panels
- Occasionally positive results

**Indeterminate**
- Continuing area of research
- No recommendations until further research

Level of Evidence:
- Evidence not available
- Higher studies in progress
- Results inconsistent, contradictory
- Results not compelling

This clinical pathway is intended to supplement, rather than substitute for, professional judgment and may be changed depending upon a patient’s individual needs. Failure to comply with this pathway does not represent a breach of the standard of care.

Copyright © 2016 EB Medicine. 1-800-249-5770. No part of this publication may be reproduced in any format without written consent of EB Medicine.
Clinical Pathway For Management Of Hyperkalemia In The Emergency Department

Patient presents with suspected hyperkalemia

- Check serum potassium
- Perform emergent ECG

Mild to moderate hyperkalemia (serum potassium 5.5 mEq/L to 7.5 mEq/L)
- Patient clinically stable; no ECG changes

Administer:
- IV fluid resuscitation
- D50 25 gm IV with regular insulin 5-10 units IV
- If serum potassium ≥ 6 mEq/L, give calcium gluconate 1 gram IV
- Albuterol 10-20 mg nebulized
- Treat the underlying cause (Class I and II)

Severe hyperkalemia (serum potassium > 7.5 mEq/L)
- ECG changes (peaked T waves in 2 leads, absent P waves, broad QRS, sine wave, bradycardia, ventricular tachycardia)

Administer:
- IV fluid resuscitation
- D50 25 gm IV with regular insulin 5-10 units IV
- Calcium chloride 1 gram IV
- Albuterol 10-20 mg, nebulized (Class I and II)
- If acidotic, consider sodium bicarbonate 50-100 mEq IV
- If end-stage renal disease, commence emergent dialysis

Cardiac arrest

Commence Advanced Cardiac Life Support®

Administer:
- IV fluid resuscitation
- Calcium chloride, 1 gram IV
- D50 25 gm IV with regular insulin 5-10 units IV (Class I and II)
- Sodium bicarbonate 50-100 mEq IV

Abbreviations: D50, dextrose 50%; ECG, electrocardiogram; IV, intravenous.
For Class of Evidence definitions, see page 10.
recommends calcium as an adjunct therapy when cardiac arrhythmias are present in a patient with hyperkalemia, but no randomized controlled trials support this recommendation.48

Calcium is available for injection as either calcium gluconate or calcium chloride. A Cochrane review recommends calcium chloride as the preferred treatment agent in the setting of cardiac arrhythmia due to a 3-fold difference in the calcium bioavailability between the gluconate and chloride solutions.48

The onset of action of calcium occurs in < 3 minutes. The recommended dose is 1 gram (10 mL of 10% solution) IV, given over 3 to 5 minutes, and it can be repeated in 5 minutes if there is no change in the patient’s ECG. The duration of the action of calcium is 30 to 60 minutes, and during this time, other interventions to lower the serum potassium should be undertaken.

**Transcellular Shift**

The administration of dextrose and insulin stimulates a transcellular shift of potassium extracellularly to intracellularly. The effect of insulin on potassium regulation is dose-dependent. Stimulation of the Na+/H+ antiporter on the cell membrane causes an activation of the Na+/K+/ATPase channel and allows the influx of extracellular potassium.

A Cochrane review recommends dextrose and insulin as a means of treatment for acute hyperkalemia.49 An intravenous dose of 25 grams of dextrose followed by 10 units of regular insulin is the recommended dosage. The dextrose should be given before the insulin to avoid accidental iatrogenic hypoglycemia.49 The onset of action of this treatment modality is < 15 minutes, with peak onset 30 to 60 minutes following infusion.48 The total duration of action ranges between 4 and 6 hours, and it can lower serum potassium 0.6 mEq/L. When combined with albuterol, a synergistic effect was reported by Allon and Copkeney, and was found to be superior to either treatment alone.50

Although a significant reduction in serum potassium is evident by this treatment, it may be complicated by hypoglycemia. Two recent studies have shown that hypoglycemia occurs at differing rates, but is most pronounced in patients with acute kidney injury or end-stage renal disease.31,52 In these retrospective chart reviews, the rate of hypoglycemia ranged from 8.7% to 13% of patients treated with this modality.51,52 In these patients, a protocol should be initiated to monitor serum glucose for several hours post treatment. A recent study by Chothia et al demonstrated that a glucose-only bolus causes a clinically significant decrease in potassium concentrations in hemodialysis patients without the side effect of hypoglycemia; however, the study contained only 10 patients.53 Further research in this area needs to be conducted before this can become common practice.

