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Managing diabetic emergencies: hyperglycemia and diabetic ketoacidosis: Review article for paramedics, emergency medical services, nursing, and health informatics

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***Abstract*---Background:** Diabetic ketoacidosis (DKA) and hyperglycemic hyperosmolar state (HHS) are severe hyperglycemic crises that can occur in individuals with diabetes. While they are often treated as separate conditions, they exist on a continuum of hyperglycemic emergencies related to inadequate diabetes management. **Aim:** This review aims to provide an overview of DKA and HHS, exploring their epidemiology, pathogenesis, diagnosis, and management strategies. The review focus on the main role of paramedics, emergency medical services, nursing, and health informatics in the management of DKA. **Methods:** The article synthesizes data from various epidemiological studies, clinical case reviews, and historical accounts of diabetic emergencies to highlight the clinical characteristics and treatment approaches for DKA and HHS. **Results:** The incidence of DKA has risen significantly, leading to over 140,000 hospitalizations annually in the United States. While DKA is more common in younger individuals with type 1 diabetes, HHS primarily affects older patients with type 2 diabetes. Both

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conditions share common treatment principles, including fluid rehydration, insulin therapy, and electrolyte replacement, with timely intervention critical for improving outcomes. **Conclusion:** DKA and HHS represent serious medical conditions that necessitate swift diagnosis and management. Understanding their epidemiology and pathogenesis is vital for healthcare providers to optimize care and reduce mortality. Effective management can significantly improve patient outcomes, especially for those experiencing recurrent hyperglycemic crises.

***Keywords*---**Diabetic ketoacidosis, hyperglycemic hyperosmolar state, diabetes management, epidemiology, insulin therapy.

Introduction

Diabetic ketoacidosis (DKA) and hyperglycemic hyperosmolar state (HHS) are critical and potentially fatal hyperglycemic crises encountered in individuals with diabetes. While DKA and HHS are often viewed as distinct conditions, they actually represent varying points along a continuum of hyperglycemic emergencies stemming from inadequately managed diabetes. Both DKA and HHS may manifest in patients with type 1 diabetes (T1D) and type 2 diabetes (T2D); nevertheless, DKA is predominantly observed in younger individuals with T1D, whereas HHS is more commonly noted in adult and elderly populations with T2D. In numerous cases, characteristics of both conditions, including ketoacidosis and hyperosmolality, can coexist. The incidence of DKA has escalated by 30% over the past decade, resulting in over 140,000 hospitalizations annually in the United States [1,2]. The frequency of hospital admissions for HHS is comparatively lower than that for DKA, comprising less than 1% of all diabetes-related admissions [3,4]. Both conditions are marked by insulin deficiency and pronounced hyperglycemia. Timely diagnosis and intervention are crucial to enhance patient outcomes. The cornerstone of treatment for both DKA and HHS includes vigorous rehydration, insulin administration, electrolyte replenishment, and identification and management of underlying precipitating factors. In this article, we examine the epidemiology, pathogenesis, and diagnosis of these conditions, while offering practical recommendations for managing patients experiencing hyperglycemic emergencies.

Historical Review of Diabetic Comas

The initial comprehensive clinical account of diabetic coma in an adult patient exhibiting severe polydipsia, polyuria, and a significant presence of glucose in the urine, followed by a progressive deterioration in mental status and subsequent death, was documented by August W. von Stosch in 1828 [5]. This report was succeeded by multiple case studies detailing young and adult patients, either newly diagnosed or with established diabetes, who exhibited a sudden clinical trajectory characterized by excessive polyuria, glycosuria, coma, and fatal outcomes [6–8]. In 1874, German physician Adolf Kussmaul noted that many instances of diabetic coma were preceded by deep, frequent respirations and pronounced dyspnea [9,10]. The phenomenon known as Kussmaul breathing

soon became a defining feature of diabetic coma. Shortly thereafter, it was reported that many of these patients had urine containing substantial quantities of acetoacetic acid and β-hydroxybutyric acid [11,12]. In 1886, Dr. Julius Dreshfeld provided a thorough description of two distinct categories of diabetic coma: one exhibiting Kussmaul breathing and positive ketones, and another, an atypical type of diabetic coma observed in older, well-nourished individuals, characterized by severe hyperglycemia and glycosuria, but lacking Kussmaul breathing, fruity breath odor, or a positive urine acetone test [13].

