JPPT | Retrospective Chart Review

Potassium-Containing Fluids for Diabetic Ketoacidosis

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OBJECTIVE The purpose of this process improvement project was to determine the appropriate potassium concentration of stocked IV fluids used in the treatment of diabetic ketoacidosis (DKA) at the Children's Hospital of The King's Daughters (CHKD) Emergency Department.

METHODS This is a retrospective chart review from July 1, 2018, through June 30, 2019. Patients ≤21 years of age with laboratory-confirmed DKA were included. The primary outcome was to determine the most used potassium concentration (20 mEq/L or 40 mEq/L) for stocked IV fluids. Secondary efficacy and safety outcomes included the percent of appropriately ordered fluids per the DKA treatment protocol, percent of patients who maintained goal serum potassium concentration, comparison of time from physician ordering to administration of prescribed IV fluids (t-elapsed), and comparison of serum potassium concentrations between the point of care (POC) test and basic metabolic panel (BMP).

RESULTS Of the 113 patients included, 73 (64.6%) received 40 mEq/L, 7 of whom received half potassium acetate plus half potassium phosphate, and 40 (35.4%) received 20 mEq/L potassium IV fluids. In 101 patients (89.4%), fluids were ordered appropriately per protocol. Of these patients, 53 (52.5%) maintained goal serum potassium concentration. The t-elapsed from physician ordering to administration of the prescribed fluid concentrations was not statistically significant. The mean POC versus BMP potassium concentration was statistically significant (4.56 mmol/L versus 4.96 mmol/L, respectively; 95% CI: −0.49 to −0.30; $p < 0.001$).

CONCLUSIONS The CHKD pharmacy should stock the most used 40 mEq/L potassium IV fluids for DKA treatment.

ABBREVIATIONS ADA, American Diabetes Association; BMP, basic metabolic panel; CHKD, Children's Hospital of The King's Daughters; DKA, diabetic ketoacidosis; ED, Emergency Department; ISPAD, International Society for Pediatric and Adolescent Diabetes; IV, intravenous; KAc, potassium acetate; KPhos, potassium phosphate; PICU, pediatric intensive care unit; POC, point of care; t-elapsed, time from physician ordering to administration of prescribed IV fluids

KEYWORDS diabetic ketoacidosis; emergency department, hospital; pediatric; potassium compounds

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Introduction

The diagnosis of diabetic ketoacidosis (DKA) includes hyperglycemia of >200 mg/dL, venous pH of <7.3 or serum bicarbonate of <15 mmol/L, and the presence of ketones in the blood, as indicated by moderate to large ketonuria.[1,2] Both the International Society for Pediatric and Adolescent Diabetes (ISPAD) and the American Diabetes Association (ADA) recommend fluid and electrolyte replacement in addition to insulin therapy.[1,2] This is because of severe fluid and electrolyte losses from dehydration and deficits in sodium, potassium, chloride, calcium, and phosphate.[1,2] The ISPAD and ADA guidance statements include specific recommendations for potassium replacement because of total body deficits ranging from 3 to 6 mEq/kg.[1,2] During DKA, potassium is lost from the intracellular pool because of hypertonicity and is then removed from the body through emesis and osmotic diuresis.[1] Additionally, potassium is lost through urinary excretion due to secondary hyperaldosteronism from volume depletion.[1] After completion of an initial IV fluid bolus, and once insulin is administered and acidosis is corrected, potassium will shift intracellularly, causing even greater hypokalemia. Because this phenomenon, potassium replacement is recommended by the ISPAD and ADA to include administration of fluids with a concentration of 40 mEq/L potassium.[1,2] After initiation of insulin therapy and potassium-containing IV fluids, serum potassium concentrations should be monitored and replaced based on serum potassium concentrations.[1,2]

After initial fluid expansion with a 0.9% sodium chloride fluid bolus, a 2-bag IV fluid system is used in the ED per the DKA treatment protocol (Table 1) at the Children's Hospital of The King's Daughters (CHKD). The first bag of the 2-bag system consists of 0.9% sodium chloride with potassium supplementation, and the second bag consists of dextrose 10% and 0.9% sodium chloride with

Table 1. CHKD Emergency Department Diabetic Ketoacidosis Treatment Protocol for 2-Bag System