Sodium bicarbonate has been classically taught as a treatment for acute hyperkalemia. However, little data exist on its efficacy as a treatment modality. In the only randomized trial of sodium bicarbonate for the treatment of acute hyperkalemia, the authors found bicarbonate therapy did not lower the serum concentration of potassium at 60 minutes.54 At this time, a Cochrane review does not recommend the routine usage of sodium bicarbonate as a monotherapy; however, sodium bicarbonate may be used as an adjunctive therapy in patients with concurrent

**Table 6. Interventions Used In The Treatment Of Hyperkalemia**

<table>
<thead>
<tr>
<th>Medication</th>
<th>Dosage</th>
<th>Onset</th>
<th>Duration</th>
<th>Therapeutic Effect/Comment</th>
</tr>
</thead>
</table>
| Calcium chloride, calcium gluconate| 1 gram IV over 5 min    | < 3 minutes | 30-60 minutes | • No effect on serum potassium; stabilizes cardiac membrane.  
• Calcium chloride may cause significant tissue irritation and necrosis (central line administration recommended).  
• Calcium gluconate may require 3 times the dosage of calcium chloride. |
| Sodium bicarbonate                 | 50-100 mEq IV           | 5-10 minutes| 2 hours    | • Redistributions serum potassium.  
• Adjunctive therapy only if patient is acidicotic. |
| Dextrose and insulin               | 25 grams dextrose and 5-10 units regular insulin IV | < 15 minutes | 4-6 hours | • Activates the Na+/K+/ATPase pump; no effect on total body potassium.  
• Monitor blood glucose closely for up to next 1-3 hours. |
| Albuterol                          | 10-20 mg nebulized over 10 min | 15-30 minutes | 2-3 hours | • Activates the Na+/K+/ATPase pump; no effect on total body potassium.  
• Use as adjunctive therapy; caution with patients with cardiovascular disease. |
| Sodium polystyrene sulfonate       | 15 to 30 grams orally   | 2-24 hours  | Variable   | • Removes potassium via the gastrointestinal tract. |
| Dialysis                           | N/A                     | 1-2 minutes after starting treatment | Unspecified | • Removes serum potassium and total body potassium. |

Abbreviation: Na+/K+/ATPase, Sodium-potassium adenosine triphosphatase.
Beta-adrenergic receptor agonists induce the upregulation of Na\(^+\)/K\(^+\)-ATPase activity through a distinct pathway that is separate from that of insulin. The typical dose needed to achieve this effect is 4 times the normal dose of albuterol that is typically given in the ED. Serum potassium levels decrease by 0.6 mEq/L after inhalation of 10 mg of albuterol and 1.0 mEq/L after 20 mg is inhaled. With dosing at 20 mg, side effects are common; however, most centers use 10 mg to 15 mg with no side effects.

Terbutaline, another beta-adrenergic receptor agonist, has also been shown to lower serum potassium levels. In a prospective trial of 14 patients with chronic kidney disease on hemodialysis, terbutaline given 7 mcg/kg subcutaneously was found to decrease serum potassium levels by 1.31 mEq/L. Given the relatively small number of patients in the study and unknown absorption rates of subcutaneous injections, the authors cannot recommend terbutaline for the emergent management of hyperkalemia at this time, but further research should be conducted in this area.

### Removal Of Potassium

#### Cation Exchange Resins

Historically, the only United States Food and Drug Administration (FDA) medication approved to treat hyperkalemia was the cation exchange resin sodium polystyrene sulfonate (SPS). In the colon, SPS exchanges sodium for potassium and binds 0.65 mmol/L of potassium in vivo. However, little data in today’s literature can support its use for the emergent treatment of hyperkalemia. The landmark study for SPS, published in 1961, found that there was very little effect of SPS compared to sorbitol alone in the treatment of hyperkalemia. A 2015 retrospective study of 138 patients found that oral SPS therapy lowered serum potassium levels by 0.14 mmol/L more than the control group (patients who did not receive SPS), but the authors questioned its true clinical significance, despite finding statistical significance, because SPS failed to lower potassium below the predetermined minimal clinically important difference of 0.2 mmol/L.

The onset of action of SPS occurs 2 hours post ingestion, with the peak onset of action at 6 hours. This slow treatment effect provides little relief of acute hyperkalemia in the acute setting. There is also a risk associated with the use of SPS. In 2009, the FDA issued a recommendation that sorbitol not be added to SPS powder due to its association with bowel necrosis. However, a recent systematic review with 58 reported cases showed that SPS with or without sorbitol was associated with bowel necrosis and one-third of these patients eventually died due to gastrointestinal injury. Therefore, cation exchange resins should not be used as an acute treatment for hyperkalemia but may be used for subacute treatment in select patient populations.

Although SPS has fallen out of favor, 2 new cation exchange resins have been developed and are currently undergoing testing for use in the treatment of hyperkalemia. Sodium zirconium cyclosilicate (ZS-9) is a cation exchanger that traps potassium in the intestine and exchanges it for sodium and hydrogen. In phase 2 testing, a reduction of 0.92 mEq/L of potassium was found after administration of ZS-9 in patients with stage 3 chronic kidney disease, as compared to placebo, at 38 hours. In phase 3 testing, ZS-9 was found to reduce serum potassium levels by 0.5 to 0.7 mmol/L, depending on the time variable studied. The authors noted that after one 10-gain dose, the mean serum potassium level decreased by 0.4 mmol/L at 1 hour and 0.6 mmol/L at 2 hours. The HARMONIZE trial (Effect of Sodium Zirconium Cyclosilicate on Potassium Lowering for 28 Days Among Outpatients With Hyperkalemia) also found a reduction of 1.1 mEq/L of potassium at 48 hours post ingestion, but a reduction of only 0.2 mEq/L at 1 hour. When studied in patients with heart failure and hyperkalemia, ZS-9 lowered potassium and maintained normokalemia during the study period of 28 days.

