ORIGINAL ARTICLE

Evaluation of a Nurse-Managed Insulin Infusion Protocol

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Abstract

Background: The purpose of this study was to evaluate the performance of an insulin infusion protocol targeting a blood glucose (BG) level of 140–180 mg/dL and to characterize protocol adherence.

Materials and Methods: This was a retrospective observational cohort study including patients for whom the protocol was ordered from January 2012 to May 2013. Performance metrics were assessed in all patients and in patients with an initial BG level of ≥ 200 mg/dL. Protocol adherence was assessed in a random subset of 50 patients without hypoglycemia and in all hypoglycemic patients.

Results: In patients with an initial BG level of ≥ 200 mg/dL, the mean time to goal was 7.1 h. The rate of decline of BG level in the first 6 h was 16.4 mg/dL/h. Mean BG level was 167 mg/dL, with 43.9% of BG values within goal and 80.3% between 80 and 199 mg/dL. The rate of hypoglycemic events was 0.14 per 100 h. The mean protocol violation rate was higher in patients with hypoglycemia compared with those without (39.8 vs. 23.5 per 100 h, $P=0.002$), and 60.7% of hypoglycemic events were attributable to protocol violations. The protocol violation rate (42.8 vs. 17.6 per 100 h; $P<0.001$) and the odds of hypoglycemia (odds ratio=5.2; 95% confidence interval, 1.6, 16.5) were higher in the cardiac surgery patients compared with other patients.

Conclusions: This protocol provides adequate BG control within the clinically acceptable range of 80–199 mg/dL but not within the narrower range of 140–180 mg/dL, with a low incidence of hypoglycemia. Risk factors for hypoglycemia and barriers to protocol adherence in the cardiac surgery population should be elucidated.

Background

GLUCOSE CONTROL IS ESSENTIAL in critically ill patients. Patients with persistent hyperglycemia are at risk for infection, neuropathy, impaired wound healing, volume contraction, and death.^{1–3} The optimal blood glucose (BG) range for critically ill patients remains elusive. Two studies by Van den Berghe et al.^{2,3} demonstrated that intensive insulin therapy to maintain BG between 80 and 110 mg/dL led to decreased mortality and morbidity (i.e., need for renal replacement therapy, duration of mechanical ventilation) compared with conventional therapy aimed at achieving BG of 180–200 mg/dL. However, both studies demonstrated an increase in hypoglycemia in the intensive insulin therapy arms. Subsequently, the NICE-SUGAR study demonstrated an increase in mortality in patients randomized to intensive

insulin therapy (BG 81–108 mg/dL) compared with conventional therapy (BG 144–180 mg/dL) with no difference in morbidity and a higher rate of severe hypoglycemia in the intensive therapy group.⁴ Because it was a large, multicenter trial including a heterogeneous patient population, the NICE-SUGAR trial has shaped the glucose management of most critically ill patients. However, given that the majority of patients in the studies of Van den Berghe et al.^{2,3} were cardiac surgery patients, tight glucose control is still favored in this population.

As a result of the NICE-SUGAR study, the American Diabetes Association recommends a target glucose range of 140–180 mg/dL for critically ill patients.⁵ The Society of Critical Care Medicine (SCCM) guidelines recommend maintaining BG <150 mg/dL and absolutely <180 mg/dL for most critically ill patients.¹ There have been several

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published insulin infusion protocols targeting BG values within this range since NICE-SUGAR, but none with a targeted range of 140–180 mg/dL.^{6–8}

The Johns Hopkins Hospital developed a nurse-managed insulin infusion protocol targeting a BG range of 140–180 mg/dL (Table 1) in April 2011 modeled after the Yale protocol.⁹ This is one of two nurse-managed insulin infusion protocols available within the institution, with the other targeting a BG level of 100–139 mg/dL used almost exclusively post-cardiac surgery. The 140–180 mg/dL protocol is used in adult intensive care units, post-anesthesia care units, and intermediate care units. Exclusion criteria for using the protocol include diabetic ketoacidosis, hyperosmolar hyperglycemic state, BG level >400 mg/dL, or patients who are status post-total pancreatectomy. Nurses who work in units where the insulin infusion protocol can be used must complete a Web-based training session.