Serum Potassium and Phosphorous at Presentation	First Bag	Second Bag
Potassium >5 and normal PO4	NS + 20 mEq KAc/L	D10NS + 20 mEq KAc/L
Potassium ≤5 and normal PO4	NS + 40 mEq KAc/L	D10NS + 40 mEq KAc/L
Potassium >5 and PO4 ≤3.0; change to phosphate-containing fluids	NS + 20 mEq KPhos/L	D10NS + 20 mEq KPhos/L
Potassium ≤5 and PO4 ≤3.0; change to phosphate-containing fluids	NS + 20 mEq KPhos/L + 20 mEq KAc/L	D10NS + 20 mEq KPhos/L + 20 mEq KAc/L

CHKD, Children's Hospital of The King's Daughters; D10, dextrose 10%; KAc, potassium acetate; KPhos, potassium phosphate; NS, 0.9% sodium chloride; PO4, phosphorous test

Table 2. Baseline Characteristics

Category	Population (N = 113)
Age, mean (range), yr	12 (0.67–20)
Sex, n (%)	
Female	62 (55)
Male	51 (45)
Race, n (%)	
African American	69 (61)
White	42 (37)
Asian	1 (1)
Native American	1 (1)
Diabetes Status, n (%)	
New onset	38 (34)
Previously diagnosed	75 (66)

potassium supplementation. The total concentration of potassium is either 20 mEq/L or 40 mEq/L, with two potassium salt options, potassium acetate (KAc) or potassium phosphate (KPhos). Unless a serum phosphorous concentration is available, patients at CHKD are first initiated on IV fluids containing KAc. The potassium salt added to the IV fluids is driven by protocol and may change based on serum potassium and phosphorous concentrations.

Our current practice at CHKD is to stock pre-made IV fluids containing 20 mEq/L KAc. These fluids are stored in the main pharmacy refrigerator in preparation for use in the ED. The fluids are given a beyond-use date of 9 days in accordance with USP <797>[3] and are compounded during the overnight shift.

Patients who present with a serum potassium concentration of <5 mEq/L should receive IV fluids containing 40 mEq/L potassium, according to the DKA treatment protocol. It is important to note potassium is ordered in mEq of potassium given from KPhos, not mmol of phosphate (conversion factor of 4.4 mEq potassium and 3 mmol phosphate per mL). This need causes the pharmacy to compound patient-specific 40 mEq/L potassium IV fluids, possibly interrupting typical workflow and extending the time from ordering to administration of the fluids.

According to the DKA treatment protocol, initial serum potassium concentration is determined upon presentation to the ED using a point of care (POC) handheld blood analyzer (iSTAT, Princeton, NJ) and a basic metabolic panel (BMP). Because the POC potassium concentration test produces results more quickly than does the BMP, initial IV fluid orders are typically driven by the POC test. Unfortunately, the resulting potassium concentrations from the POC and BMP may differ, causing the incorrect IV fluid to be administered per the protocol.

This process improvement project was performed to determine the most used potassium concentration (20 mEq/L or 40 mEq/L) for stocked IV fluids in order to expedite use in patients who present to the ED with DKA. Outcomes of this project could change the practice model at CHKD and at other institutions by streamlining DKA patient care and treatment when the most used IV fluids are readily available.

Materials and Methods

Study Design. This observational, retrospective chart review, process improvement project included pediatric patients who presented to the CHKD ED with laboratory-confirmed DKA from July 1, 2018, through June 30, 2019. The primary outcome was to determine the most used potassium concentration (20 mEq/L or 40 mEq/L) for stocked IV fluids. The secondary efficacy and safety outcomes included the following: percent of appropriately chosen fluids, in accordance with the DKA treatment protocol, based on presenting serum potassium concentration; the percent of patients who maintained goal serum potassium concentration (3.5–5 mEq/L) to assess risk for hyperkalemia; comparison of time from physician ordering to administration of prescribed IV fluids (t-elapsed) between fluid concentrations to assess efficiency of workflow; and comparison of serum potassium concentrations between the POC and BMP to guide selection of initial IV fluid potassium concentration.

