A quality improvement initiative to successfully reduce the frequency of hypoglycemia during treatment of hyperglycemic crises at an academic safety-net hospital: Insights and results

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ABSTRACT

Background: Diabetic ketoacidosis (DKA) and hyperosmolar hyperglycemic state (HHS) are potentially life-threatening complications of diabetes. Many hospitals have developed protocols to guide the management of these conditions and align with best practices. One of the main complications encountered in the treatment of hyperglycemic crises is hypoglycemia.

Methods: At our institution, we undertook a review of our insulin infusion titration protocol, rates of hypoglycemia, and time to clinical resolution for patients with hyperglycemic crises. A multidisciplinary team performed a literature review and analyzed baseline hospital data with the existing protocol. With the input of multiple stakeholders, several changes were made to the titration algorithm over multiple PDSA cycles to refine the protocol. Effectiveness and safety of the protocol, as well as fidelity with the protocol, were assessed after each PDSA cycle.

Results: After the initial cycle, chart review showed a reduction in hypoglycemia rates of more than 50% in patients treated with the new protocol without any increase in time to resolution of DKA. A second version of the protocol was implemented to improve usability, and improvement in hypoglycemia was maintained.

Conclusion: Despite the fact that the initial protocol had been developed based on best practice recommendations, rates of hypoglycemia were initially high. Critical assessment of pitfalls in management allowed changes to the protocol that significantly and sustainably reduced hypoglycemia.

Introduction

Diabetic ketoacidosis (DKA) and hyperosmolar hyperglycemic state (HHS) are potentially life-threatening complications of diabetes. Patients with DKA present with hyperglycemia, ketosis, and metabolic acidosis. Those with HHS have marked hyperglycemia and a hyperosmolar state. It is possible for patients to present with features of both syndromes [1]. Together, these conditions are classified as hyperglycemic crises. While hospitalizations for DKA had previously been in decline, the number of cases in the United States increased by more than 50% from 2009 to 2014 [2]. With approximately 30 million people in the US estimated to have diabetes, and the number increasing annually, hospitals should ensure that they have protocols in place to encourage best practices and safe patient care [2–3].

The principles of treatment for hyperglycemic crises include fluid resuscitation, electrolyte repletion, and insulin therapy. While some patients with mild DKA can be managed with subcutaneous insulin, most patients with DKA, and all patients with HHS, require management with a continuous intravenous insulin infusion, generally administered in an intensive care setting [4]. Close monitoring is imperative, as patients can suffer a number of complications during treatment, including hypoglycemia, hypokalemia and cerebral edema, all of which have been linked to worsened outcomes and increased mortality [5]. Despite the well-known risk, there is limited published data about hypoglycemia frequency from continuous insulin infusions for hyperglycemic crises, with studies showing a wide range from 9 to 35% [1,6–7].

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A consensus statement published by the American Diabetes Association (ADA) in 2009 summarizes best practices in diagnosis and management of hyperglycemic crises [5]. This consensus statement recommends treatment with a continuous infusion of regular insulin either at a dose of 0.14 units/kg/hour or with an initial bolus of regular insulin at 0.1 units/kg/hour followed by an insulin infusion at a rate of 0.1 units/kg/hour. Once glucose levels reach 200 mg/dL (in the case of DKA) or 300 mg/dL (in the case of HHS), the insulin infusion rate is reduced and fluids containing dextrose are started to prevent hypoglycemia. To standardize treatment for hyperglycemic crises, many hospitals have implemented treatment protocols to guide management based on these best practices [8]. Though treatment protocols have been demonstrated to yield improvements in time to resolution of DKA, safety outcomes, including resultant hypoglycemia, remain a concern [9]. Our hospital has maintained a medication guideline for the management of hyperglycemic crises based on the treatment principles in the ADA consensus statement that summarizes diagnosis and management principles for more than 15 years [10].

We sought to thoroughly review evidence-based practice for management of hyperglycemic crises and to enact changes to our institution's existing hyperglycemic crisis insulin infusion protocol with the goal of improving patient safety. In particular, the goal was to reduce rates of hypoglycemia, defined as blood glucose (BG) < 70 mg/dL. Here we report the process, interventions, and the results of this project.