SCCM recently published guidelines for the evaluation of the quality and safety of insulin infusion protocols.¹ Recommended metrics include mean and median BG levels per patient, percentage of BG values <150 mg/dL and <180 mg/dL, mean and median time to reach the desired glycemic target, and percentage of total time spent in range. The guidelines also suggest reporting hypoglycemic events per patient, as a percentage of all BG values, and per 100 h of insulin infusion. Data suggest that variability in glycemic control can lead to poor outcomes.¹⁰ The SD of mean BG or the mean daily range of BG can be used to describe glucose variability.^{11,12}

The purpose of this study was to evaluate the performance metrics of an insulin infusion protocol targeting a goal BG range of 140–180 mg/dL. Nursing adherence to the protocol was also characterized.

Materials and Methods

This was a retrospective observational cohort study including all patients for whom the protocol was ordered from January 2012 through May 2013. This time period was chosen based on the availability of point-of-care (POC) BG data collected from our NovaMax[®] meters (Nova Diabetes Care, Billerica, MA) and within a time frame from protocol implementation to allow adequate time for nurses to master the use of the protocol. Demographic data were collected from the electronic medical record. All POC BG values along with date and time of collection for the first 72 h after protocol initiation were gathered from a wireless server. Patients were classified as belonging to a functional unit (medicine, surgery, neurology, or oncology) based on their location upon discharge from the hospital. For patients with multiple orders for the protocol, only the first order was used to evaluate performance metrics. Patients were excluded if the insulin infusion protocol was discontinued within 1 h of ordering. Exposure to dextrose-containing solutions was not collected, as the protocol does not require or account for administration of these solutions.

Protocol performance metrics were used to evaluate whether patients met the target BG range. Descriptive statistics were used to calculate mean and median time to achieve BG <180 mg/dL, mean and median BG per patient, and percentage of BG values within the goal range of 140–180 mg/dL and within a clinically acceptable range of

80–199 mg/dL as determined by the authors of the Yale protocol.⁹ Mean daily range of BG was calculated as the difference between maximum and minimum BG values for each patient per day while on the protocol. The rate of decline of BG within the first 6 h after protocol initiation was derived in a longitudinal data analysis using a marginal model with protocol order as a cluster variable, using an unstructured covariance matrix with robust standard errors. These metrics were evaluated separately for the entire dataset and for patients with initial BG level of ≥ 200 mg/dL.

Safety metrics of the protocol were evaluated. Hypoglycemia was defined as BG <70 mg/dL per SCCM guidelines.¹ All hypoglycemic events were included in this analysis regardless of whether they occurred during the first order for the protocol or during a subsequent order. A hypoglycemic event included all BG values subsequent to the first hypoglycemic value until BG level was ≥ 70 mg/dL. Mild hypoglycemia was defined as a BG level of 60–69 mg/dL, moderate hypoglycemia as 40–59 mg/dL, and severe hypoglycemia as <40 mg/dL. The BG nadir was used to characterize hypoglycemic events as mild, moderate, or severe. Percentage of BG readings <70 mg/dL was calculated using the total number of BG readings as the denominator. Hypoglycemia rates were reported as number of patients with hypoglycemia per 100 patients and number of events per 100 h of insulin infusion. Hypoglycemia rates were calculated using the total number of patients and total number of hours of insulin infusion including first and subsequent orders. A hypoglycemic event was determined to be a laboratory error if the BG level was >70 mg/dL with a repeat check without clinical intervention.

A nested case control study was also performed. In this analysis we captured the location of insulin administration (rather than location at discharge). Protocol violations were characterized for a random subset of 50 patients as controls. Patients were excluded from this analysis if the insulin infusion was never initiated, if the protocol was discontinued within 1 h, or if they were <18 years of age. A protocol violation was defined as a change in insulin infusion rate that was not indicated by the protocol, no change in rate when a change was indicated, incorrect starting rate, more than 2 h between BG measurements, or use of the protocol when prescriber-managed insulin was indicated. Both serum and POC glucose measurements were included for this analysis. Protocol violations were collected for all hypoglycemic cases to determine whether the event could have been attributed to a protocol violation. An aggressive violation was defined as a protocol violation from the protocol that led to the patient receiving more insulin than indicated or failure to check the BG level for ≥ 2 h.

A post hoc analysis was conducted comparing hypoglycemia and protocol violation rates between the cardiovascular surgery intensive care unit (CVSICU) and all other units. The estimated rate of hypoglycemia for the CVSICU and other units was calculated per 100 patients and per 100 h of insulin infusion by extrapolating the proportion of patients and hours on the infusion in each location from the random subset to the entire population.