Prior to the discovery of insulin in 1921, the mortality rate among patients with diabetic ketoacidosis (DKA) exceeded 90%. The first successful treatment of DKA with insulin was reported by Banting and colleagues [14], involving a 14-year-old boy who presented with a blood glucose level of 580 mg/dL and strongly positive urinary ketones at the Toronto General Hospital in 1923. The authors observed a remarkable improvement in glycosuria along with the disappearance of acetone bodies in the urine following several doses of pancreatic extract injections [14]. After the advent of insulin, the mortality rate associated with diabetic comas plummeted to 60% in 1923 and further decreased to 25% by the 1930s [15]. By the 1970s, this rate had fallen to 7% to 10% [16,17], and currently, it is less than 2% for patients with DKA [1,18,19] and between 5% and 16% for patients with hyperglycemic hyperosmolar state (HHS) [20,21].

Epidemiology

While diabetic ketoacidosis (DKA) is more prevalent among individuals with autoimmune type 1 diabetes (T1D), the cumulative incidence of DKA cases reported in patients with type 2 diabetes (T2D) accounts for at least one-third of all instances [22]. Global epidemiological studies have examined the incidence of DKA in T1D patients. For example, an analysis conducted by the Prospective Diabetes Registry in Germany, which included 31,330 patients, revealed a DKA admission rate of 4.81 per 100 patient-years (95% confidence interval [CI], 4.51–5.14) [23]. Those at the highest risk typically included individuals with elevated hemoglobin A1c (HbA1c) levels, prolonged diabetes duration, adolescents, and females [23]. Data from three registries across five nations involving 49,859 children (aged <18 years) with T1D indicated similarly higher odds of DKA among females (odds ratio [OR], 1.23; 99% CI, 1.10–1.37), ethnic minorities (OR, 1.27; 99% CI, 1.11–1.44), and individuals with an HbA1c of 7.5% or greater (OR, 2.54 [99% CI, 2.09–3.09] for HbA1c from 7.5 to <9% and OR 8.74 [99% CI, 7.18–10.63] for HbA1c of 9.0%) [24]. Furthermore, data from the T1D Exchange Clinic Network, encompassing 2,561 patients, indicate that young adults (ages 18–25 years) exhibit the highest incidence of DKA (approximately 5%), defined as one or more events in the preceding three months [25].

Hyperglycemic hyperosmolar state (HHS) predominantly occurs in older patients with T2D [20], although it is increasingly recognized as an emerging issue in children and young adults [26]. Mortality rates for DKA have been reported to be similar across European countries, but they remain above 10% in Indonesia and various sub-Saharan African nations [27,28]. HHS is most commonly associated with older T2D patients experiencing concurrent illnesses, such as infections, surgeries, or ischemic events, and is linked to a higher mortality rate than DKA.

The mortality rate for HHS is reported to be between 5% and 16%, approximately tenfold greater than that for DKA [20,21,29]. Notably, death in patients with DKA and HHS rarely stems from metabolic complications arising from hyperglycemia or metabolic acidosis; rather, it is often related to the underlying precipitating factors, the severity of dehydration, and advanced age [1,4,30].

The management of patients with DKA and HHS incurs significant mortality rates and healthcare costs. DKA represents the leading cause of mortality among children and young adults with T1D, accounting for around 50% of all fatalities in diabetic patients younger than 24 years [1]. In the United States, the overall inpatient mortality rate for DKA is less than 1% [1,2]; however, higher rates have been documented among elderly patients with life-threatening illnesses [1,2,31,32]. While similar mortality rates have been observed in European countries, those with limited acute care resources report mortality rates exceeding 10% [28]. A history of recurrent DKA episodes considerably elevates long-term mortality risk following discharge, particularly among young, socioeconomically disadvantaged adults with significantly high HbA1c levels [33]. In a retrospective analysis from the United Kingdom, the long-term mortality rate after a single DKA episode was 5.2% (with a follow-up of 4.1 years [range, 2.8–6.0]), compared to 23.4% in individuals with recurrent DKA admissions (2.4 years of follow-up [range, 2.0–3.8]; hazard ratio, 6.18) [33].

Inpatient mortality associated with HHS has been reported to range from 5% to 16%, a rate that is approximately tenfold higher than that of DKA [20,21,29]. The prognosis and outcomes for patients with HHS are influenced by factors such as the severity of dehydration, the presence of comorbidities, and advanced age. Additionally, individuals with a history of HHS face a significant risk of post-hospitalization mortality, particularly those with multiple episodes. A recent study indicated that, after adjusting for age, sex, selected comorbidities, and monthly income, the mortality hazard ratio was 2.8 for subjects with one hyperglycemic crisis episode and 4.5 for those with two or more episodes [34]. National statistics reveal a decline in deaths associated with hyperglycemic crises, with an absolute decrease of 529 deaths from 1990 to 2010 (2.7 fewer cases per 10,000; 95% CI, 2.4–3.0) [35]. The treatment of hyperglycemic crises imposes a substantial economic burden, with an estimated total annual hospital cost of $2.4 billion [1]. In the United States, DKA episodes are estimated to account for over $1 of every $4 spent on direct medical care for adult patients with T1D and $1 of every $2 for those experiencing multiple DKA episodes [36].