Population. Patients were included if they were ≤21 years of age, because CHKD policy allows ED admission up to age 21, and if they had laboratory-defined DKA (glucose >200 mg/dL, pH <7.3 or bicarbonate <15

Table 3. Potassium IV Fluids Ordered and Time from Physician Ordering to Administration

Potassium Concentration of IV Fluids	Patients, n (%)	Time from Ordering to Administration, mean (range), min
20 mEq/L KAc	40 (35.4)	47.8 (8–114)*
40 mEq/L K	73 (64.6)	
40 mEq/L KAc	66 (58.4)	51.4 (3–103)
20 mEq/L KAc + 20 mEq/L KPhos	7 (6.2)	35.6 (12–59)
p value		0.20

K, potassium; KAc, potassium acetate; KPhos, potassium phosphate

* One outlier was excluded from the analysis.

Table 4. Post-Fluid Initiation Basic Metabolic Panel Serum Potassium Concentration

Serum Potassium Concentration Post-Fluid Initiation, mmol/L	Potassium Concentration of IV Fluids, mEq/L	Patients, n	Patients Within Potassium Limits, n (%)
<3.5	20	0	11 (10.9)
	40	11	
3.5–5.0	20	13	53 (52.5)
	40	40	
>5.0	20	21	37 (36.6)
	40	16	

mmol/L, and presence of ketones). Patients were excluded for the following reasons: if located in any unit outside of the ED; if they had a past medical history of cystic fibrosis; or if their medical record had any missing documentation necessary for statistical analysis, including presenting serum potassium concentration prior to initiation of fluids, the concentration of potassium used in the IV fluids, and documentation of laboratory values for the diagnosis of DKA.

Data Collection. Information collected included patient demographics; diabetes status as "new onset" or "previously diagnosed"; initial IV fluids ordered and their appropriateness, based on presenting serum potassium concentration, in accordance with the DKA treatment protocol; serum potassium, glucose, and bicarbonate concentrations from both the POC and BMP; presence of ketones in the urine; and the time fluids were ordered, verified, and administered.

Statistical Analysis. Outcomes with continuous variables were analyzed as means with SD. Outcomes as categorical variables were analyzed as frequency and percentage. The distribution of t-elapsed was compared between the IV fluid potassium concentration groups (20 mEq/L versus 40 mEq/L) using the *t*-test, excluding outliers, and the Mann-Whitney *U*-test, including outliers. Comparison between the POC and BMP serum potassium concentrations was assessed using the paired *t*-test, excluding outliers, and the Wilcoxon Rank Sum test, including outliers. All statistical tests were performed using SPSS version 26.0 (Chicago, IL). Statistical tests were 2-sided, and $p < 0.05$ was considered statistically significant.

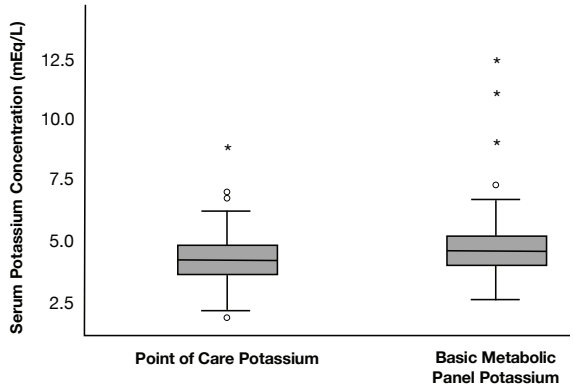
Results

This process improvement project included 113 patients. For baseline characteristics, the average patient age was 12 years, and the majority of patients were female, African American, and previously diagnosed with diabetes (Table 2).

The primary outcome demonstrated that the majority of IV fluids ordered contained 40 mEq/L potassium. More specifically, 73 patients (64.6%) received 40 mEq/L, of which 7 received 20 mEq/L KAc plus 20 mEq/L KPhos (6.2%), and 40 patients (35.4%) received 20 mEq/L potassium IV fluids (Table 3). In 101 patients (89.4%), potassium IV fluids were ordered appropriately, following protocol recommendations, based on serum potassium concentration at presentation. Of these 101 patients, 53 (52.5%) maintained goal serum potassium concentrations (3.5–5 mEq/L) after initiation of potassium IV fluids. Furthermore, 40 patients who received 40 mEq/L potassium IV fluids maintained goal serum potassium concentrations (Table 4).

