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A Review of Bicarbonate Use in Common Clinical Scenarios

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Abstract

Background: The use of sodium bicarbonate to treat metabolic acidosis is intuitive, yet data suggest that not all patients benefit from this therapy.

Objective: In this narrative review, we describe the physiology behind commonly encountered nontoxicologic causes of metabolic acidosis, highlight potential harm from the indiscriminate administration of sodium bicarbonate in certain scenarios, and provide evidence-based recommendations to assist emergency physicians in rationale use of sodium bicarbonate.

Discussion: Sodium bicarbonate can be administered as a hypertonic push, as a resuscitation fluid, or as an infusion. Lactic acidosis and cardiac arrest are two common scenarios where there is limited benefit to routine use of sodium bicarbonate, although certain circumstances, such as patients with concomitant acute kidney injury and lactic acidosis may benefit from sodium bicarbonate. Patients with cardiac arrest secondary to sodium channel blockade or hyperkalemia also benefit from sodium bicarbonate therapy. Recent data suggest that the use of sodium bicarbonate in diabetic ketoacidosis does not confer improved patient outcomes and may cause harm in pediatric patients. Available evidence suggests that alkalinization of urine in rhabdomyolysis does not improve patient-centered outcomes. Finally, patients with a nongap acidosis benefit from sodium bicarbonate supplementation.

Conclusions: Empiric use of sodium bicarbonate in patients with nontoxicologic causes of metabolic acidosis is not warranted and likely does not improve patient-centered outcomes, except in select scenarios. Emergency physicians should reserve use of this medication to conditions with clear benefit to patients.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Keywords

sodium bicarbonate; lactic acidosis; cardiac arrest; diabetic ketoacidosis; metabolic acidosis; rhabdomyolysis

Introduction

Bicarbonate was first used by the Egyptians in the form of natron, a naturally occurring compound salt. The applications were vast, including routine use for skin care, as an agent in the mummification process, and even as a topical wound disinfectant (1, 2). Sodium bicarbonate continues to have broad utility throughout industrial, commercial, and clinical practices. It is commonly used in fungicides, household cleaning products, fire extinguishers, and as a leavening agent in baking. The medical indications for sodium bicarbonate have traditionally been reserved for treatment of hyperkalemia, urinary alkalinization for nephrotoxic agents, and treatment of certain toxic ingestions (e.g., tricyclic antidepressant and other sodium channel blocker overdoses). However, current use of sodium bicarbonate in the emergency department (ED) is variable and without clear guidance in a variety of clinical scenarios outside of these well-accepted clinical indications, particularly in the setting of profound metabolic acidosis.

Sodium bicarbonate is frequently used to treat acid–base disturbances. Acid–base homeostasis is critical for overall energy production, oxygen delivery, and hemodynamic stability. Decreased serum pH (< 7.35) is called acidemia, and is the consequence of the process of acidosis, which may occur due to impaired ventilation or various metabolic etiologies. Inadequate gas exchange and impaired respiration lead to excess circulating CO_2, which is converted to carbonic acid, leading to acidemia. Metabolic acidosis occurs when there is bicarbonate loss or acid accumulation. Metabolic acidosis can be further distinguished as anion gap metabolic acidosis (AGMA) and non–anion gap metabolic acidosis (NAGMA). Although it may seem intuitive to treat all acidoses with an alkalotic bicarbonate solution, there are several potential ways that indiscriminate bicarbonate administration may be nonbeneficial or potentially harmful. Here, we provide an evidence-based approach to sodium bicarbonate administration for the practicing emergency physician. As physiologic effects from acute respiratory acidosis are distinct and generally better tolerated than metabolic acidosis, we have chosen to limit this review to the less well-established uses of bicarbonate in metabolic acidosis from nontoxicologic metabolic acidosis (3).

Methods

The authors conducted a narrative review of the available literature of bicarbonate therapy in selected topics. The literature search was completed using Google Scholar and PubMed databases for articles written in English published between November 1990 and November 2022. Search terms included: “bicarbonate,” “cardiac arrest,” “lactate,” “lactic acidosis,” “diabetic ketoacidosis,” “rhabdomyolysis,” “acidosis,” and “acidemia.” Abstracts were reviewed by two authors (S.H., G.W.) for appropriateness and discrepancies were adjudicated by a third author (C.T.). Preference was given to recent randomized trials and

meta-analyses. Additional articles were identified if judged relevant in references of selected articles. We reviewed a total of 143 abstracts, of which 27 original research studies and 4 meta-analyses were included.