Methods

Hyperglycemic crises management protocol

Our institution is the largest safety-net hospital in New England and an academic medical center with graduate residency and fellowship programs. Our hospital maintains a medication guideline for management of hyperglycemic crisis. The guideline includes an intravenous insulin infusion titration protocol that allows nursing staff to adjust the insulin infusion rate based on blood glucose values, avoiding the need for hourly physician dose titration. Volume resuscitation recommendations are not included in the protocol and are at the discretion of the primary management team. Every two years, this guideline is reviewed and updated as needed by the Endocrine Subcommittee of Pharmacy and Therapeutics, a multidisciplinary group focused on safety and quality improvement.

The hospital's Endocrine Subcommittee of Pharmacy and Therapeutics maintains guidelines for the hospital related to best practices for patients with various endocrine conditions. This multidisciplinary committee consists of endocrinologists, endocrinology fellows, pharmacists, diabetes nurse practitioners, certified diabetes educators, nurses, dietitians, and information technology (IT) specialists. In addition to the medication guideline for hyperglycemic crises and the insulin titration protocol, the committee maintains an order set bundle in the electronic medical record (EMR) to facilitate appropriate ordering of medications and laboratory studies for patients treated for hyperglycemic crises. The hyperglycemic crises order set contains specific orders for continuous insulin infusions, intravenous fluids, electrolyte repletion, and laboratory monitoring.

During the 2018 review cycle, the committee decided to reassess the safety of the insulin infusion titration protocol, as the impression of clinicians on the committee was that hypoglycemia rates during treatment for hyperglycemic crises were high. Specifically, members had noted several incidents where insulin infusions had been titrated to high rates (more than 20 units/hour), particularly in patients with poor renal function, resulting in hypoglycemia several hours later.

Design

Members of the committee performed a literature review of consensus statements and review articles pertaining to best practice in the management of hyperglycemic crises to guide potential changes to the insulin titration protocol. Original articles describing randomized trial protocols for hyperglycemic crises were examined as well [11–15]. Additionally, published protocols and protocols used at other institutions were reviewed. This brought the committee to note several features, described below, of the existing insulin titration protocol that could potentially be improved upon to reduce the risk of hypoglycemia. Simultaneously, the group performed a chart review to gather baseline data over a three-month period (n = 35) regarding performance of the existing guideline. Results suggested an association with insulin infusion dose and rates of hypoglycemia, as well as frequent premature discontinuation of the infusion to prevent hypoglycemia (Fig. 1). Based on the baseline data and ideas gleaned from protocols used at other sites, the committee decided to move forward with protocol adjustments and evaluation of patient outcomes after implementation.

Initial metrics for baseline data were determined by the committee members based on parameters perceived to be most helpful in understanding potential causes of hypoglycemia. Over two subsequent PDSA cycles, metrics were refined and those felt to have continued relevance were reviewed in subcommittee meetings.

Measures

In this interrupted time series study, the primary outcome of interest was frequency of hypoglycemic episodes (BG < 70 mg/dL [level 1 hypoglycemia] and BG < 54 mg/dL [level 2 hypoglycemia]). BG values included both point of care fingerstick glucose and serum glucose values. Additionally, fidelity and effectiveness of the intervention were evaluated as secondary measures. Fidelity was assessed by evaluating the frequency of correct use of the protocol with respect to appropriate insulin dose titration. Effectiveness was assessed by time to resolution of DKA. We did not assess time to resolution of HHS due to the small numbers of these patients and wide variation in time to resolution of hyperosmolar state. Length of ICU and hospital stay were not included as prior quality improvement projects at our institution have shown that these are confounded by nursing and bed availability, along with social and other factors.