The t-elapsed did not show a statistically significant difference between the stocked 20 mEq/L KAc fluids (47.8 minutes) compared with the patient-specific 40 mEq/L KAc fluids (51.4 minutes) and the 20 mEq/L KAc plus 20 mEq/L KPhos fluids (35.6 minutes) ($p = 0.20$)

Figure. Pre-fluid initiation point of care versus basic metabolic panel serum potassium concentrations.



* extreme outlier; ○, mild outlier

(Table 3). One outlier of 172 minutes from the 20 mEq/L KAc fluid group was removed from the analysis without affecting the result. The need to make patient-specific IV fluids did not extend the time to administration.

The mean POC serum potassium concentration of 4.56 mEq/L, compared with the mean BMP serum potassium concentration of 4.96 mEq/L, showed a statistically significant difference (mean ± SD difference = −0.39 ± 0.49 mEq/L; 95% CI: −0.49 to −0.30; $p < 0.001$) (Figure). The outliers were removed from the analysis without affecting the result.

Discussion

The outcomes from this process improvement project indicate the CHKD pharmacy should stock 40 mEq/L potassium IV fluids based on current usage rates. This aligns with the recommendations of the ISPAD and ADA DKA treatment guidelines because they recommend initial IV fluids contain 40 mEq/L potassium for replacement.[1,2] The majority of initial potassium IV fluids were ordered appropriately in accordance with the DKA treatment protocol, based on presenting serum potassium concentrations. Additionally, the majority of serum potassium concentrations after administration of the appropriate potassium IV fluids per protocol remained within goal (3.5–5 mEq/L). It is important to note that our goal potassium per protocol is stricter than the typical potassium goal (3.5–5.5. mEq/L). Therefore, this outcome showed minimal risk for hyperkalemia.

There was no statistically significant difference in the t-elapsed between the two potassium IV fluid concentrations. The need to make patient-specific IV fluids did not extend the time to administration compared with the stocked IV fluids. Some possible confounding factors to this outcome include the time for patients to obtain functioning IV access and the time to complete the initial 0.9% sodium chloride fluid bolus before starting the 2-bag IV fluid system. Additionally, a possible factor could include the need to change the original potassium concentration ordered to align with the DKA treatment protocol when POC and BMP serum potassium concentrations have conflicting results. For example, fluids are ordered based on the POC, and while the 0.9% sodium chloride fluid bolus is administered, the BMP results with a different potassium concentration, causing the need to change the fluids to align with the DKA treatment protocol. Despite there being no statistically significant difference in the t-elapsed, there is clinical importance to stocking the more used 40 mEq/L potassium IV fluids. This includes the decreased request for patient-specific IV fluids to be compounded by pharmacy, limiting technician and pharmacist disruption to normal workflow, and less waste of stocked IV fluids.

The POC versus BMP serum potassium concentrations showed a statically significant difference. Despite achieving this outcome, there are limitations to this result, and it is not considered clinically significant. The most important limitation for this outcome was the level of hemolysis. This key information was not recorded during data collection and could not be accounted for during statistical analysis. Therefore, using this result should be considered with caution when determining which potassium concentration of IV fluids to initiate if serum potassium concentrations from the POC are close to 5 mEq/L. Furthermore, statistical analysis was not performed in such a way that we were able to determine the number of mismatched potassium concentrations between the POC and BMP methods and their effect on the need to change the potassium concentration of the IV fluid ordered. There are additional limitations to this process improvement project. These include its smaller sample size, retrospective nature, and the short evaluation period.

After evaluation of this process improvement project, multiple future directions for research are suggested. One is an analysis of the effect that hemolysis has on the POC and BMP serum potassium concentrations and another is an analysis of how many fluid orders were changed when a mismatched POC and BMP serum potassium concentration occurred. Both of these analyses factor into the ordering of fluids and could help streamline which fluids to order when a patient presents with a potassium concentration near 5 mEq/L. Additionally, it would be interesting to follow these patients into the PICU to determine if the work done in the ED is offset by a change of fluids upon admission to the PICU when new laboratory values are available.

Conclusion

In conclusion, the CHKD pharmacy should change their practice for DKA treatment by stocking the most used 40 mEq/L potassium IV fluids. When adhering to the DKA treatment protocol, use of the 40 mEq/L potassium IV fluids did not show increased risk for hyperkalemia because the majority of patients maintained goal serum

potassium concentrations. Additionally, this change limits both the interruption to pharmacy workflow and waste of stocked IV fluid bags.

Article Information

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