Levels of Evidence and Strength of Recommendations

The definitions used for grading the level of evidence and the strength of recommendations were adapted from the method used for the American College of Emergency Physicians Clinical Policies and are summarized in Table 1.

Discussion

Review of Sodium Bicarbonate and Physiologic Effects of Acidosis

Sodium bicarbonate comes prepared in 8.4% and 7.5% concentrations in 50-mL ampules and as a 4.2% concentration in a 10-mL ampule for pediatric patients. The solutions contain equal amounts (mEq/mL) each of sodium and bicarbonate ions. The 8.4% concentration contains 1 mEq/mL, the 7.5% solution contains 0.892 mEq/mL, and the 4.2% solution contains 0.5 mEq/mL of each ion, respectively. These solutions are extremely hyperosmolar —2000 mOsm/L for the 8.4% concentration and 1786 mOsm/L for the 7.5% concentration. The onset of action for IV sodium bicarbonate after a push is rapid, with mean onset at 8–10 min (5). Sodium bicarbonate can be administered as a bolus via ampules or through a continuous infusion, depending on the clinical indication and treatment goals. There are several different formulations of IV sodium bicarbonate infusions. Examples of com- mon infusion formulations include sodium bicarbonate 150 mEq in 1 L of 5% dextrose (D5W) (578 mOsm/L), sterile water (300 mOsm/L), or, less commonly, 150–100 mEq sodium bicarbonate in 0.45% normal saline or D5W. Lactated Ringer's solution is not used as a base for an infusion of sodium bicarbonate, although it does contain 130 mmol/L of sodium, 28 mmol/L of lactate (which is converted in the liver to bicarbonate), and no bicarbonate.

Physiologic Effects of Metabolic Acidosis

Physiologic effects of metabolic acidosis include compromised myocyte contractility, cardiac irritability, decreased systemic vascular tone, impaired response to endogenous and infused catecholamines, and pulmonary vasoconstriction (6–9). In addition, immune response and leukocyte function may be impaired, predispos- ing patients to immunosuppression and potential infec- tion (10, 11). However, there are some beneficial effects of metabolic acidosis, including decreased hemoglobin affinity for oxygen, increasing oxygen availability to tissues, vasodilation causing increased blood flow to tissues, and increased availability of ionized calcium, which may augment myocardial contractility (12, 13).

Potential Harm from Bicarbonate Administration

Although it may seem intuitive to treat all metabolic acidoses with bicarbonate supplementation, there are several ways that sodium bicarbonate administration can potentially cause harm. Excessive administration of sodium bicarbonate has been associated with decreased availability of oxygen at the tissue level due to a leftward shift in the oxygen dissociation curve (14). Although rare, aggressive bicarbonate therapy may result

in alkalemia, causing increased binding of calcium to albumin, leading to a drop in ionized calcium levels and subsequent depressed cardiac contractility and hypotension. In addition, due to the hyperosmolar nature of the solution sodium load associated with these preparations, patients may experience fluid shifts, notably pulmonary and cerebral edema. It is also important to note that the use of sodium bicarbonate relies on the ability of the patient to have effective ventilation. The bicarbonate anion combines with hydrogen ions to ultimately form CO_2. If minute ventilation is restricted, preventing adequate exhalation of CO_2, excessive administration of sodium bicarbonate may inadvertently cause hypercarbia and paradoxically lower the pH. Peripheral vein thrombophlebitis is another potential cause of iatrogenic complications from rapid administration of 8.4% sodium bicarbonate, particularly in situations with faulty peripheral intravenous catheters, although recent data suggest that lower concentrations may not cause localized injury (15, 16).

