



ORIGINAL ARTICLE

# Use of a Computer-Based Insulin Infusion Algorithm to Treat Diabetic Ketoacidosis in the Emergency Department

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## Abstract

**Background:** Efforts at improving quality metrics in diabetes focus on minimizing adverse events and avoiding re-admissions to the hospital. Our experience with Glucommander™ (Glytec, Greenville, SC), a cloud-based insulin management software system, suggested that its use in the emergency department (ED) would be useful in treating patients with mild diabetic ketoacidosis (DKA).

**Materials and Methods:** Thirty-five patients seen in the ED with hyperglycemic crises and diagnosed with DKA during one calendar year were reviewed. A retrospective chart review was performed on patients who were placed on Glucommander™ for DKA management. We excluded patients with significant acidosis or concomitant medical illnesses.

**Results:** Initial average capillary glucose level was  $487 \pm 68$  mg/dL, average time to target glucose was 5 h 11 min, and rate of hypoglycemia (blood glucose level  $<70$  mg/dL) was less than 0.3%. Sixteen patients treated with the protocol were discharged from the ED directly, and 19 were admitted. Patients were maintained for an average of  $14 \pm 1$  h on the Glucommander™ protocol. There was a significantly higher anion gap ( $P=0.002$ ) and lower serum bicarbonate level ( $P=0.006$ ) in the admitted group. We found very low evidence of re-admission (6%) within 30 days of discharge from the ED for DKA patients. No significant glucose-related adverse events were noted.

**Conclusions:** Use of Glucommander™ for guiding the insulin treatment of mild DKA in the ED can decrease admissions to the hospital for DKA by 45%. Low rates of hypoglycemia make this an option to improve efficiency of utilization of inpatient hospital beds. The cost savings for nonadmissions were estimated at \$78,000 over the 12 months of the study. Our results suggest that Glucommander™ is a safe and efficient tool for use in the ED to manage mild to moderate DKA.

## Introduction

THE CENTERS FOR DISEASE CONTROL and Prevention estimated that in 2011, about 175,000 emergency department (ED) visits for people of all ages had a hyperglycemic crisis, specifically diabetic ketoacidosis (DKA) and hyperglycemic hyperosmolar state, as the first-listed diagnosis.<sup>1</sup> Furthermore, there has been an increase in the number of hospital discharges with DKA as the first-listed diagnosis: from about 80,000 discharges in 1988 to about 140,000 in 2009.<sup>2</sup>

The cost of treatment of this condition is staggering,<sup>3</sup> and the direct and indirect annual cost of DKA hospitalizations is 2.4 billion U.S. dollars in 2009.<sup>4</sup> The management of DKA usually involves correction of the metabolic derangements and volume repletion, as well as identification and treatment of the precipitating cause at the initial outset, followed by preventative recommendations and consolidation of a long-term treatment plan.

Selected patients with mild DKA who are able to manage their condition well and taking fluids orally may be treated

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under observation and sent home without admission.<sup>4</sup> The American Diabetes Association guidelines for hospital admission indicate that it may be appropriate to admit a patient whose plasma glucose concentration is greater than 250 mg/dL (13.9 mmol/L) with an arterial pH level below 7.30, a serum bicarbonate level of less than 15 mEq/L, and a moderate or greater level of ketones in the serum or urine.<sup>5</sup> Although hospitals and healthcare systems are continually moving toward making health care more streamlined, affordable, and efficient while preventing re-admissions, it is necessary to have tools to help institutions capably manage, triage, and channel patients in and out of the ED. Although there are limited studies indicating that mild DKA can be treated with subcutaneous insulin injections,<sup>6,7</sup> it is generally well accepted that intravenous insulin (IV) infusions are the safer and more effective strategy for the treatment of DKA.

Glucommander™ (Glytec, Greenville, SC) is a cloud-based, integrated glycemic management system used to calculate individualized insulin dosing recommendations. After selecting initial glucose target ranges and starting a patient, Glucommander™ recommends an insulin infusion rate and a time to check the next blood glucose level. It calculates new insulin dose adjustment recommendations each hour based on bedside glucose measurements until the patient reaches the target range and will then recommend blood glucose checks every 2 h. Changes in blood glucose, response to insulin, and glucose velocity, as well as other inputs, allow the product to continuously follow and measure a patient's individualized insulin sensitivity, which can then be used to calculate precise dosing of subcutaneous insulin when the patient is ready to transition from IV administration.

## Materials and Methods

This is a retrospective chart review of patients presenting to the ED with a diagnosis of DKA. The protocol as a component of a system-based quality improvement project was reviewed by the Institutional Review Board. All patients were treated at a single site, a community hospital with approximately 300 beds serving southeastern Virginia. We report our experience with 35 patients with DKA who were seen and managed in the ED. This study was conducted from January 2012 to December 31, 2012.