Patiromer (Veltassa) is a novel cation exchange resin that binds potassium in exchange for calcium in the colon. In patients with chronic kidney disease who were receiving renin-angiotensin-aldosterone system therapy, a reduction of 1.01 mEq/L of potassium was noted at 72 hours post ingestion. Other studies, including PEARL-HF (Prevention of Hyperkalemia in Patients with Heart Failure using a novel polymeric potassium binder, RLY5016), and AMETYST-DN (Effect of Patiromer on Serum Potassium Level in Patients With Hyperkalemia and Diabetic Kidney Disease) have all shown the varying degrees of potassium reduction in select populations, but they have not examined the acute phase. Adverse reactions, including gastrointestinal symptoms, hypokalemia, and hypomagnesemia have all been reported in varying degrees. Despite these 2 novel agents and their promise to lower potassium levels, neither has been studied in the acute phase, and until further studies elucidate their role in the treatment of acute hyperkalemia, they cannot be recommended.

### Dialysis

Dialysis is the only other form of definitive potassium removal and should be considered in patients with severe hyperkalemia or patients with moderate hyperkalemia and end-stage renal disease. Two studies have shown that the usage of low-potassium or potassium-free dialysate is both safe and effective in lowering the serum potassium level, and, by increasing the blood flow during dialysis, a greater effect on potassium lowering is also noted.

Although dialysis removes 1 mmol/L of se-
rum potassium in the first hour and 2 mmol/L by 3 hours, a rebound of serum potassium can be seen post dialysis. The magnitude of postdialysis serum potassium rebound is proportional to the predialysis serum potassium level, with 35% of the reduction equated by 1 hour post treatment.68

Special Considerations

Rapid Sequence Intubation
Although controversial, many physicians are concerned with succinylcholine-induced hyperkalemia. Succinylcholine results in skeletal muscle cell depolarization, causing an intracellular potassium efflux and subsequent neuromuscular blockade. Recent literature found that this efflux results in a mean potassium increase of 0.4 mEq/L, usually occurring a few minutes after administering succinylcholine.69 Often, this increase is transient and without clinical impact, but cases have described sudden death following the administration of succinylcholine. Patients with upper or lower motor neuron defects, prolonged chemical denervation, direct muscle trauma (crush injury), thermal trauma, disuse atrophy, and severe infection have all been linked to an increased risk of hyperkalemia following rapid sequence intubation with succinylcholine. If there is a high clinical suspicion of hyperkalemia either by history or from an ECG suggesting associated changes, alternative paralytics should be used for rapid sequence intubation.

Genetic Disorders
Bartter syndrome, Gitelman syndrome, and Liddle syndrome are all genetic disorders that can present with hypokalemia early in life. Bartter syndrome is caused by a dysfunction of sodium reabsorption in the ascending limb of the loop of Henle. This causes renal salt loss and a hypokalemic metabolic alkalosis. Gitelman syndrome is caused by defects in the distal convoluted tubule. In Gitelman syndrome, patients present during adolescence with muscle cramps and weakness and are found to have hypomagnesemia, hypokalemia, and metabolic alkalosis on routine laboratory testing. Liddle syndrome is an autosomal dominantly inherited disease that presents with hypertension and hypokalemia at a young age, secondary to a decrease in renin activity and aldosterone secretion. Acute management should be aimed at correction of potassium based upon symptomatology and serum values.

Myocardial Infarction
In patients with myocardial infarction, both hypokalemia and hyperkalemia have been associated with increased mortality. In a retrospective study of 468 patients, patients with hypokalemia were 4 times more likely to have a malignant ventricular arrhyth-

mia when compared to normokalemic patients who had also suffered a myocardial infarction.70 According to Grodzinsky et al, patients with hyperkalemia on admission for acute myocardial infarction also had an increase in mortality. In this retrospective review of 38,689 patients with acute myocardial infarction, inhospital mortality exceeded 15% once potassium was > 5.5 mEq/L, regardless of whether or not the patient was dialysis dependent.71 Based upon these studies, the emergency clinician should aggressively treat patients with hypokalemia and hyperkalemia in the setting of acute myocardial infarction.

Digoxin Toxicity
The foxglove plant, Digitalis purpurea, was first used by Sir William Withering in 1785 to treat heart failure. The usage of digoxin has continued since this time for heart failure treatment, but it has also been associated with significant mortality. Digoxin is considered a cardiac glycoside that reversibly inhibits the Na+/K+-ATPase pump, causing an increase in intracellular sodium and a decrease in intracellular potassium, leading to an increase in potassium in the serum. In an acute toxicity, mortality correlates with the degree of hyperkalemia. The first study to correlate hyperkalemia with mortality during digoxin toxicity noted that no patients with a potassium level > 5.5 mEq/L survived, but patients with a potassium level < 5 mEq/L survived.72 Due to these findings, it has been accepted that patients with a serum potassium level > 5 mEq/L should receive digoxin-specific antibody fragments.