Clinical Scenarios

Lactic Acidosis

Unbalanced lactate production or consumption leads to elevated lactate levels, known as hyperlactatemia (lactate > 2 mmol/L). Lactic acidosis is defined by a serum lactate > 4 mmol/L and pH < 7.35 (17). Hyperlactatemia can be further subdivided based on the etiology of the elevated lactate level (18, 19). Type A hyperlactatemia includes states of dysoxia and decreased tissue perfusion, as seen in shock, significant anemia, and severe hypoxia. Type B hyperlactatemia broadly encompasses disorders of oxidative phosphorylation within the mitochondria, sepsis, ineffective lactate clearance in the liver, and congenital inborn errors of metabolism. Septic shock is a common cause of hyperlactatemia in critically ill patients encountered in the ED. Hypotension leads to increased anaerobic glycolysis (type A) and decreased hepatic clearance of lactate. Acidemia also shunts excess pyruvate towards lactate production and prevents lactate from entering the Cori cycle for gluconeogenesis. Sepsis can cause significant hyperlactatemia in the absence of hypoperfusion through accelerated glycolysis in the absence of hypotension (type B).

Acidemia has been implicated in contributing to cardiovascular instability and decreased responsiveness to catecholamines and severe lactic acidosis is associated with increased mortality (20, 21). This has led to the general belief and clinical practice that severe acidemia (usu- ally defined as a pH ≤ 7.10 to 7.20), should be corrected in the setting of lactic acidosis while awaiting definitive treatment of or response to treatment for the underlying cause. When surveyed, 86% of nephrologists and 67% of intensivists would initiate buffer treatment for patients with lactic acidosis, and 87% of nephrologists and 75% of intensivists would target a pH ≥ 7.2 (22).

Despite widespread use, it is unknown whether treating extracellular acidosis with sodium bicarbonate affects clinical outcomes. Prior data have indicated that sodium bicarbonate administration does not improve hemodynamics in critically ill patients with lactic acidosis (23, 24). Interestingly, there is no effect seen even in patients with severe acidemia (pH 6.90–7.20) and concurrent vasopressor use. Various studies, including the recent analysis of the Medical Information Mart for Intensive Care III database, have found

that sodium bicarbonate does not improve mortality in critically ill patients with severe acidemia (pH < 7.20) or in septic patients with metabolic acidosis, except in patients with concomitant acute kidney injury (25–28). Importantly, most publications evaluating the effect of supplemental bicarbonate therapy in patients with lactic acidosis have been observational or retrospective. The BICAR-ICU (Sodium Bicarbonate Therapy for Patients with Severe Metabolic Acidaemia in the Intensive Care Unit) trial is the only randomized trial published that randomized 394 adult patients with pH < 7.2, bicarbonate < 21 mmol/L, and arterial serum lactate 2 > mmol/L to receive supplemental bicarbonate therapy (26). The trial used a 4.2% sodium bicarbonate infusion to target a pH > 7.3 in critically ill patients admitted to the ICU—and did not include patients in the emergency department or those who had received a bicarbonate infusion in the 24 h prior to enrollment. The authors found no difference in 28-day mortality or presence of single-organ failure at day 7 (primary composite outcome) in patients randomized to receive bicarbonate infusion vs. the control group. However, the authors completed a prespecified subgroup analysis in which they found that patients with acute kidney injury and pH < 7.2 did have a decrease in mortality at 28 days (63% vs. 46%; $p = 0.017$). The au- thors also found that renal replacement therapy need was decreased in those randomized to receive the bicarbon- ate infusion. Notable adverse events in the bicarbonate group included higher rates of hypernatremia, hypocalcemia, and metabolic alkalosis.

In summary, there is no mortality benefit or demonstrated improvement in hemodynamics with use of sodium bicarbonate in lactic acidosis, although emerging data suggest patients with persistent metabolic acidosis and acute kidney injury may benefit from an infusion of bicarbonate after initial resuscitation. Emphasis should be placed on treatment of the underlying cause of the acidosis.

Recommendation—The routine use of bicarbonate supplementation for lactic acidosis and shock states is not recommended. There may be a role for an infusion of sodium bicarbonate after initial resuscitation in patients with acute kidney injury and pH < 7.2, although data are limited, and ongoing trials are evaluating benefit (29) (Level of evidence: B).