Precipitating Causes

DKA serves as the initial manifestation of diabetes in approximately 15% to 20% of adults and in roughly 30% to 40% of children with Type 1 Diabetes (T1D) [4, 37, 38]. While infection is recognized as the most prevalent trigger of DKA worldwide, inadequate adherence to insulin therapy emerges as the most frequent precipitating factor.

The incidence of diabetic ketoacidosis (DKA) among young individuals with Type 1 Diabetes (T1D) and within urban populations in the United States has been documented extensively [39–41]. A recent study conducted at a safety net hospital

in Atlanta indicated that insulin discontinuation was responsible for 56% of initial DKA cases and 78% of recurrent episodes [39]. Additional potential triggers for DKA encompass infections (14%) and non-infectious conditions (4%) [39], including acute myocardial infarction, cerebrovascular accidents, alcohol misuse, and pancreatitis [42]. Psychological risk factors, such as depression and eating disorders, have been identified in up to 20% of recurrent ketoacidosis cases in younger patients [39, 43, 44]. The malfunction of insulin pumps has historically been acknowledged as a contributing factor to DKA [45, 46], primarily due to the short-acting insulin formulations utilized in these devices; however, such occurrences are less prevalent with the advent of newer, advanced pump technologies [47, 48].

Urinary tract infections and pneumonia are frequently observed as precipitating factors for hyperglycemic hyperosmolar state (HHS) [46, 49], alongside acute cardiovascular incidents and other concurrent medical conditions [20, 50]. Poor adherence to prescribed medical regimens and new-onset diabetes are less commonly identified as precipitating causes of HHS compared to DKA [49]. Various medications that influence carbohydrate metabolism may trigger the onset of DKA and HHS, including glucocorticoids, beta-blockers, thiazide diuretics, certain chemotherapeutic agents [50, 51], and atypical antipsychotics [52–55]. A significant retrospective review from the United Kingdom revealed that hyperglycemic emergencies occurred at a frequency of 1 to 2 per 1,000 person-years following the initiation of antipsychotic therapy [56]. Among the antipsychotics, olanzapine and risperidone were associated with the highest risk [56].

Recently, sodium-glucose cotransporter 2 (SGLT-2) inhibitors—a novel category of oral antidiabetic agents that reduce plasma glucose levels by inhibiting the proximal tubular reabsorption of glucose in the kidneys—have been correlated with DKA in patients with T1D and Type 2 Diabetes (T2D) [57, 58]. A distinctive manifestation of DKA, termed “euglycemic DKA,” characterized by only mild to moderate increases in blood glucose, has been noted, often resulting in delayed recognition and treatment [57]. Aggregated data from randomized studies involving SGLT-2 inhibitors indicated a very low incidence of DKA in individuals with T2D (approximately 0.07%) [59, 60]; however, the risk of ketosis and DKA is heightened in patients with T1D. Approximately 10% of individuals with T1D receiving SGLT-2 inhibitors experience ketosis, with 5% necessitating hospitalization for DKA [57]. Proposed mechanisms for this phenomenon include elevated glucagon levels, a decrease in daily insulin requirements leading to reduced suppression of lipolysis and ketogenesis, and diminished urinary excretion of ketones [58, 61].

Pathophysiology

The two principal pathophysiological mechanisms underlying diabetic ketoacidosis (DKA) and hyperglycemic hyperosmolar state (HHS) are marked insulin deficiency and elevated levels of counterregulatory hormones, including glucagon, catecholamines, cortisol, and growth hormone (Fig. 1) [62–64]. In patients with Type 1 Diabetes (T1D), insulin deficiency is typically absolute, whereas in individuals with Type 2 Diabetes (T2D), it may be relative, particularly

in the context of stress or concurrent illness [65]. The combination of insulin deficiency and increased counterregulatory hormones results in heightened hepatic glucose production through enhanced gluconeogenesis and glycogenolysis [66], alongside diminished glucose utilization in peripheral tissues, especially in muscle [67]. Furthermore, insulinopenia activates hormone-sensitive lipase, promoting the breakdown of triglycerides into free fatty acids (FFAs) [68].