Although hyperkalemia is a major concern for the emergency clinician when faced with digitalis toxicity, the clinician should also be aware of the effects of hypokalemia in association with the usage of digoxin. In patients with hypokalemia, digoxin toxicity may occur at normal serum concentration levels because both potassium and digoxin competitively bind to the Na+/K+-ATPase pump. In patients with hypokalemia and digoxin toxicity, potassium should be repleted cautiously, to selectively inhibit the binding of digoxin to the Na+/K+-ATPase pump. All patients receiving digoxin-specific antibody fragments should have their potassium monitored closely due to the rapid fluctuations in potassium that may occur, and they should be admitted to a monitored bed.

Periodic Paralysis

Hypokalemic Periodic Paralysis
Hypokalemic periodic paralysis (HPP) is the most common form of periodic paralysis, with an incidence of 1 in 100,000.73 HPP is 4 times more common in men than women, and in the majority of cases, it is caused by a mutation in the gene that codes for the alpha–1-subunit of the dihydropyridine-sensitive calcium channel in skeletal muscle. At this time, the
exact cause of potassium transport that leads to HPP is unknown. Attacks occur in late childhood and are provoked by stress, vigorous activity, or a high-carbohydrate meal.

During an attack, the patient may experience hyporeflexia, generalized weakness that is more profound in the proximal muscles as compared to the distal, in the legs as compared to the arms, and with preserved respiratory status. Cardiac dysrhythmias are uncommon during an attack despite showing classic signs of hypokalemia on an ECG tracing. Diagnosis is typically made by a family history of similar episodes, but if presenting for the first time, a complete workup for hypokalemia and thyroid disorders should be initiated. Treatment during an acute attack should commence only after confirmation of hypokalemia. If the patient is able to tolerate oral potassium replacement, 2 protocols have been used. The first protocol recommends 30 mEq of potassium chloride every 30 minutes until normalization of serum potassium. This method, however, may overshoot the amount of potassium needed and cause hyperkalemia. A second, more conservative protocol recommends 10 mEq of potassium chloride every hour until normalization of the serum potassium. All patients with HPP should be admitted to a monitored bed until serum potassium levels normalize.

**Hyperkalemic Periodic Paralysis**

Hyperkalemic periodic paralysis (PP) is another uncommon channelopathy that the emergency clinician may face. PP is caused by SCN4A mutation that causes sodium channels on skeletal muscle cells to close slowly and undergo mytonia that eventually leads to paralysis. During paralysis, potassium is released from the cells into the extracellular matrix. Attacks typically occur in the first decade of life and may present as single-limb weakness. Episodes of PP are typically more common than those associated with HPP, but they last a shorter duration. Acute attacks will usually not warrant treatment unless cardiac dysrhythmias are present.

**Andersen Syndrome**

Andersen syndrome is characterized by the triad of periodic paralysis, ventricular arrhythmias, and dysmorphic body features in association with a prolonged QT interval. Typically manifesting in the first or second decade of life, potassium levels may be low, normal, or high during an attack. The majority of cases are related to a mutation in the gene encoding KCNH2. Acute treatment should not be initiated until laboratory values are obtained, due to the varied potassium levels during an attack. If treatment is initiated prior to laboratory values being obtained, the emergency clinician should tailor treatment modalities based upon the patient’s ECG.

---

**Controversies And Cutting Edge**

The major controversy in the management of potassium disorders lies in the usage of SPS for the treatment of emergent hyperkalemia. SPS was designed when dialysis was still in its infancy and physicians had few options for treatment. The original study conducted by Scherr et al was the first to use a binding substance in an attempt to lower serum potassium. In the study, 32 patients with renal failure were enrolled to receive SPS and a low-calorie diet. At the conclusion of the study, 30 patients had a decrease or no increase in serum potassium and 23 patients had a mean fall of potassium of at least 0.4 mEq/L.

Several confounding factors were present in the study and perhaps overlooked by the FDA. Only 7 of the 32 patients from the study were truly hyperkalemic (potassium > 5 mEq/L), and 22% of the enrolled participants were given other medications that can also lower potassium (insulin and bicarbonate) at the same time. Oliguric patients (23) were treated differently from patients with chronic renal failure by receiving 20% dextrose and a high-calorie diet, which can increase carbohydrate load and may have increased natural insulin driving potassium into the cells. Furthermore, no control group was used in the study.