Cardiac Arrest

The benefit of rapid pushes of ampules of sodium bicarbonate therapy in cardiac arrest is controversial. Decreased perfusion leads to hypoxia, anaerobic glycolysis, and generation of lactate. In addition, cessation of spontaneous ventilation causes buildup of carbon dioxide, decreases coronary perfusion pressure, and contributes to a mixed metabolic and respiratory acidosis. Acidemia has detrimental effects on hemodynamics, increases myocardial irritability, and lowers the threshold for dysrhythmias. Indeed, the use of sodium bicarbonate was initially part of Advanced Cardiac Life Support (ACLS) guidelines dating back to 1976 (30). However, over the years, data emerged that did not show improvement in resuscitation outcomes with bicarbonate supplementation, thus calling into question the routine use of sodium bicarbonate during resuscitation. Subsequently, incorporation of sodium bicarbonate during cardiac arrest began to fall out of favor, instead emphasis has

shifted to early defibrillation and high-quality cardiopulmonary resuscitation to augment coronary perfusion with improved patient centered outcomes (31).

The literature to support sodium bicarbonate use during cardiac arrest is mixed. Overall, most studies have found that either there is no effect on outcomes or there is worse survival with bicarbonate use. However, it is possible that worse outcomes are seen in the sodium bicarbonate groups as providers might be more likely to give base therapy to more severely ill patients. In 2006, Vukmir et al. found no improvement with outcomes when sodium bicarbonate was administered for out-of-hospital cardiac arrest, but they did note improved survival in the subset of patients with prolonged arrest of > 15 min (32.8% bicarbonate group vs. 15.4% control group; $p = 0.007$) (32). A retrospective study from Bar-Joseph et al. in 2005 also found that hospitals that routinely used sodium bicarbonate (defined as those institutions who used bicarbonate in > 50% of arrests and within 10 min of first epinephrine dose) had higher rates of return of spontaneous circulation and favorable neurologic outcomes compared with sites that did not use sodium bicarbonate as frequently (33). However, the sites who were more apt to use sodium bicarbonate also started ACLS interventions, including first epinephrine dose quicker than hospitals who did not use bicarbonate as often. Overall, these studies suggest that if there is any potential benefit to bicarbonate administration during cardiac arrest, the timing of administration during resuscitation may be key and requires further study.

In 2010, the American Heart Association (AHA) removed sodium bicarbonate from the undifferentiated arrest ACLS algorithm for routine use (34). The most recent 2020 Adult AHA guidelines are unchanged, stating “routine use of sodium bicarbonate is not recommended for patients in cardiac arrest” (Class of Recommendation 3: no benefit [moderate], Level of Evidence B-R: moderate quality of evidence from ≥ 1 randomized controlled trial [RCT] or metanalyses of these RCTs) (35). The 2020 AHA guidelines discuss that there have been no new convincing studies since the 2010 publication to indicate that sodium bicarbonate is beneficial to patient-centered outcomes, and some data have indicated a negative impact on mortality and neurologic outcomes. The AHA only recommends sodium bicarbonate cardiac arrest from suspected hyperkalemia, tricyclic antidepressant overdose, and other sodium channel blockade toxicities, such as cocaine overdose (36). Similarly, the 2020 Pediatric AHA guidelines state “routine use of sodium bicarbonate is not recommended in pediatric cardiac arrest in the absence of hyperkalemia or sodium channel blocker toxicity” (Class of Recommendation 3: harm [strong], Level of Evidence B-NR: moderate quality evidence from ≥ 1 nonrandomized studies or meta-analyses of these studies) (37). The pediatric guidelines also reviewed eight studies that suggested an association between bicarbonate use and decreased survival, which led to the current recommendations.

Recommendation—Pushes of sodium bicarbonate are not recommended for use in undifferentiated cardiac arrest for adult or pediatric patients. However, they are recommended in selected cases, including suspected hyperkalemia or sodium channel blockade toxicity (Level of evidence: B).