For the purpose of this study, we defined DKA as any type 1 diabetes patient who presented to the ED with signs and symptoms of DKA with hyperglycemia above 200 mg/dL, acidosis of  $\leq 20$  mmol/L, an anion gap of  $>14$ , and positive urine ketones. The severity of DKA was determined by the level of bicarbonate: mild and moderate DKA patients were those who had serum bicarbonate above 10 mmol/L, and severe DKA was defined as those who had a serum bicarbonate level of less than 10 mmol/L.

All patients were treated with standard of care therapy for DKA treatment, including fluids resuscitation and replacement of electrolytes. Attempts were made to identify sources of DKA such as infections, and insulin was administered to all patients via the IV route using the Glucommander™ computer-based system, using a physician-selected glucose target range and a weight-based multiplier. Almost all patients received diabetes education and diabetes-related handouts from a certified diabetes educator in the ED.

All the blood sugars are measured by point-of-care testing with OneTouch® SureStep Flexx® glucose meters (LifeScan, Milpitas, CA) using finger-stick blood sampling.

There was no control arm in this project. All subjects were treated with the Glucommander™. A conventional insulin protocol was not used because hospital policy had transitioned all standard paper protocols to use of Glucommander™ for IV insulin delivery.

Episodes of hypoglycemia are recognized within 30 min. Based on the Glucommander™ algorithm, insulin is held for 30 min and until the glucose level is  $>60$  mg/dL. Previously published reports<sup>8</sup> have validated the efficacy of the correction of hypoglycemia by the Glucommander™. A protocol for treating hypoglycemia has been incorporated into the Glucommander™ since 1995 using IV dextrose based on a formula in the program for correction of hypoglycemia with 50% glucose levels =  $(100 - \text{blood glucose}) \times 0.2$  g.<sup>8</sup>

## Results

Forty patients with presented with hyperglycemic crisis, with chart-confirmed DKA in 35 patients. Of these 35 patients, 16 patients were discharged home, and 19 were admitted to the acute care floor of the hospital. The baseline demographics as indicated in Table 1 are separated into patients who were admitted versus patients who were discharged from the ED. There was a significant difference in the anion gap ( $P=0.002$ ) and in the serum bicarbonate level ( $P=0.006$ ) between the groups, suggesting that patients with a higher anion gap and lower bicarbonate levels were more likely to be transitioned to acute care for inpatient admission. There was no statistical significant difference in blood glucose concentrations between the admitted group versus the discharged group.

Data gathered from the Glucommander™ software are shown in Table 2. The mean capillary blood glucose as measured by point-of-care testing on admission to the ED was  $487 \pm 68$  mg/dL. Patients reached target blood sugar as

TABLE 1. BASELINE CHARACTERISTICS OF PATIENTS WHO WERE EITHER ADMITTED OR DISCHARGED AFTER INITIAL TREATMENT IN THE EMERGENCY DEPARTMENT

	Admitted patients	Discharged patients
Age (years)	30.3 $\pm$ 2.0	33.7 $\pm$ 1.9
Sex (male/female)	11/8	10/6
Race		
African American	6	2
White	13	14
Height (inches)	65.7 $\pm$ 0.7	65.7 $\pm$ 1.3
Weight (pounds)	135.6 $\pm$ 6	141.9 $\pm$ 7
BMI (kg/m <sup>2</sup> )	20.8 $\pm$ 0.7	22.1 $\pm$ 0.7
Anion gap	23.2 $\pm$ 1.7	17.9 $\pm$ 0.8 <sup>a</sup>
Bicarbonate (mmol/L)	13.5 $\pm$ 1.1	17.9 $\pm$ 0.7 <sup>b</sup>
BUN (mg/dL)	20.6 $\pm$ 1.9	18.5 $\pm$ 1.5
Creatinine (mg/dL)	0.9 $\pm$ 0.1	1.0 $\pm$ 0.1
Venous blood glucose (mg/dL)	546.4 $\pm$ 44.6	573.5 $\pm$ 36.8

Data are mean  $\pm$  SE values. Statistical significance was tested by Student's *t* test. A significant difference was defined by  $P < 0.05$ .

<sup>a</sup> $P=0.002$ , <sup>b</sup> $P=0.006$ .

BMI, body mass index; BUN, blood urea nitrogen.