Outcomes were collected at baseline, as well as for five months after the implementation of the first new protocol version and for three months after the implementation of the second protocol version to determine the effects of the intervention. Data were collected for five months after implementation of the first new protocol version due to a low volume of admissions for hyperglycemic crises during the first three months after protocol implementation, and also to allow time for nursing staff to acclimate to the substantial changes to the protocol.
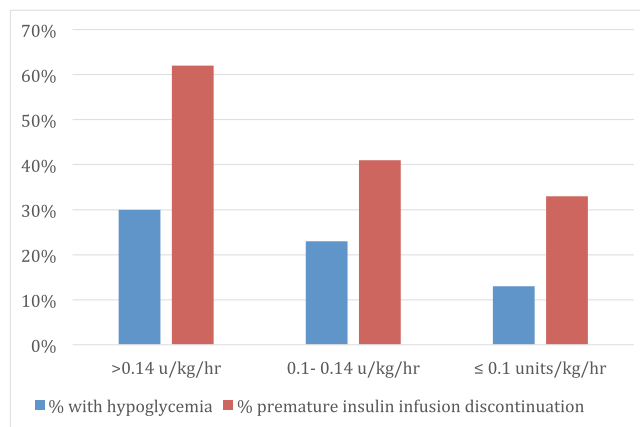

Fig. 1. Percentage of patients with hypoglycemia (blood glucose < 70 mg/dL) or who required premature insulin infusion discontinuation to prevent hypoglycemia in the baseline state by maximum insulin dose.

After each intervention cycle, a list of all patients admitted to the hospital with a diagnosis of DKA or HHS, identified by ICD-10 code, during the time frame was obtained. Chart review was performed by an endocrinologist or endocrinology fellow to obtain patient level data. Clinical data, including weight, admission BG levels, correct diagnosis of hyperglycemic crises, presence of renal injury, maximal insulin infusion rate, and vasopressor use were collected as baseline data. Additionally, data related to the use and performance of the insulin infusion protocol were collected, including correct titration of the insulin infusion, requirement to increase insulin infusion rate, number of hypoglycemic episodes, premature discontinuation of insulin infusion for downtrending glucose, and time to resolution of DKA in minutes.

Analysis

Analysis of variance, Kruskal-Wallis, and Fisher's exact tests were used to assess the differences in performance metrics and outcomes between the three protocol versions. For continuous variables, results are expressed as means and standard deviations for normally distributed variables or medians (interquartile range [IQR]) for non-parametric data. Categorical variables are expressed as numbers and percentages. All p-values are two-sided, level of significance of 0.05. Data analyses were performed with SAS® OnDemand for Academics (SAS Institutes, Cary, NC).

Results

Hyperglycemic crisis admissions

During the study period, data were collected for 122 admissions to the medical intensive care unit (ICU) for hyperglycemic crises. The frequencies of DKA, HHS, both, or neither on admission are shown in Table 1. Patients who had neither DKA nor HHS were coded as having had one or the other via ICD-10 code, but on manual chart review were found to not meet criteria for hyperglycemic crises. The inpatient diabetes consult service, managed by a team of endocrinologists, was consulted on 89.3% of admissions included in the study period.

PDSA cycle #1

The baseline findings suggested an association between increased frequency of hypoglycemia and higher insulin infusion rates (Fig. 1). Based on this, the existing titration guideline was assessed for areas of improvement. The baseline version of the insulin infusion titration protocol is shown in Fig. 2. Of note, the baseline protocol includes instructions for the nurse to increase the insulin infusion rate if the BG is not falling at the expected rate. This was based on text in the 2006 ADA hyperglycemic crises management consensus statement that stated "if the plasma glucose does not decrease by 50–75 mg from the initial value in the first hour, the insulin infusion may be doubled every hour until a steady glucose decline is achieved" [10]. Additionally, in the 2009 ADA consensus statement, the recommendation is "if glucose does not decrease by 50–75 mg from the initial value in the first hour, the insulin

infusion should be increased every hour until a steady glucose decline is achieved" [5]. This recommendation is based on the principle that with adequate hydration and insulinization, BG levels will generally decline at this rate. However, in clinical practice, patients with significantly reduced renal function may not have such a rapid improvement in BG levels and are at increased risk for hypoglycemia due to reduced renal clearance of insulin [16]. As such, the committee determined that insulin infusion rate should not be increased by default per protocol, but instead only if a physician was notified and determined that a higher rate was appropriate. This would then require a separate order by the physician.