Diabetic Ketoacidosis

Diabetic ketoacidosis (DKA) results in severe metabolic acidosis in several ways. First, insulin deficiency and high levels of counterregulatory hormones (e.g., glucagon, catecholamines, and cortisol) trigger the release of hormone-sensitive lipase. This results in lipolysis of free fatty acids into ketoacids (β-hydroxybutyrate, acetoacetate), which reliably results in a AGMA (38). These unmeasured anions are the predominant components in DKA. In addition, volume losses from osmolar diuresis, anorexia, and vomiting lead to acute kidney injury, which may contribute to AGMA or NAGMA. Injury to renal glomeruli and tubules may also result in inadequate excretion of other unmeasured anions, such as sulfate, phosphate, and urate, worsening acidemia and increasing the anion gap. Finally, a lactic acidosis may occur due to decreased tissue perfusion, catecholamine excess, and altered glucose metabolism, which may shunt pyruvate from glycolysis to produce lactate as well (39).

Evidence supporting bicarbonate therapy as either pushes of ampules of sodium bicarbonate or as a resuscitation fluid are lacking. A systematic review by Chua et al. examined clinical and physiologic outcomes with the use of bicarbonate therapy in adult and pediatric patients with DKA and showed no mortality benefit with sodium bicarbonate use compared with conventional fluid resuscitation (38). In addition, in three pediatric studies, investigators observed an association between bicarbonate therapy and development of cerebral edema. One multicenter study calculated a relative risk for the development of cerebral edema as high as 4.2 (95% CI 1.5–12.1). However, the two remaining studies found no association after adjusting for baseline acidosis (40–42). There were no available studies examining the risk of cerebral edema in adult DKA populations. There was no difference in neurologic recovery with bicarbonate therapy in adult patients with DKA and no available studies on this endpoint in pediatric patients. Two studies examined hemodynamic parameters (i.e., heart rate, respiratory rate, and mean arterial pressure) in adult patients with DKA and found no difference with or without bicarbonate therapy (43, 44). Importantly, an older, small RCT found that among patients with DKA with a pH between 6.90 and 7.14, there was no improvement in morbidity or mortality or time to resolution of DKA among patients receiving bicarbonate therapy (45). Another found no difference in the length of hospital stay with bicarbonate therapy (46). More recently, a retrospective study evaluated time to resolution of acidosis and hospital length of stay in ED patients presenting with DKA and an initial pH < 7.0 (47). Patients were stratified into two groups based on receipt of bicarbonate or not. The authors found no significant difference in time to resolution of acidosis or hospital length of stay between patients who received bicarbonate and those who did not, including in a predefined subgroup of patients with initial pH < 6.9. The lack of conclusive data is reflected in the various society guidelines and sodium bicarbonate administration is still recommended by some professional societies if pH is < 6.9, but not others (48, 49).

Several studies suggest a potential role for bicarbonate therapy in the recovery phase of DKA. After volume resuscitation, bicarbonate is regenerated, but may be offset by development of hyperchloremia, as ketoacids are preferentially excreted over chloride anions. In addition, patients with persistent kidney injury and reduced production of renal bicarbonate may theoretically benefit from bicarbonate administration to correct this

relative bicarbonate deficiency. Two adult RCTs found quicker reversal of acidosis with bicarbonate therapy at 2 h, but this benefit was not sustained beyond 2 h (43, 46). There were no significant differences in glycemic control, insulin sensitivity, tissue oxygenation, or cerebrospinal fluid acidosis, but increased rates of hypokalemia. Finally, two studies found paradoxical worsening of ketonemia with bicarbonate therapy, theorized to be due to augmented hepatic ketogenesis (46, 50).

Recommendation—Sodium bicarbonate therapy in the initial resuscitation or recovery phase of DKA is not recommended and may cause harm in pediatric patients, although data in patients with severe acidosis (pH < 7.0) and hyperkalemia are lacking (Level of evidence: B).

Rhabdomyolysis

Rhabdomyolysis is a condition characterized by the breakdown of muscle tissue resulting in systemic release of intracellular components, including myoglobin, creatine kinase, aldolase, lactate dehydrogenase, and potassium. The causes of rhabdomyolysis are varied, but most are associated with crush injuries, vigorous exercise, ischemia embolism or thrombosis, illicit toxins, medications, seizures, immobilization, hyperthermia, shock states, and metabolic disorders. Acute kidney injury is common and may cause life-threatening hyperkalemia, particularly in more severe cases. The cornerstone of treatment is fluid resuscitation, which optimizes renal perfusion, thereby diminishing ischemic injury to the kidneys and increases urinary flow (51). Ultimately, this prevents buildup of intratubular casts and improves excretion of potassium.