The second study on SPS was also fraught with errors. Flinn et al conducted a study where patients received SPS and sorbitol and a second group received sorbitol alone. Both study groups were provided a diet without potassium, and serum levels were checked on day 0 and day 5. The SPS/sorbitol group had a decrease of 1.4 mEq/L, while the sorbitol-alone group had a decrease of 1.7 mEq/L. Based upon this study, it was found that sorbitol alone can decrease potassium at a greater rate than SPS/sorbitol; however, SPS alone was approved for the management of hyperkalemia.

Neither the Scherr et al study nor the Flinn et al study are relevant to the emergent management of hyperkalemia in the ED. The primary endpoint of the Scherr et al study was to determine the lowering effects of SPS on potassium at 24 hours while the Flinn study used 5 days as its time frame.

Although SPS may not be warranted for the treatment of emergent hyperkalemia in the modern world, several circumstances exist where SPS is indicated. During austere conditions of natural or man-made disasters in which dialysis may not be readily available, SPS can be used to treat hyperkalemia in the interim, as well as extending inter-dialysis intervals for patients with end-stage renal disease. Another instance in which SPS may be beneficial is when there is a prolonged time to dialysis in patients who present to the ED. These patients should undergo transcellular shifting of potassium, and, in
1. “Sure, the patient had hypokalemia, and I was treating it with intravenous potassium, but I didn’t think she needed a monitor.”
   All patients receiving potassium via the intravenous route should be on a cardiac monitor both during and after infusion to assess for dysrhythmias.

2. “That end-stage renal disease patient is always here with moderate hyperkalemia. I gave him a dose of sodium polystyrene sulfate and sent him to dialysis.”
   Emergent dialysis is the treatment of choice for patients who are dialysis-dependent with hyperkalemia. The binding resins have not been proven to rapidly lower potassium levels in the acute setting.

3. “Although the patient’s potassium was 7.1 mEq/L, she had a normal ECG.”
   The ECG is unreliable in predicting which patients with hyperkalemia will rapidly decompensate and it should not be the sole factor in initiating treatment.

4. “The laboratory results were clearly due to hemolysis, so I didn’t treat the hyperkalemia.”
   Although new data have shown that not all laboratory tests need to be redrawn, particularly in patients with normal renal function and a normal ECG, the clinical picture should guide care. If you suspect renal failure with associated hyperkalemia, then the patient should be treated appropriately and tests redrawn.

5. “The patient’s potassium was the low end of normal after his myocardial infarction, and his cardiac arrest was most likely secondary to his underlying heart condition.”
   Hypokalemia has been associated with ventricular fibrillation in myocardial infarction patients and a serum potassium of at least 4.5 mEq/L should be maintained.

6. “The patient had moderate hyperkalemia with ECG changes. I gave a dose of calcium and admitted him to the internist. I can’t believe he coded when he got to the floor.”
   Calcium is a membrane stabilizer and is cardioprotective for patients with hyperkalemia. However, it does not lower the total serum potassium, and other interventions must be employed.

7. “Sure, the child had some fatigue, but he looked well. I sent him back to his pediatrician for a further workup.”
   Genetic renal disorders of childhood can present with vague complaints and warrant testing in the ED, if suspected.

8. “The patient’s potassium was 2.4 mEq/L, but she was asymptomatic. I sent her home with a prescription for oral potassium replacement and a repeat basic metabolic panel in a week.”
   Severe hypokalemia warrants intravenous potassium replacement and admission for further stabilization, due to the risk of arrhythmia.

9. “I treated the patient’s hyperkalemia with insulin and dextrose and sent him to the floor. I am not sure why he was unresponsive when he got there.”
   Patients treated with insulin and dextrose for hyperkalemia should be placed on a glucose monitoring protocol for several hours.

10. “I gave the patient one of the new potassium-binding resins for her hyperkalemia and sent her home for follow-up with her primary care physician.”
    Both sodium zirconium cyclosilicate and patiromer have not been studied in the acute management of hyperkalemia. The only proven acute management strategy for potassium removal is dialysis.
Time-And Cost-Efficient Strategies

- It may not be necessary to repeat the serum potassium blood draw if it is hemolyzed. **Risk Management Caveat:** This practice has been reported in the literature only once and is not common practice. Khodorkovsky reported that, if the serum potassium specimen is hemolyzed but the patient has a normal ECG and a GFR > 60, then the negative predictive value for true hyperkalemia was 100%. If laboratory tests are to be repeated, it may be cheaper to check a serum potassium only instead of another basic metabolic panel.

- If hyperkalemia is suspected, treatment should begin without laboratory confirmation. **Risk Management Caveat:** Based upon the history and physical examination and a simple rhythm strip, hyperkalemia can be inferred. Treatment can begin with membrane stabilization until laboratory tests confirm hyperkalemia. However, one must be cognizant of other medications that the patient may be taking, especially digoxin.

- Knowing which medications can cause hypokalemia and hyperkalemia may decrease undue hospital admissions.

- Knowing how certain medications interact with others may decrease the amount of hypokalemia and hyperkalemia.