In addition, several other changes were made to the titration protocol, including the addition of a statement that if the BG was falling by greater than 100 mg/dL/hour, the nurse would reduce the infusion rate in an effort to decrease risk of hypoglycemia. In the baseline state, insulin infusions were ordered in units/hour. This required the physician to calculate a dose using the patient's recorded weight, introducing the potential for human error. Hourly administration adjustments were then made in units/hour, which was not in line with the consensus statement recommending doses in units/kg/hour. In order to align more closely with the published consensus statement and reduce the potential for error, insulin infusion orders for patients in hyperglycemic crises were changed to be in units/kg/hour. This was done in conjunction with pharmacy, and individual menus were set up in the intravenous infusion pumps to allow the nurse to select the correct dosing units, with units/kg/hour for hyperglycemic crises and units/hour for critically ill patients managed with a separate insulin infusion protocol.

The committee then drafted a new version (Version 1 [V1]) of an insulin infusion titration guideline that could be followed by nursing staff. The guideline was reviewed by intensive care nurse educators and managers for feedback prior to implementation. As part of implementation, intensive discussion and education were performed with frontline staff prior to releasing the new guideline. Nursing staff were educated regarding changes via in-person in-service trainings and a required online education module. Other ICU staff, including residents, attending physicians, and pharmacists were also provided with information regarding the changes via email and in-person didactic sessions. Order sets in the EMR were updated to reflect the new protocol, and the medication guideline was updated and made available on the hospital intranet to be consistent with the new changes. The EMR order set also contains an embedded link to the hyperglycemic crises medication guideline to allow for improved access by clinicians.

Five months after the implementation of V1, data was obtained on all patients admitted with diagnosis of DKA or HHS during that time frame and reviewed as described above. The frequency of hypoglycemia declined by over 50% following initiation of the new V1 protocol compared to baseline. Additionally, no episodes of level 2 hypoglycemia (BG < 54 mg/dL) were recorded (Table 2).

The committee also noted that infusion rates were infrequently increased by the provider beyond 0.14 units/kg/hour once the default order to increase the rate in the protocol was removed. However, a decrease in fidelity with the protocol was seen, with correct titration observed in only 77% of cases as compared to nearly 86% of cases with the baseline protocol (Table 2). Time to resolution of DKA did increase from a baseline of 547 minutes to 736.5 minutes with the V1 protocol.

PDSA cycle #2

The committee solicited feedback about the V1 protocol from frontline nursing staff and ICU nurse educators, who subsequently requested several modifications to the new protocol (Fig. 3). This included a limited ability to increase the infusion rate without contacting the provider in order to expedite changes when blood sugar was not falling as expected. The committee agreed to this change, with the exception that a physician order would be required to increase the dose beyond 0.14 units/kg/hour. In addition, there was concern that nurses

Table 1
Hyperglycemic Crisis Diagnoses.

	Baseline protocol(n = 35)	Version 1(n = 39)	Version 2(n = 48)
DKA	28 (80)	22 (56.4)	37 (77.1)
HHS	0	7 (18.0)	4 (8.3)
Both DKA/HHS	3 (8.6)	3 (7.7)	0
No DKA or HHS	4 (11.4)	7 (18.0)	7 (14.6)

DKA = diabetic ketoacidosis. HHS = hyperosmolar hyperglycemic state. Data reported as n (%).

Intravenous Insulin Titration Protocol for Hyperglycemic Crisis (order set in EMR)	
Blood glucose < 80 mg/dL	Stop drip, give 12.5 gm dextrose 50%, repeat finger stick in 15 minutes. ○ If BG > 80 mg/dL after 15 minutes, restart drip at half previous insulin rate. ○ If BG < 80 mg/dL after 15 minutes, repeat 12.5 gm dextrose 50% and call physician.
Blood glucose 80-149 mg/dL	Decrease insulin drip by half and ensure patient is on dextrose-containing IV fluids.
Blood glucose 150-250 mg/dL	Continue current insulin infusion rate and ensure patient is on dextrose-containing IV fluids.
Blood glucose > 250mg/dL	If blood glucose dose not fall by 50 mg/dL every hour, multiply current rate by 1.5 to determine new rate.

Fig. 2. Baseline insulin infusion titration protocol.

Table 2
Outcomes for all protocol versions.