The primary theorized benefit of bicarbonate therapy in patients with rhabdomyolysis is alkalinization of urine. In animal models, it has been observed that precipitation of myoglobin complexes is worsened in acidic urine, thereby further damaging renal tubules (52). Metmyoglobin-induced vasoconstriction has also been reported to be more profound in acidotic states (53). Finally, investigational research has found that heme produced free radicals can damage the renal tubules directly and that myoglobin-induced oxidation and lipid peroxidation may be reduced by urine alkalinization (54).

There is limited clinical evidence to support urinary alkalinization with an infusion of sodium bicarbonate. A retrospective study by Homsi et al. found no difference in creatinine levels in critically ill patients with rhabdomyolysis when treated with sodium bicarbonate, and suggested that bicarbonate administration is not needed if appropriate saline resuscitation is completed (55). Two systematic reviews evaluating evidence-based recommendations for prevention of rhabdomyolysis associated renal failure found no evidence to support a preferred resuscitation fluid (56, 57). In addition, there was no evidence to support bicarbonate supplementation with or without mannitol as superior to fluid resuscitation alone. However, the authors did conclude that bicarbonate could be used if needed to correct metabolic acidosis. Brown et al. conducted a retrospective study of 382 trauma patients and found that there was no difference in the rates of renal failure, dialysis, or mortality between those who received bicarbonate and mannitol vs. those who did not (58). Multiple professional societies have released clinical practice guidelines suggesting

against routine use of sodium bicarbonate, as they found no difference in renal outcomes; however, some comment that alkalinization could be considered in patients with severe metabolic acidosis (59, 60).

Recommendation—Urinary alkalinization with bicarbonate does not improve patient-centered outcomes in patients with rhabdomyolysis and is not recommended based on the available evidence (Level of evidence: A). It is uncertain whether patients with severe metabolic acidosis from rhabdomyolysis would benefit from a resuscitation strategy including sodium bicarbonate as a resuscitation fluid based on the available evidence.

NAGMA

NAGMA occurs by direct loss of bicarbonate in the gastrointestinal or urinary systems, direct or indirect chloride administration, or impaired ammonia excretion with chronic kidney disease (61). The role of bicarbonate therapy in NAGMA depends largely on the mechanism by which the acidosis occurred. Renal tubular acidosis may cause a decrease in serum bicarbonate concentration by inadequate proton excretion in the distal tubules (type 1), inadequate bicarbonate resorption in the proximal tubules (type 2), or reduced sodium resorption in the collecting ducts (type 4), which causes hyperkalemia and hyponatremia in addition to NAGMA. Direct loss of bicarbonate in the gastrointestinal or urinary systems most often occurs through secretory diarrhea, enteric fistulae, or ureteroileostomy. Concomitant hyponatremia, hypokalemia, and volume depletion may occur. Hyponatremia and decreased extracellular fluid volume stimulate the renal retention of both Na^+ and Cl^-. Retained Cl^- replaces the lost HCO_3^-, generating a relative excess of chloride. Chloride administration may occur directly, through volume resuscitation with Cl^--rich normal saline, or indirectly, through administration of total parenteral nutrition, which contains metabolic precursors to hydrochloric acid (62). Importantly, mortality rates associated with NAGMA, particularly those from administration of chloride-rich solutions, are lower than those with AGMA (63). In addition, there are no available randomized controlled studies to direct the initiation and dosing of bicarbonate therapy in critical NAGMA. However, there is a strong physiologic rationale to replace the lost bicarbonate, which is why this is often recommended and likely why RCTs do not exist.

Recommendation—Sodium bicarbonate supplementation is indicated in cases with severe NAGMA (Level of evidence: B).

Conclusions

The use of sodium bicarbonate for the treatment of metabolic acidosis remains controversial in the medical community. Review of the literature overall does not support routine use of bicarbonate, particularly in anion gap metabolic acidosis. The processes underlying pH balance in human physiology are multifaceted, and an understanding of the mechanisms at play, as well as the methods of providing sodium bicarbonate supplementation, will serve an emergency physician well. There are few data demonstrating improved clinical outcomes with sodium bicarbonate use in patients with shock states, DKA, rhabdomyolysis, or cardiac arrest (except in the presence of sodium channel blockade toxicity or hyperkalemia), as

shown in Table 2. However, it may benefit patients with NAGMA and, despite physiologic rationale, there are minimal data from RCTs to justify this.