### Summary

Potassium disorders can be life-threatening, and emergent management skills are necessary to prevent deterioration. A heightened sense of awareness for these disorders is needed due to the vagueness of the symptomatology that a patient may present with, and a stepwise, evidence-based approach to the treatment of both hypokalemia and hyperkalemia is crucial. In all cases, the underlying cause for either hypokalemia or hyperkalemia should be identified and aggressively treated. For patients with asymptomatic hypokalemia and a normal ECG, oral replacement with potassium chloride is the treatment of choice, but for patients with an abnormal ECG or who are symptomatic, intravenous potassium chloride and magnesium sulfate are indicated. In a patient with mild hyperkalemia, interventions to shift potassium transcellularly are indicated, while in patients with moderate to severe hyperkalemia, calcium for membrane stabilization is recommended. Potassium-binding agents are not recommended for acute management in that they have relative variability in their onset times; however, they may have a role in the subacute phase of care, especially in patients who do not have immediate access to dialysis.

### Case Conclusions

In the first case, you explained to the admitting physician that treatment with IV fluids of the elderly patient with weakness from diarrhea was currently underway, which was targeting the underlying cause of dehydration. You already gave the patient calcium chloride 1 gram IV, dextrose 50% 25 grams IV plus regular insulin 10 units IV, and nebulized albuterol 20 mg. You explained that the current best-practice evidence supports emergent dialysis and does not support the routine use of SPS because it may unnecessarily expose the patient to the risk of bowel necrosis.

For the young patient with diarrhea and vomiting, outpatient management was inappropriate, given that the patient had ECG changes associated with hyperkalemia. You began treatment with 20 mEq of potassium chloride IV, 40 mEq of potassium chloride orally, and started empirically with 2 grams IV magnesium sulfate. You discussed with the internist your concern that her serum magnesium levels could be unreliable due to only a small percentage of ionized magnesium being found in the serum. Together, you decided that taking the patient to an observation unit was the best disposition location in this case.
For the dialysis-dependent patient with dyspnea and weakness, you did a quick MEDLINE® search and learned that although both sodium zirconium cyclosilicate and patiromer have shown promise as potassium-binding agents, they have not been studied in acute hyperkalemia, and the only definitive means of potassium removal is through dialysis. You shared this with the renal consultant, who agreed to admit him for dialysis.

### References

Evidence-based medicine requires a critical appraisal of the literature based upon study methodology and number of subjects. Not all references are equally robust. The findings of a large, prospective, randomized, and blinded trial should carry more weight than a case report.

To help the reader judge the strength of each reference, pertinent information about the study is included in bold type following the reference, where available.

26. Mercer CW, Logic JR. Cardiac arrest due to hyperkalemia following intravenous potassium administration. *Chest.* 1973;64(5):358-359. (Case study; 1 patient)
27. Raebel MA. Hyperkalemia associated with the use of angiotensin converting enzyme inhibitors and angiotensin receptor blockers. *Cardvasc Ther.* 2012;30(3):e156-e166. (Review)


47. Antoniou T, Gomes T, Mamdani M, et al. Trimethoprim-sulfamethoxazole induced hyperkalemia in elderly patients receiving spironolactone: nested case control study. *BMJ*. 2011;343:d5228. (Case-control study; 6903 patients)


2. Which of the following medications does NOT cause hyperkalemia?
   a. Heparin
   b. Angiotensin-converting enzyme inhibitors
   c. Angiotensin receptor blockers
   d. Cisplatin

3. Through which mechanism does trimethoprim cause hyperkalemia?
   a. It is a potassium-containing agent
   b. It affects aldosterone secretion
   c. It causes tubular resistance to the action of aldosterone
   d. It causes transmembrane shifting of potassium

4. Typically, what is the earliest ECG finding in hyperkalemia?
   a. Peaked T waves
   b. Prolongation of the PR interval
   c. QRS widening
   d. Sine wave formation

5. Post myocardial infarction, what level should the clinician aim for the patient’s serum potassium to be?
   a. 3.2 mEq/L
   b. 3.6 mEq/L
   c. 3.8 mEq/L
   d. 4.5 mEq/L

6. If a patient has severe hypokalemia, what other electrolyte should be given?
   a. Calcium
   b. Magnesium
   c. Phosphorus
   d. Chloride

7. Which of the following treatments for hyperkalemia removes total potassium from the serum?
   a. Dialysis
   b. Insulin and dextrose
   c. Sodium bicarbonate
   d. Albuterol

8. In which of the following situations should succinylcholine NOT be used for rapid-sequence intubation?
   a. Motor vehicle crash
   b. Asthma
   c. Guillain-Barré syndrome
   d. Myocardial infarction
Our latest release, *Emergency Trauma Care: Current Topics And Controversies, Volume II* reviews aspects of emergency trauma care that you manage virtually every day. You’ll learn about 6 of the most pressing concerns facing emergency clinicians today, including:

- **Treating Pain In Trauma**
- **Geriatric Trauma**
- **Obese Patients**
- **Trauma Malpractice - Tips For Avoiding Risks**
- **Sports Injuries**
- **Ballistic Injuries**

In addition to our distinguished authors’ discussions, we have included pertinent commentaries on each topic from the emergency medical services, research, surgical, legal, economic, and nursing perspectives—in an effort to give a view of all aspects of trauma care.