TABLE 2. INTRAVENOUS INSULIN THERAPY IN THE EMERGENCY DEPARTMENT OVER A 12-MONTH PERIOD ADMINISTERED TO PATIENTS WITH MILD TO MODERATE DIABETIC KETOACIDOSIS

Measurement	Value
Total number of patients	35
Average Initial BG (mg/dL)	487 ± 34
Average BG (mg/dL)	145
Average time to target	5 h 11 min
Average time on Glucommander™	14 h
Hypoglycemia	
<70 mg/dL	0.3% (18 BGs)
<40 mg/dL	0.0% (0 BGs)
Hyperglycemia >250 mg/dL post-D-50 administration for correction of hypoglycemia	0.0% (0 BGs)
Total number of BG measurements	490

Data were gathered from the Glucommander™ software pertaining to insulin infusion.

BG, blood glucose; D-50, 50% dextrose solution.

set by the admitting ED provider in 5 h 11 min (mean sugar level of 284.1 ± 38 mg/dL), with a mean of 145 ± 18 mg/dL at the time of discharge home. Once in target there were no glucose events above 250 mg/dL. There were no episodes of hypoglycemia less than 40 mg/dL and 18 events (0.3%) less than 70 mg/dL. During the total stay in the ED, patients used a total of 19.7 ± 4 units of insulin and were maintained on the Glucommander™-driven IV insulin protocol for 14 ± 1 h before being discontinued off Glucommander™ or transferred out of the ED.

Of the 35 patients, three patients were immediately admitted because of their overall medical condition. One of the three patients was transferred to another hospital and admitted for inpatient management of DKA. Only one patient who was treated and released from the ED using Glucommander™ was re-admitted in a 30-day interval. The 30-day hospital re-admission rates for DKA are variable, but one study indicated that the diabetes-related re-admission rate is as high as 33%.<sup>9</sup>

## Discussion

Computer-based insulin infusion algorithms have been shown to be safe in preventing hypoglycemia while achieving normoglycemia in a robust and effective way.<sup>8</sup> In particular, Glucommander™ has been well utilized in the inpatient setting, particularly in the intensive care units. Few studies have examined its efficacy in the ED setting. Furthermore, this software is a nurse-directed protocol, giving nursing staff a clear and unequivocal means of obtaining drip rates, correction of hypoglycemia, and frequency of testing.

Our study indicates that the use of Glucommander™ is safe and effective in treating mild DKA without requiring an inpatient admission. During the time interval reviewed only one patient who was treated and released from the ED using Glucommander™ was re-admitted in a 30-day interval. Analysis of this one case indicated that for this patient there was no resolution of acidosis before discharge; the rest of the patients who were discharged had resolution of acidosis before discharge. Furthermore, this patient was being treated by means

of an insulin pump, and interval pump malfunction could be excluded as a cause for re-admission.

The average time for blood sugar “normalization” (blood glucose level of less than 180 mg/dL) was around 5 h. This indicates the use of Glucommander™ aided in stratifying patients with DKA who were sicker and therefore unable to be weaned off the IV insulin drip. If blood glucose has not improved within 5 h, one should consider the patient for admission. This could potentially help EDs with a high patient volume to effectively determine those patients who might require hospital admission versus those that can be maintained under observation status or those who can be discharged home. There was no hypoglycemia demonstrated in any of these patients.

Using a cost-to-treat analysis provided the statistic that it cost Sentara Healthcare \$6,000 per DKA admission so there was a cost savings of \$78,000 for the nonadmissions of 16 patients. Inpatient costs for DKA admission tend to vary variable, and DKA hospitalizations make up a significant portion of healthcare costs for diabetes.<sup>10</sup> Data from the 1990s indicate that the mean cost per hospitalization was \$10,876 ± 11,024.<sup>3</sup> Our study did not have a control comparison of the standard protocol for insulin infusion. All patients seen at the ED with DKA are provided diabetes education, and as such we are unable to ascertain the benefit that this played in prevention of re-admission. There are costs for diabetes education and for the licensing of Glucommander™ software, which were not taken into account for calculation of cost savings.

In conclusion, Glucommander™ management of insulin infusion in treatment of DKA in the ED setting was safe and effective at resolving the metabolic abnormalities in an efficient manner. Analysis of our data presents a novel mechanism to stratify patients requiring hospital admission versus home disposition. Results from our experience suggest that use of a computer-based insulin infusion algorithm in the ED can decrease admissions to the hospital for DKA by approximately 45%. The rate of re-admission of mild DKA patients was minimal, supporting the effectiveness and appropriateness of ED management of mild DKA. Prospective studies are required to demonstrate the safety and efficacy of computer-based insulin titration in hyperglycemic crises in the ED setting.

## Author Disclosure Statement

R.M. is an employee of Glytec, the manufacturer of Glucommander™ software. J.U., M.B., and J.A. declare no competing financial interests exist.

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