	Baseline (n = 35)	Version 1 (n = 39)	Version 2 (n = 48)	p
Number of patients with BG < 70 mg/dL	9 (25.7)	4 (10.3)	6 (12.5)	0.18
Number of events of BG < 70 mg/dL	12	5	6	0.16
Number of patients with BG < 54 mg/dL	2	0	2	
Correct titration of protocol	30 (85.7)	27 (77.1)*	39 (81.3)	0.53
Maximum insulin dose units/kg/hour	0.12 (0.10)	0.11 (0.04)	0.10 (0.04)	0.09
Number of patients with maximum insulin dose greater than 0.14 units/kg/hour	17 (48.6)	3 (7.7)	7 (14.6)	0.0003
Time to resolution of DKA, minutes**	547 (1204)	736.5 (1495)	833 (776)	0.82

Data reported as n (%) or median (IQR). BG = blood glucose.
*For Version 1, four subjects were missing protocol titration data.
**Results restricted to patients with a diagnosis of DKA, baseline n = 28, Version 1 n = 18, Version 2 n = 37.

were required to use the weight recorded in the EMR to determine the insulin dose, and that entered weights from the emergency department were not always accurate. While it had been the policy for several years that all patients have a weight performed upon admission to the hospital, in practice this was not always done in a timely manner. To

address this, two new scales were purchased and made available in the medical ICU to weigh patients upon arrival. Finally, some patients were noted to have a rapid decline in BG after the first few hours of treatment with insulin and fluids, leading to a premature down-titration of the infusion rate. Because of this, the protocol was updated to allow one episode of BG falling greater than 100 mg/dL in an hour without lowering the rate.

The above changes were incorporated into the final hyperglycemic crises insulin infusion guideline (Version 2 [V2]), shown in Fig. 4. Changes were again distributed to nurse educators for dissemination to staff. Three months after implementation of V2, data on rates of hypoglycemia and time to resolution of DKA were obtained and improvements seen with V1 were found to be preserved (Table 2) with a sustained 50% reduction in hypoglycemic events. There was no significant increase in the time to resolution of DKA between baseline and the new versions: baseline 547 [IQR 1204] minutes vs. V1 736.5 (IQR 1495) minutes vs. V2 833 [IQR 779] minutes, $p = 0.82$. Additionally, fidelity with the protocol was improved, with correct insulin titration in 81% of cases. There were no deaths in any of the groups.