**Included in this book:**

1. 80 pages of evidence-based content, covering six high-impact topics
2. 18 AMA PRA Category 1 Credits™ that are trauma specific
3. Summarized information to help you keep up with current guidelines and best practices
4. Treatment recommendations to help you determine the critical actions required when caring for these patients
5. And much more!

**2 Easy Ways To Order:**

1. Go online to: www.ebmedicine.net/NJBXDX
2. Call 1-800-249-5770 or 678-366-7933

*Use Promotion Code: NJBXD at checkout*
Leverage The Latest Advances In Stroke Care!

Emergency Stroke Care: Advances And Controversies, Volume I is a brand-new resource that reviews the latest research, recommendations, and guidelines for the diagnosis and management of patients with stroke.

Andy Jagoda, MD, Medical Director at Mount Sinai, who is recognized nationally for his work in neurological emergencies, describes Emergency Stroke Care: Advances and Controversies as “a clinically relevant update on the state of the art in diagnosing and managing transient ischemic attacks and stroke.” Highlights of the book include:

Acute Stroke:
- Expanding opportunities for IV rtPA use in acute stroke: What is the very latest in expanding the time window? What is its use in minor stroke and rapidly improving stroke symptoms? What are the contraindications for IV rtPA?
- Update on advanced acute stroke imaging: What is the latest research on CT, CTA, CT perfusion, and 4D CT? What are the concerns and limitations of multimodality neuroimaging?
- Endovascular therapies for acute ischemic stroke: What are the recommendations following the most recent trials on mechanical thrombectomy with stentriever? A full analysis of the latest evidence on this major paradigm shift in stroke care.
- Update on stroke systems of care: What are Acute Stroke-Ready Hospitals, and how do they fit into your hospital’s practice? The most current Joint Commission guidelines and information you need on how stroke certifications affect practice in your ED are covered.

Transient Ischemic Attack:
- A review of the latest guidelines from the American Heart Association/American Stroke Association.
- What you need to know to diagnose TIA quickly and accurately.
- Is the ABCD2 score still the best risk stratification tool?
- Current evidence on cardiac evaluation in TIA.
- Echocardiography, CT, or MRI – which is the best choice for imaging?
- The latest on current therapies: antiplatelet agents, anticoagulants, thrombolysis, and risk-factor control.

2 Easy Ways To Order:
1. Go online to www.ebmedicine.net/NJBXE
2. Call 1-800-249-5770 or 678-366-7933

Use Promotion Code: NJBXE at checkout
SPECIAL SAVINGS ON
The 2014-2017 Lifelong Learning And Self-Assessment Study Guides

Receive FREE article reprints*, CME, and more when you order yours today!

Your *Lifelong Learning And Self-Assessment Study Guides* include full reprints* of the original articles plus a handy summary of key points and an in-depth discussion to clarify and elaborate those key points. In addition, the study guides provide sample questions to help you quiz yourself on your knowledge of the material with answers and explanations to drive home the main points.

Our LLSA Study Guides are available in print or online formats and are designed to provide you with the practical knowledge needed to ace the LLSA exams.

“Excellent. I like the format with the synopsis and key points followed by the full article. Easy to read. Easy to navigate.”
- ANITA L’ITALIEN, MD

“I have been using your LLSA Study Guides for over seven years now. They are concise, thoughtful, and extremely helpful. With the CME credits now offered for free, it is definitely money well spent.”
- JAMES ROSBRUGH, MD

*Due to copyright restrictions, 1 article from the 2016 LLSA, the tables from 1 article in the 2014 LLSA, and 2 articles and 1 table from the 2017 LLSA are not included.

2 Easy Ways To Order:
1. Go online to: www.ebmedicine.net/NJBXF
2. Call 1-800-249-5770 or 678-366-7933

Use Promotion Code: NJBXF at checkout to secure your discount

Accreditation: EB Medicine is accredited by the Accreditation Council for Continuing Medical Education (ACCME) to provide continuing medical education for physicians. This activity has been planned and implemented in accordance with the accreditation requirements and policies of the ACCME. Credit Designation: EB Medicine designates this enduring material for a maximum of 35 AMA PRA Category 1 Credits™ per study guide. Physicians should claim only the credit commensurate with the extent of their participation in the activity. Faculty Disclosure: It is the policy of EB Medicine to ensure objectivity, balance, independence, transparency, and scientific rigor in all CME-sponsored educational activities. All faculty participating in the planning or implementation of a sponsored activity are expected to disclose to the audience any relevant financial relationships and to assist in resolving any conflict of interest that may arise from the relationship. In compliance with all ACCME Essentials, Standards, and Guidelines, all faculty for this CME activity made a full disclosure statement. This information will be presented as part of the course materials. Commercial Support: This activity received no commercial support.
Physician CME Information

Date of Original Release: November 1, 2016. Date of most recent review: October 10, 2016.
Termination date: November 1, 2019.