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ARTICLE SUMMARY

Why is this topic important?

Sodium bicarbonate is administered in a variety of clinical scenarios in the emergency department. Inappropriate and indiscriminate therapy with sodium bicarbonate may result in patient harm. There is variability in use of this medication in emergency departments in certain controversial areas.

What does this review attempt to show?

We describe the underlying physiology of various nontoxicologic clinical scenarios (lactic acidosis, cardiac arrest, diabetic ketoacidosis, rhabdomyolysis, and non–anion gap metabolic acidosis) where sodium bicarbonate is administered. We highlight the relevant literature on how sodium bicarbonate impacts patient-centered outcomes. We provide recommendations to practicing emergency physicians on appropriate use of sodium bicarbonate across a variety of scenarios where there is debate on the utility of this drug.

What are the key findings?

There is minimal data to suggest empiric use of sodium bicarbonate therapy for patients with lactic acidosis, cardiac arrest, diabetic ketoacidosis, or rhabdomyolysis. In select scenarios, such as cardiac arrest secondary to sodium channel blockade toxicity or hyperkalemia, sodium bicarbonate is recommended. Emerging data suggest that an infusion of sodium bicarbonate may benefit patients with an acute kidney injury and metabolic acidosis, although these data are extrapolated from patients in the intensive care unit. There is physiologic rationale and outcome data suggesting sodium bicarbonate benefits patients with a nongap metabolic acidosis.

How is patient care impacted?

Appropriate use of sodium bicarbonate may improve patient-centered outcomes. We recommend that use of sodium bicarbonate be reserved for clinical scenarios where there is evidence demonstrating benefit rather than empiric use.

Table 1.

Levels of Evidence and Strength of Recommendations

Level of Evidence	Strength of Recommendation
Level I	Level A
Randomized, controlled trial or meta-analysis of randomized trials	Generally accepted principles for patient care that reflect a high degree of clinical certainty (e.g., based on evidence from 1 or more Class of Evidence I or multiple Class of Evidence II studies).
Level II	Level B
Nonrandomized trial or retrospective	Recommendations for patient care that may identify a particular strategy or range of strategies that reflect moderate clinical certainty (e.g., based on evidence from 1 or more Class of Evidence II studies or strong consensus of Class of Evidence III studies).
Level III	Level C
Case series	Recommendations for patient care that are based on evidence from Class of Evidence III studies or, in the absence of adequate published literature, based on expert consensus.

Source: American College of Emergency Physicians (4).

Table 2.

Summary of Clinical Scenarios and Recommendations

Clinical Scenario	Recommendation	Strength of Recommendation	Comments/Caveats
Lactic acidosis and circulatory shock	Routine use of bicarbonate supplementation is not recommended	B	There may be role for sodium bicarbonate infusion after initial resuscitation in patients with acute kidney injury and pH < 7.20.
Cardiac arrest	Routine use of bicarbonate supplementation is not recommended except in select cases (e.g., tricyclic antidepressant toxicity or hyperkalemia)	B	Bicarbonate administration is still recommended in sodium channel blockade toxicity, hyperkalemia. Limited trials completed in undifferentiated cardiac arrest, timing may be an important variable, requires more research.
DKA	Sodium bicarbonate therapy in initial resuscitation or subsequent phases is not recommended	B	May potentially be harmful in pediatric patients due to increased cerebral edema. Data for or against use in DKA with severe acidosis pH < 7.0 and hyperkalemia are lacking but is still recommended by some professional societies.
Rhabdomyolysis	There is no benefit to bicarbonate to alkalinize urine.	A	Fluid resuscitation is the priority. No randomized trials have been completed to specify fluid type during initial resuscitation.
NAGMA	Sodium bicarbonate supplementation is recommended in severe NAGMA	B	There are limited randomized controlled trials, but strong physiologic rationale for use of bicarbonate in NAGMA.

DKA = Diabetic ketoacidosis; NAGMA = non-anion gap metabolic acidosis.