Within the liver, FFAs undergo oxidation to form ketone bodies, a process predominantly stimulated by glucagon [69, 70] and characterized by an elevated glucagon-to-insulin ratio [71]. This increased glucagon-to-insulin ratio decreases the activity of malonyl coenzyme A, an enzyme responsible for regulating the transport of FFAs into the hepatic mitochondria, where fatty acid oxidation occurs. The excessive production of ketone bodies, namely acetoacetate and β-hydroxybutyrate, two potent acids, results in decreased bicarbonate levels and the onset of metabolic acidosis.

Various mechanisms have been proposed to elucidate the absence or minimal presence of ketone bodies in patients with HHS, which include elevated circulating insulin levels, lower concentrations of counterregulatory hormones and FFAs, and the inhibition of lipolysis induced by the hyperosmolar state (see Fig. 1). Among these factors, the enhanced secretion of insulin appears to be the most critical mechanism for preventing ketosis in HHS as compared to patients with DKA [64]. This phenomenon arises from the fact that the antilipolytic effect of insulin is approximately one-tenth that of its role in glucose utilization.

Oxidative Stress and Inflammation

Numerous experimental and clinical investigations have demonstrated that the onset of hyperglycemia and ketoacidosis precipitates an inflammatory state, characterized by an elevation in pro-inflammatory cytokines and heightened markers of oxidative stress [72, 73]. Severe hyperglycemia induces macrophages to produce pro-inflammatory cytokines, including tumor necrosis factor-alpha, interleukin (IL)-6, IL-1β, and C-reactive protein, which collectively result in impaired insulin secretion and diminished insulin sensitivity [73–75]. Additionally, increased free fatty acids (FFAs) contribute to insulin resistance and hinder nitric oxide production in endothelial cells, leading to endothelial dysfunction [76]. The augmented inflammatory response, oxidative stress, and generation of reactive oxygen species can disrupt capillary function and cause cellular damage to lipids, membranes, proteins, and DNA [73, 77].

Diagnosis of Diabetic Ketoacidosis

Signs and Symptoms

Patients presenting with diabetic ketoacidosis (DKA) often exhibit a brief clinical history marked by fatigue and the classic symptoms of hyperglycemia: polyuria, polydipsia, and weight loss. Gastrointestinal disturbances are prevalent, with diffuse abdominal pain reported in 46% of patients and nausea and vomiting affecting up to two-thirds of individuals [42]. Approximately half of the patients display lethargy and stupor, while fewer than 25% experience loss of

consciousness [1]. Upon physical examination, signs of dehydration are common, including dry mucous membranes, poor skin turgor, tachycardia, and hypotension. Patients may also demonstrate Kussmaul respirations and a distinctive fruity (acetone) breath odor.

Laboratory Findings

The clinical syndrome of DKA is defined by the triad of hyperglycemia, ketonemia, and metabolic acidosis. The American Diabetes Association categorizes DKA into mild, moderate, or severe based on the degree of acidosis (indicated by bicarbonate levels) and alterations in sensorium [1]. Most individuals with DKA present with mild to moderate forms, exhibiting blood glucose levels exceeding 250 mg/dL, bicarbonate concentrations between 10 and 18 mEq/L, an arterial pH greater than 7.3, elevated ketone levels in urine or blood, and an increased anion gap metabolic acidosis of more than 12. The anion gap is computed using the formula: sodium [Na^+] – chloride [Cl^-] + bicarbonate [HCO_3^-]. While the majority of patients present with plasma glucose levels above 250 mg/dL, some may only demonstrate mild elevations in glucose, a condition termed "euglycemic DKA" [78]. This occurrence has been noted in pregnant individuals, patients undergoing prolonged starvation, those consuming alcohol, partially treated patients receiving insulin, and more recently, in conjunction with SGLT-2 inhibitor usage [57, 79, 80].

The critical diagnostic criterion for DKA is the elevation of total blood ketone levels coupled with high anion gap metabolic acidosis exceeding 12. Ketonemia can be assessed using the nitroprusside reaction in urine or serum, which offers a semi-quantitative estimate of acetoacetate and acetone concentrations. Although the nitroprusside test is highly sensitive, it may underestimate the severity of ketoacidosis, as it does not detect β-hydroxybutyrate, the primary metabolic product in ketoacidosis [67, 81]. Therefore, direct measurement of serum β-hydroxybutyrate is preferred for accurate diagnosis [82].

Diagnosis of Hyperglycemic Hyperosmolar State
Symptoms and Signs

Most patients with Hyperglycemic Hyperosmolar State (HHS) present with a history of polyuria, polydipsia, weakness, blurred vision, and a gradual decline in mental status [50, 83]. The typical patient is often over 60 years old, often with an underlying infection or acute illness, and has delayed seeking medical attention. On physical examination, similar to diabetic ketoacidosis (DKA), patients with HHS frequently exhibit clear signs of dehydration, such as dry mucous membranes, poor skin turgor, and hypotension [50].