The committee also reviewed several other factors to determine the association with hypoglycemia. In examination of outcomes across all protocol versions, lack of fidelity with the protocol, as assessed by frequency of incorrect titration, showed a moderate association with hypoglycemia (Cramer's V 0.25, $p = 0.05$). Additionally, hypoglycemia was most frequently seen in patients with pre-existing renal impairment (chronic kidney disease or end-stage renal disease), with 66.7% of patients with pre-existing renal impairment experiencing a hypoglycemic episode as compared to 12.9% of patients with acute kidney injury or
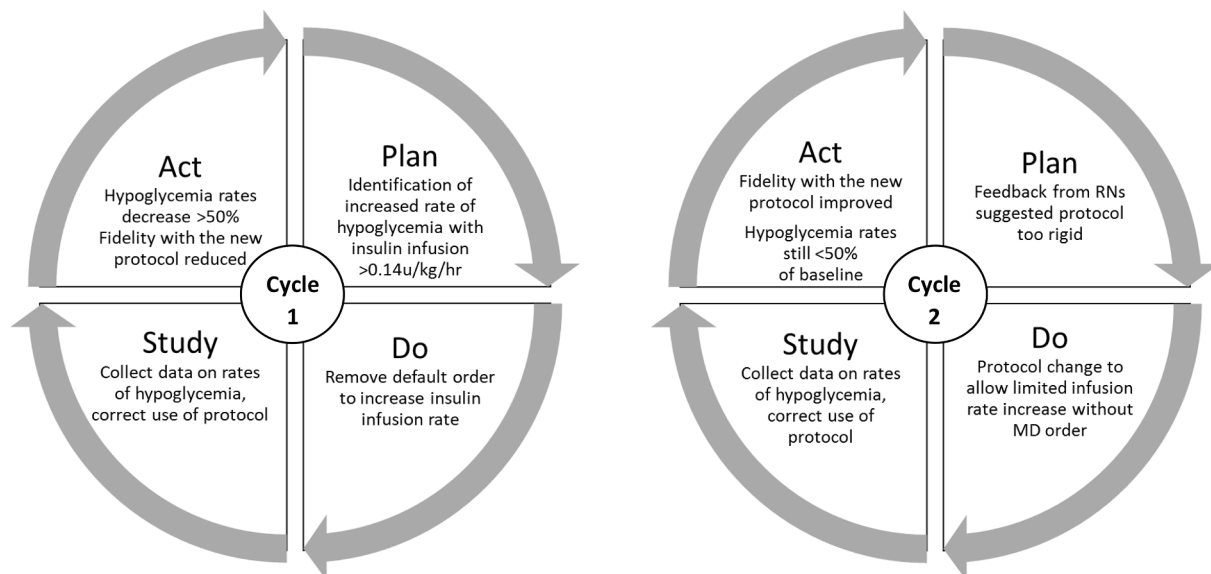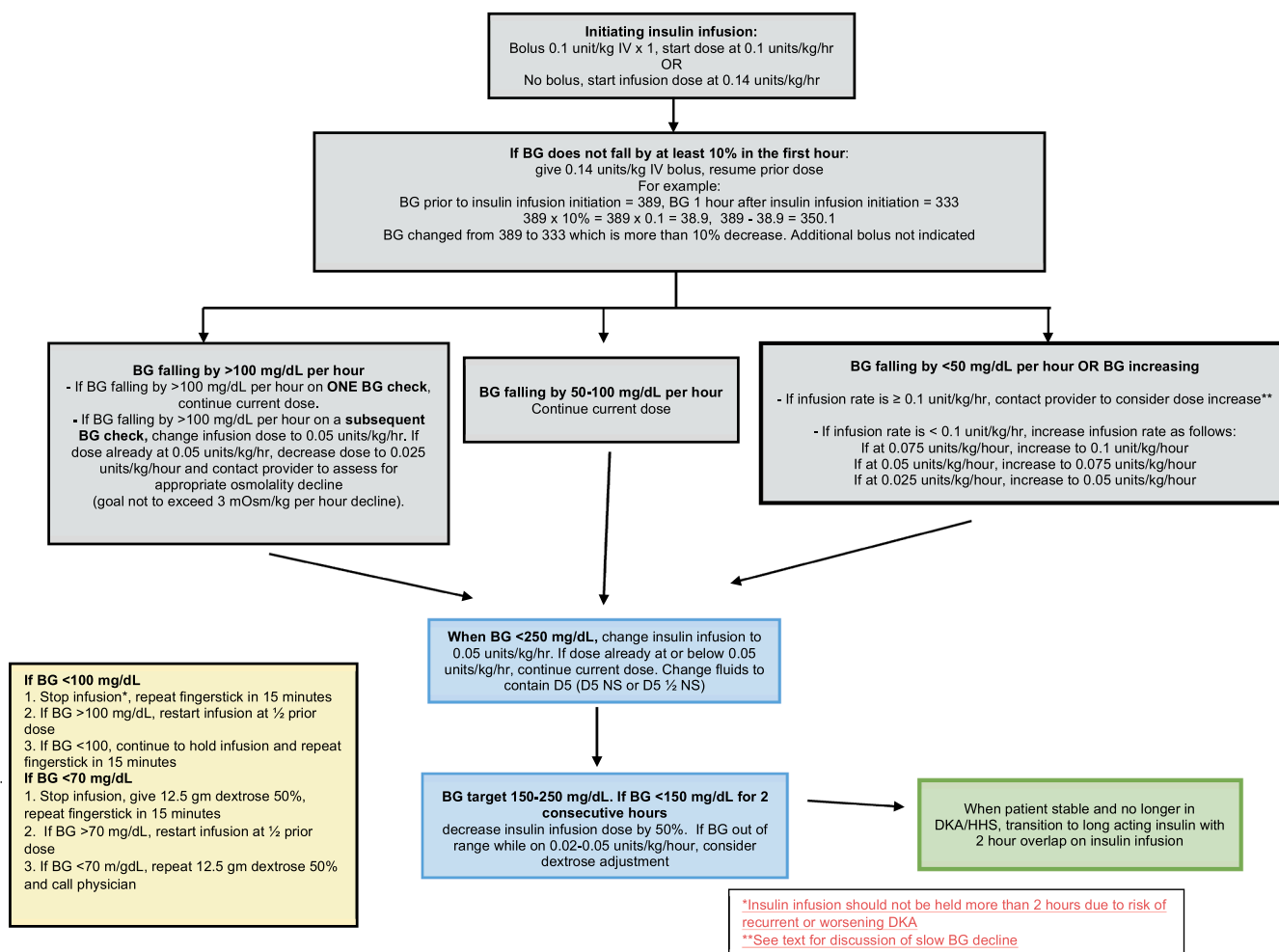

Fig. 3. PDSA Cycles.