Accreditation: EB Medicine is accredited by the Accreditation Council for Continuing Medical Education (ACCME) to provide continuing medical education for physicians. This activity has been planned and implemented in accordance with the accreditation requirements and policies of the ACCME.

Credit Designation: EB Medicine designates this enduring material for a maximum of 4 AMA PRA Category 1 Credits™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

AMA Accreditation: Emergency Medicine Practice is approved by the American College of Emergency Physicians for 48 hours of ACEP Category 1 credit per annual subscription.

AAFP Accreditation: This Medical Journal activity, Emergency Medicine Practice, has been reviewed and is acceptable for up to 48 Prescribed credits by the American Academy of Family Physicians per year. AAFP accreditation begins July 1, 2016. Term of approval is for one year from this date. Each issue is approved for 4 Prescribed credits. Credit may be claimed for one year from the date of each issue. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

AOA Accreditation: Emergency Medicine Practice is eligible for up to 48 American Osteopathic Association Recognized Credits. AOA Program Code: 11000. This activity is approved for 2-A or 2-B credit hours per year.

ABIM Accreditation: Successful completion of this CME activity, which includes participation in the evaluation component, enables the participant to earn up to 4 MOC points in the American Board of Internal Medicine's (ABIM) Maintenance of Certification (MOC) program. Participants will earn MOC points equal to the amount of CME credits claimed for the activity. It is the CME activity provider's responsibility to submit participant completion information to ACCME for the purpose of granting ABIM MOC credit.

Needs Assessment: The need for this educational activity was determined by a survey of medical staff, including the editorial board of this publication; review of morbidity and mortality data from the CDC, AHA, NCHS, and ACEP; and evaluation of prior activities for emergency physicians.

Target Audience: This enduring material is designed for emergency medicine physicians, physician assistants, nurse practitioners, and residents.

Goals: Upon completion of this activity, you should be able to: (1) demonstrate medical decision-making based on the strongest clinical evidence; (2) cost-effectively diagnose and treat the most critical presentations; and (3) describe the most common medicolegal pitfalls for each topic covered.

Discussion of Investigational Information: As part of the journal, faculty may be presenting investigational information about pharmaceutical products that is outside Food and Drug Administration-approved labeling. Information presented as part of this activity is intended solely as continuing medical education and is not intended to promote off-label use of any pharmaceutical product.

Faculty Disclosure: It is the policy of EB Medicine to ensure objectivity, balance, independence, transparency, and scientific rigor in all CME-sponsored educational activities. All faculty participating in the planning or implementation of a sponsored activity are expected to disclose to the audience any relevant financial relationships and to assist in resolving any conflict of interest that may arise from the relationship. In compliance with all ACCME Essentials, Standards, and Guidelines, all faculty for this CME activity were asked to complete a full disclosure statement. The information received is as follows: Dr. Ashurst, Dr. Sergent, Dr. Wagner, Dr. Pfennig, Dr. Stovis, Dr. Damilini, Dr. Toscano, Dr. Jagoda, and their related parties report no significant financial interest or other relationship with the manufacturer(s) of any commercial product(s) discussed in this educational presentation.

Commercial Support: This issue of Emergency Medicine Practice did not receive any commercial support.

Earning Credit: Two Convenient Methods: (1) Go online to www.ebmedicine.net/CME and click on the title of the article. (2) Mail or fax the CME Answer And Evaluation Form (included with your June and December issues) to EB Medicine.

Hardware/Software Requirements: You will need a Macintosh or PC to access the online archived articles and CME testing.

Additional Policies: For additional policies, including our statement of conflict of interest, source of funding, statement of informed consent, and statement of human and animal rights, visit www.ebmedicine.net/policies.

In upcoming issues of Emergency Medicine Practice....

- Priapism
- Pelvic Inflammatory Disease
- Maxillofacial Trauma
- Noninvasive Ventilation
- Sedative/Hypnotic Withdrawal

Direct all inquiries to:
EB Medicine
Phone: 1-800-249-5770 or 1-678-366-7933
Fax: 1-770-500-1316
5550 Triangle Parkway, Suite 150
Norcross, GA 30092
E-mail: ebm@ebmedicine.net
Website: www.ebmedicine.net
To write a letter to the editor, please email: jagodamd@ebmedicine.net

Subscription Information

Full annual subscription: $349 (includes 12 monthly evidence-based print issues; 48 AMA PRA Category 1 Credits™, 48 ACEP Category I credits, 48 AAFP Prescribed credits, and 48 AOA Category 2A or 2B CME credits. Call 1-800-249-5770 or go to www.ebmedicine.net/subscribe to subscribe.

Individual issues: $39 (includes 4 CME credits). Call 1-800-249-5770 or go to www.ebmedicine.net/EMPissues to order.

Group subscriptions at discounted rates are also available. Contact groups@ebmedicine.net for more information.

Reprints: www.ebmedicine.net/empissues

Copyright © 2016 EB Medicine. All rights reserved.