Laboratory Findings

The diagnostic criteria for HHS include a plasma glucose level exceeding 600 mg/dL, effective osmolality greater than 320 mOsm/kg, and the absence of ketoacidosis [1]. Effective osmolality can be calculated using the formula:

Effective Osmolality=sodium (mEq/L)+1.6×glucose (mg/dL)18

Although HHS is defined by a pH greater than 7.3, bicarbonate levels exceeding 18 mEq/L, and negative ketone bodies, mild to moderate ketonemia may still be present. Patients with HHS may also exhibit an increased anion gap metabolic acidosis due to concomitant ketoacidosis, elevated serum lactate levels, or renal failure [21].

Common Laboratory Pitfalls

Patients with DKA often show significant leukocytosis, with white blood cell counts ranging from 10,000 to 15,000 mm^3. A leukocyte count exceeding 25,000 mm^3 or greater than 10% neutrophil bands is typically indicative of a bacterial infection [64, 84]. In ketoacidosis, leukocytosis is attributed to stress, dehydration, and the demargination of leukocytes. The admission serum sodium may be low due to the osmotic movement of water from the intracellular to the extracellular space in the context of hyperglycemia. To evaluate the severity of sodium and water deficit, serum sodium levels can be corrected by adding 1.6 mg/dL for each 100 mg/dL of glucose above 100 mg/dL [1]. An increase in serum sodium concentration amid severe hyperglycemia indicates significant dehydration and water loss.

The admission serum potassium concentration is typically elevated in patients with both DKA and HHS. Several studies have indicated that the mean serum potassium levels in these patients are approximately 5.6 mEq/L and 5.7 mEq/L, respectively [1, 39, 85]. These elevated levels occur due to the translocation of potassium from the intracellular to the extracellular space, driven by insulin deficiency and hypertonicity, along with acidosis in DKA [86]. It is crucial to note that during insulin treatment and fluid replacement, potassium levels may decrease due to a return of potassium to the intracellular space, potentially resulting in hypokalemia. Similarly, serum phosphate levels in patients with DKA do not accurately reflect the body's total deficit, as phosphate moves from the intracellular to the extracellular space due to insulin deficiency, hypertonicity, and a catabolic state. Dehydration can also elevate total serum protein, albumin, amylase, and creatinine phosphokinase levels in patients experiencing hyperglycemic crises.

Not all patients presenting with ketoacidosis have DKA. Individuals with chronic ethanol abuse may present with alcoholic ketoacidosis following a binge that leads to nausea, vomiting, and acute starvation. A key distinguishing feature between diabetic and alcohol-induced ketoacidosis is blood glucose concentration [87]. The presence of ketoacidosis without hyperglycemia in an alcoholic patient is virtually diagnostic of alcoholic ketoacidosis. Additionally, patients with significantly reduced caloric intake (less than 500 calories per day for several days) may present with starvation ketosis. Patients experiencing starvation ketosis typically do not present with serum bicarbonate concentrations lower than 18 mEq/L, as the slow onset of ketosis allows for increased ketone clearance by peripheral tissues (such as the brain and muscle) and enhances the kidney's ability to excrete ammonia, compensating for the increased acid production [88].

Management Of Hyperglycemic Crises:

The algorithm established by the American Diabetes Association for the management of hyperglycemic emergencies is illustrated in Fig. 2. Similar therapeutic strategies are suggested for addressing DKA and HHS. Generally, the objectives of treatment encompass the rectification of dehydration, hyperglycemia, hyperosmolality, electrolyte imbalances, and heightened ketonemia, along with the identification and management of precipitating factors. The average time for resolution is estimated to be between 10 and 18 hours for DKA [89,90] and approximately 9 to 11 hours for HHS [4]. Throughout the treatment process, it is essential to frequently monitor vital signs, fluid volume and administration rate, insulin dosage, and urine output to evaluate the effectiveness of medical intervention. Additionally, laboratory assessments of glucose and electrolytes, venous pH, bicarbonate levels, and the anion gap should be repeated every 2 to 4 hours [91].

Most patients with uncomplicated DKA can be effectively treated in the emergency department or in step-down units, provided that close nursing oversight and monitoring are available. Numerous studies have not shown significant advantages in treating DKA patients within the intensive care unit (ICU) compared to step-down units [92–94]. The mortality rates, length of hospital stay, or duration required to resolve ketoacidosis are comparable between patients treated in ICU and non-ICU environments. Furthermore, ICU admission has been linked to increased laboratory testing and higher hospitalization costs for patients with DKA [36,92]. Patients experiencing mild to moderate DKA can be safely managed in the emergency department or in step-down units, while only those with severe DKA or a critical illness as a precipitating factor (e.g., myocardial infarction, gastrointestinal bleeding, sepsis) [1,95] should receive treatment in the ICU. Due to the frequent presentation of altered mental status and significantly elevated mortality rates in patients with HHS compared to those with DKA, it is advisable that individuals with HHS be treated in the ICU.