Fig. 4. Final Version 2 insulin infusion titration protocol.

normal renal function (p = 0.005). The presence of pre-existing renal impairment was strongly associated with development of hypoglycemia (Cramer's V 0.32, p = 0.005). Finally, the committee noted that not infrequently patients were incorrectly diagnosed as having hyperglycemic crises and started on the insulin infusion protocol designed for patients with hyperglycemic crises. These patients had higher rates of hypoglycemia during treatment than those patients correctly diagnosed with hyperglycemic crisis (Table 3). Across all three protocol versions, 13.5% of patients correctly diagnosed with hyperglycemic crises had BG < 70 mg/dL and 27% of patients without hyperglycemic crises had BG < 70 mg/dL (p = 0.16).

Discussion

Hospital admissions for hyperglycemic crises have been increasing over the last 10 years, and while many institutions, including our own,

have instituted protocols for management, little data about safety of different protocols that hospitals have adopted for use is available. We found that limiting increases in insulin infusion rate by requiring physician assessment and a separate order to increase the rate above 0.14u/kg/hr was associated with decreasing rates of hypoglycemia. Despite this, there was no significant increase in time to resolution of DKA.

While several changes were made to the insulin titration protocol during each PDSA cycle, the most significant change that was felt to have led to the reduction in hypoglycemia was removing the default order to increase the infusion rate if the BG was not falling at the expected rate, as baseline data showed a strong association with increasing infusion rate and hypoglycemia, as would be expected. This is supported by the fact that in V1 and V2 the average maximum dose of insulin was lower, as was the frequency of insulin doses greater than 0.14 units/kg/hour. We found that while the protocol did allow for this up-titration, by

Table 3
Hypoglycemia by presence of hyperglycemic crisis diagnosis.

	Crisis				No Crisis			
	Baseline (n = 31)	Version 1 (n = 32)	Version 2 (n = 41)	P	Baseline (n = 4)	Version 1 (n = 7)	Version 2 (n = 7)	P
Number of patients with BG < 70 mg/dL	6 (19.4)	3 (9.4)	5 (12.2)	0.49	3 (75)	1 (14.3)	1 (14.3)	0.067
Number of patients with BG < 54 mg/dL	1 (3.2)	0	1 (2.4)		1 (25)	0	1 (14.3)	

BG = blood glucose.

involving the physician to determine if higher doses were appropriate and removing the default up-titration, higher doses were less commonly administered.

Based on our chart review, hypoglycemia was strongly associated with pre-existing chronic renal dysfunction. There are no standardized guidelines that address insulin infusion dosing in patients with chronically impaired renal function, particularly in the case of hyperglycemic crises, and this is an area that warrants more research to guide management.

After the initial change to the protocol (V1), the rates of hypoglycemia were the lowest out of the three versions. Though not statistically significant, likely due to small sample size, the 50% reduction in hypoglycemia was felt to be clinically significant. Despite this improvement in hypoglycemia rates, the nursing staff found aspects of the protocol challenging and were concerned about delays in care with less flexibility in insulin dosing, which may have contributed to the lowest fidelity with this version of the protocol. With the addition of the changes requested by nursing staff into V2, though the rates of hypoglycemia were slightly higher than with V1, they remained improved compared to baseline and the fidelity of the protocol was improved. Additionally, the acceptance of the protocol, per discussion with nursing and nurse educators, was improved, though this was not formally assessed. Although the initial committee devising the guidelines did include ICU nursing representatives, this raised an important point that even if patient outcomes were improved, if the usability of the protocol was limited, the short-term improved results may not be sustainable. This demonstrated the importance of follow-up discussions with frontline staff, as it can be expected that improving usability of the protocol may contribute to better fidelity and patient outcomes. Rates of protocol fidelity were higher for those with DKA than the overall rates, suggesting a lower rate of fidelity with HHS management or in those without hyperglycemic crises, a finding which should be further explored. This may be suggestive of increased comfort or familiarity with DKA relative to HHS, and an area to focus further education efforts.