Fluid therapy:

Intravenous (IV) fluids play a crucial role in managing hyperglycemic emergencies. Administering IV fluids alone helps to expand intravascular volume, restore renal perfusion, and mitigate insulin resistance by lowering circulating counterregulatory hormone levels [62]. Isotonic saline (0.9% NaCl) is the preferred fluid and is administered at an initial rate of 500 to 1000 mL/h during the first 2 to 4 hours. A study comparing two IV fluid regimens with sodium chloride and lactated Ringer’s found no significant difference in the duration to resolution of DKA; however, the time required to correct hyperglycemia was notably longer in the lactated Ringer's group [96]. After rectifying intravascular volume depletion, the infusion rate of normal saline should be reduced to 250 mL/h or adjusted to 0.45% saline (250–500 mL/h) depending on serum sodium concentration and hydration status [1]. Once the plasma glucose level approaches approximately 200 mg/dL (11.1 mosm/L), the replacement fluids should incorporate 5% to 10% dextrose to facilitate continued insulin administration until ketonemia is resolved while preventing hypoglycemia [97]. Adequate fluid resuscitation is particularly crucial in the management of HHS, as many patients may experience

improvements or resolution of mental status alterations following the correction of fluid deficits [83].

Potassium:

Metabolic acidosis and insulin deficiency both contribute to the extracellular movement of potassium. Therefore, while serum potassium levels may be normal or elevated in DKA, patients are actually depleted of total body potassium. Similarly, HHS is associated with a total body potassium deficit due to insufficient insulin and elevated plasma osmolality [20,86]. The total body potassium deficit is estimated to be approximately 3 to 5 mEq/kg [85,98]. Insulin therapy reduces serum potassium levels by facilitating the re-entry of potassium into the intracellular space. Consequently, potassium replacement should commence when the serum concentration drops below 5.2 mEq/L to maintain a level between 4 and 5 mEq/L. Administering 20 to 30 mEq of potassium per liter of fluids is adequate for most patients; however, lower doses are necessary for those with acute or chronic renal failure. In patients presenting with admission hypokalemia, defined as serum potassium levels below 3.3 mEq/L, insulin administration may lead to severe symptomatic hypokalemia, resulting in muscle weakness and a heightened risk of cardiac arrhythmias. For these individuals, potassium replacement should initiate at a rate of 10 to 20 mEq/h, with insulin therapy delayed until potassium levels exceed 3.3 mEq/L.

Bicarbonate:

The routine administration of bicarbonate has not been demonstrated to enhance clinical outcomes, including time to resolution, length of hospital stay, or mortality among patients with DKA [99–102]. It is generally recommended solely for patients with life-threatening acidosis, specifically those with a pH of less than 6.9. Bicarbonate therapy may elevate the risk of hypokalemia and cerebral edema [103,104]. Although no studies have assessed the impact of bicarbonate therapy in individuals with severe acidosis, clinical guidelines recommend administering 50 to 100 mmol of sodium bicarbonate as an isotonic solution (dissolved in 400 mL of water) until the pH exceeds 6.9. For patients with mild DKA and a pH greater than 7.0 or those with HHS, bicarbonate therapy is not warranted.

Insulin Regimens:

Insulin administration is the mainstay of DKA therapy because it lowers the serum glucose by inhibiting endogenous glucose production and increasing peripheral use. Insulin also inhibits lipolysis, ketogenesis, and glucagon secretion, thereby decreasing the production of ketoacidosis. A continuous IV infusion of regular insulin is the treatment of choice. Most treatment protocols recommend the administration of 0.1 U/kg body weight bolus followed by continuous insulin infusion at 0.1 U/kg per hour until blood glucose is approximately 200 mg/dL (see Fig. 2). At this point, the dose is reduced by one-half (0.05 U/kg per hour) and the rate is adjusted between 0.02 to 0.05 U/kg per hour, along with the addition of 5% dextrose, to maintain glucose concentrations between 140 and 200 mg/dL until resolution of ketoacidosis.