There were several unintended findings of this project. The first was the recognition of the frequency of inaccurate weights upon admission to the medical ICU. While we did not quantify this, nursing staff noted this as an issue and as a result, more scales were made available. Of note, the baseline DKA protocol also used the weights that were recorded in the emergency department, so while the source of the weights used for dosing did not change, it had not previously been identified as an area of concern.

We also noted the frequency of incorrect diagnosis of hyperglycemic crises in up to 18% of cases, which has implications for management. Due to severe insulin resistance associated with hyperglycemic crises, insulin titration guidelines created for patients with hyperglycemic crises generally use higher doses of insulin than are appropriate for those simply with hyperglycemia. This is consistent with our findings that a higher proportion of those without hyperglycemic crises treated with the protocol developed hypoglycemia. This also held true for level 2 hypoglycemic events at baseline and with V2, though there were no episodes of level 2 hypoglycemia with V1 of the protocol. In addition to these patients being administered unnecessarily high doses of insulin, insulin infusion necessitates ICU admission at our institution. By misdiagnosing these patients as having DKA or HHS, they may be admitted to a higher level of care than is needed, at increased cost to the system. To aid in making the correct diagnosis, the hospital guidelines for management of hyperglycemic crises contain a section on definitions for DKA and HHS, and house officers in the ICU receive monthly educational lectures about diagnosis and management of hyperglycemic crises. Potential further interventions to help in selecting appropriate patients for use of the hyperglycemic crises insulin infusion protocol are being considered.

In terms of impact on systems, development and implementation of these changes required more than one year on the part of committee members to collect the baseline data and complete the PDSA cycles.

There was additional time required by nurse educators and nursing staff to receive training in the new protocols, as well as house officer trainings throughout the year. IT support and pharmacy assistance were also critical to ensuring safe initiation of the new protocols in the EMR and maintaining an intranet repository for hospital guideline management. Additionally, there were expected challenges that occurred on a day–today basis with a new protocol that required support from the endocrinology attendings and fellows. We did not note any other significant drawbacks to the changes.

There are a number of limitations to our study. Our findings related to hypoglycemia and the exact protocol adjustments we describe may not be generalizable to all institutions as there is a diversity of protocols in use at other institutions. We also were not able to obtain clinical information about symptoms during episodes of hypoglycemia. Additionally, long-term sustainability of the improvements in safety and fidelity with the protocol was not evaluated. However, we feel that the methods and principles we used can be effective to help other hospitals evaluate their own rates of hypoglycemia and implement changes to protocols to make improvements. Additionally, at each PDSA cycle several adjustments were made to the titration protocol; therefore, we are not able to determine the impact of each individual change. We also were not able to stratify the patients with DKA by severity of DKA, so it is possible that outcomes may differ based on DKA severity and skew the results of assessing the protocol versions. Finally, while many of the effects were not found to be statistically significant, this is likely due to the small sample sizes in each PDSA cycle. Thehe results were still felt to be clinically significant, particularly with the continued improvement over the two cycles, but recognizing the limitations given the small case number.

Conclusions

Though our prior institutional guidelines for the management of hyperglycemic crises had been based on recommendations for best practice, we found that adjusting the insulin infusion titration guideline and limiting protocol-driven dose increases above 0.14 units/kg/hour improved patient safety by substantially reducing hypoglycemia. There is a lack of data about rates of complications, including hypoglycemia, and risk factors for complications in the treatment of hyperglycemic crises in routine clinical practice, and further research in this area and how to mitigate these problems is needed.

CRediT authorship contribution statement

Katherine L. Modzelewski: Conceptualization, Investigation, Writing – original draft. **Ariana Cannavo:** Investigation, Data curation, Writing – original draft. **Kathryn L. Fantasia:** Methodology, Formal analysis, Writing – original draft. **Sira Korpaisarn:** Investigation, Data curation. **Sara M. Alexanian:** Conceptualization, Writing – original draft, Supervision.

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.

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