Several studies have demonstrated that the administration of subcutaneous doses of rapid insulin analogs (Lispro and Aspart) every 1 to 2 hours is an effective alternative to the IV infusion of regular insulin in terms of time to resolution of DKA. Patients are treated with an initial bolus of 0.2 to 0.3 U/kg followed by 0.1 to 0.2 U/kg every 1 to 2 hours, respectively, until glucose is less than 250 mg/dL. The dose is then reduced by one-half to 0.05 U/kg every 1 hour or 0.01 U/kg every 2 hours until the resolution of DKA. Using scheduled subcutaneous insulin allows for safe and effective treatment in the emergency room and stepdown units without the need for ICU care. The use of intramuscular injections of rapid-acting insulin is also effective in the treatment of DKA, but this route tends to be more painful than subcutaneous injection and might increase the risk of bleeding among patients receiving anticoagulation therapy. It is important to keep in mind that the use of rapid-acting subcutaneous insulin analogues is not recommended for patients with arterial hypotension, severe and complicated DKA, or with HHS.

Transition to Maintenance Insulin Regimen:

Resolution of DKA is defined when glucose levels are lower than 250 mg/dL, venous pH is greater than 7.30, there is a normal anion gap, and serum bicarbonate is 18 mEq/L or greater. HHS resolution is achieved when effective serum osmolality is less than 310 mOsm/kg and the glucose level is 250 mg/dL or less (13.8 mmol/L) in a patient who has recovered mental alertness and regained mental status. Because of the short half-life of intravenous insulin (<10 minutes), abrupt cessation of the insulin may result in rebound hyperglycemia, ketogenesis, and recurrent metabolic acidosis. Subcutaneous basal insulin (NPH, Glargine, Detemir, Degludec) should be given at least 2 hours before discontinuing the IV insulin infusion. Earlier initiation, 3 to 4 hours before discontinuation of the insulin drip, should be considered when using basal insulin analogues (Glargine, Determir, Degludec), which have a longer delay in onset of action than NPH insulin. One randomized controlled trial evaluated the effect of coadministration of IV insulin with subcutaneous Glargine shortly after the onset of treatment of DKA compared with IV insulin alone. Patients who received Glargine had a trend towards shorter time to resolution of DKA (based on closure of anion gap) and shorter duration of hospital stay; however, these differences were not statistically significant. Another study found that the administration of Glargine early in the course of treatment reduced the frequency of rebound hyperglycemia after transitioning off of the insulin drip.

For insulin-naïve patients, a starting total daily insulin dose of 0.5 to 0.6 U/kg may be started (one-half as basal and one-half as bolus). Patients with poor oral intake should receive basal insulin alone or, alternatively, may be continued on an insulin drip until they are able to eat. Patients with known diabetes can be restarted on their previous insulin regimens; however, an adjustment of the previous regimen should be considered if there is a history of frequent hypoglycemia, or significantly uncontrolled hyperglycemia before admission, as indicated by admission HbA1c. Multidose insulin regimens with basal insulin and prandial rapid-acting insulin analogues are the preferred insulin regimen for patients with T1D and DKA, and for most patients with HHS. A randomized, controlled trial in DKA patients compared transition regimens of NPH and regular

insulin twice daily versus Glargine once daily and Glulisine before meals found similar glycemic control between the two groups; however, the NPH/regular insulin group had more than double the rate of hypoglycemia (<70 mg/dL) compared with the Glargine/Glulisine group.

Role of Paramedics, EMS, Nursing, and Health Informatics:

In managing hyperglycemic crises such as Diabetic Ketoacidosis (DKA) and Hyperglycemic Hyperosmolar State (HHS), paramedics, nursing staff, emergency medical services (EMS), and health informatics play critical roles in ensuring effective patient care. Paramedics serve as the first responders to diabetic emergencies, often encountering patients in critical conditions. Their responsibilities include immediate stabilization, administering fluids and insulin, and monitoring vital signs en route to the hospital. Rapid recognition of symptoms like altered mental status, dehydration, or labored breathing (Kussmaul respirations) is vital. Paramedics also initiate glucose monitoring and may provide essential medications, working under protocols that allow them to start treatment before hospital admission.

Nursing staff in emergency departments and intensive care units are central to the ongoing management of DKA and HHS patients. They monitor fluid balance, blood glucose, and electrolytes, ensuring timely insulin administration and adjusting doses based on patient needs. Nurses also play a critical role in educating patients and their families about diabetes management, emphasizing adherence to medication regimens to prevent future episodes. Emergency Medical Services (EMS) systems provide the infrastructure and coordination necessary for an efficient response to diabetic crises. EMS dispatchers guide callers through immediate life-saving measures, while EMS personnel work closely with hospitals to ensure a smooth handover, relaying critical information that informs initial treatment decisions.

Health informatics enhances the overall management of diabetic emergencies by facilitating rapid access to patient records, lab results, and treatment protocols. Real-time data sharing between EMS teams, hospitals, and physicians allows for accurate, timely decisions, helping improve outcomes and reduce complications. Informatics systems also track patient outcomes, aiding in the development of evidence-based guidelines for managing hyperglycemic crises.

Conclusion

Diabetic ketoacidosis (DKA) and hyperglycemic hyperosmolar state (HHS) are critical medical conditions that require urgent attention due to their potential for severe morbidity and mortality. As outlined in this review, the rising incidence of DKA, particularly among young individuals with type 1 diabetes, underscores the need for increased awareness and proactive management strategies. The alarming statistics regarding hospitalization rates for DKA highlight the urgency of addressing this growing health concern. Similarly, HHS, predominantly affecting older adults with type 2 diabetes, presents its unique challenges and risks, particularly in the context of concurrent medical illnesses. The effective management of these hyperglycemic crises hinges on timely diagnosis and

intervention. The cornerstone of treatment involves comprehensive strategies that encompass vigorous rehydration, insulin administration, and electrolyte replenishment, tailored to each patient's needs. Furthermore, identifying and addressing underlying precipitating factors is essential in preventing recurrence, particularly among high-risk populations. Continued education for healthcare providers and patients alike is paramount in recognizing the early signs of these conditions, as prompt action can significantly mitigate risks. Moreover, further research is warranted to enhance our understanding of the long-term outcomes and economic burdens associated with DKA and HHS, guiding the development of evidence-based interventions and policies. In conclusion, the integration of awareness, education, and comprehensive management strategies will be vital in improving patient outcomes and reducing the incidence of these serious diabetic emergencies.

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إدارة حالات الطوارئ السكريّة: ارتفاع سكر الدم والحماض الكيتوني السكري - مقالة مراجعة للمسعفين، وخدمات الرعاية الحرجة والطارئة، والممرضين، والمعلومات الصحية.

الملخص:

الخلفية :يعتبر الحماض الكيتوني السكري (DKA) والحالة فرط الاسموزية السكرية (HHS) من أزمات فرط سكر الدم الحادة التي قد تحدث للأشخاص المصابين بالسكري. وعلى الرغم من أنه يتم التعامل معهما كحالتين منفصلتين، إلا أنهما تتواجدان على سلسلة متصلة من طوارئ فرط سكر الدم المرتبطة بعدم كفاية إدارة مرض السكري.

الهدف :تهدف هذه المراجعة إلى تقديم نظرة شاملة عن الحماض الكيتوني السكري والحالة فرط الاسموزية السكرية، مع استكشاف علم الأوبئة الخاص بهما، ومرضهما المَرضي، وأساليب التشخيص والإدارة. وتركز المراجعة على الدور الرئيسي للمسعفين، وخدمات الطوارئ الطبية، والتمريض، والمعلوماتية الصحية في إدارة الحماض الكيتوني السكري.

المنهجية :يجمع المقال بيانات من دراسات وبائية مختلفة، ومراجعات حالات سريرية، وسجلات تاريخية حول طوارئ السكري لتسليط الضوء على الخصائص السريرية وطرق العلاج الخاصة بالحماض الكيتوني السكري والحالة فرط الاسموزية السكرية.

النتائج :ارتفعت حالات الحماض الكيتوني السكري بشكل ملحوظ، مما أدى إلى أكثر من 140,000 حالة دخول إلى المستشفيات سنويًا في الولايات المتحدة. في حين أن الحماض الكيتوني السكري أكثر شيوعًا لدى الشباب المصابين بداء السكري من النوع الأول، تؤثر الحالة فرط الاسموزية السكرية بشكل رئيسي على المرضى الأكبر سنًا المصابين بداء السكري من النوع الثاني. يشترك كلا الحالتين في مبادئ علاجية أساسية، بما في ذلك تعويض السوائل، والعلاج بالأنسولين، واستبدال الإلكتروليتات، حيث يُعد التدخل في الوقت المناسب ضروريًا لتحسين النتائج.

الخلاصة :يمثل كل من الحماض الكيتوني السكري والحالة فرط الاسموزية السكرية حالات طبية خطيرة تتطلب تشخيصًا وإدارة سريعين. يعد فهم علم الأوبئة ومرض هذه الحالات أمرًا حيويًا لمقدمي الرعاية الصحية لتحسين جودة الرعاية وتقليل الوفيات. يمكن أن يؤدي الإدارة الفعالة إلى تحسين نتائج المرضى بشكل كبير، خاصة بالنسبة لأولئك الذين يعانون من أزمات فرط سكر الدم المتكررة.

الكلمات المفتاحية :الحماض الكيتوني السكري، الحالة فرط الاسموزية السكرية، إدارة السكري، علم الأوبئة، العلاج بالأنسولين.