The Stata statistical software package (version 12.1; StataCorp LP, College Station, TX) was used for data analysis. Student's two-sided *t* test was used to compare continuous, normally distributed data. The Wilcoxon rank sum test was

TABLE 1. ADAPTED YALE PROTOCOL TARGETING BLOOD GLUCOSE LEVELS OF 140–180 MG/DL

	Current BG value					
	BG 100–139 mg/dL	BG 140–159 mg/dL	BG 160–179 mg/dL	BG 180–250 mg/dL	BG 251–400 mg/dL	Instructions ^a
BG <100 mg/dL If BG <100 mg/dL turn insulin drip OFF and recheck BG every 1 h until BG >180 mg/dL. Restart the insulin infusion at 50% of most recent rate. If BG <80 mg/dL discontinue insulin infusion. Give D50 IV 12.5 g (25 mL). Recheck BG every 20 min. If glucose remains <80 mg/dL administer a second dose of D50 12.5 g (12.5 mL). When BG >180 mg/dL wait 1 h, check BG and then restart drip at 50% of most recent rate. If BG <60 mg/dL implement the institutional hypoglycemia protocol.	BG <100 mg/dL	BG ↑ >50 mg/dL	BG ↑ >50 mg/dL	BG ↑ (any increase) OR BG unchanged OR BG ↓ <25 mg/dL	BG ↑ (any increase) OR BG unchanged OR BG ↓ <25 mg/dL	↑ Infusion by amount in (B) below
	BG ↑ (any increase)	BG ↑ <30 mg/dL OR BG unchanged OR BG ↓ <20 mg/dL	BG ↑ <30 mg/dL OR BG unchanged OR BG ↓ <30 mg/dL	BG ↑ 30–50 mg/dL OR BG ↓ <25 mg/dL	BG ↓ 25–50 mg/dL	↑ Infusion by amount in (A) below
	BG ↑ (any increase)	BG ↑ <30 mg/dL OR BG unchanged OR BG ↓ <20 mg/dL	BG ↑ <30 mg/dL OR BG unchanged OR BG ↓ <30 mg/dL	BG ↓ 25–50 mg/dL	BG ↓ 51–75 mg/dL	No infusion change
BG unchanged	BG ↓ (any decrease)	BG ↓ >50 mg/dL	BG ↓ >50 mg/dL	BG ↓ >75 mg/dL	BG ↓ >100 mg/dL	Hold for 60 min. Recheck BG. If BG is >180 mg/dL restart infusion by decreasing infusion by the amount in (B) below.
	BG ↓ (any decrease)	BG ↓ >50 mg/dL	BG ↓ >50 mg/dL	BG ↓ >75 mg/dL	BG ↓ >100 mg/dL	Hold for 60 min. Recheck BG. If BG is >180 mg/dL restart infusion by decreasing infusion by the amount in (B) below.

If two or more blood glucose (BG) values are <140 mg/dL, turn off the infusion and notify the prescriber to determine whether the patient should remain on insulin infusion.

^aThe initial bolus and infusion rate are determined by dividing the initial BG level by 200 and rounding to the nearest 0.5 units. When the patient is on an insulin infusion, BG is checked hourly. If the BG level is <180 mg/dL and the insulin infusion is off, BG is checked every 2 h. Changes in insulin infusion rate are calculated based on change in BG for the previous hour. For a current rate as specified the following rate changes were used: for <3 units/h, 0.5 (A) or 1 (B) units/h; for 3–6 units/h, 1 (A) or 2 (B) units/h; for 6.5–9.5 units/h, 1.5 (A) or 3 (B) units/h; for 10–14.5 units/h, 2 (A) or 4 (B) units/h; for 15–19.5 units/h, 3 (A) or 6 (B) units/h; for 20–24.5 units/h, 4 (A) or 8 (B) units/h; and >25 units/h, 5 (A) or 10 (consult prescriber) (B) units/h. D50, 50% dextrose; IV, intravenously.

used to analyze continuous data that were not normally distributed. The χ^2 or Fisher's exact test was used to analyze categorical data, as appropriate. Odds ratios were calculated using simple logistic regression. Statistical significance was designated as a value of $P < 0.05$. This study was approved by the Institutional Review Board.

Results

During the study period, 595 patients were ordered the insulin infusion protocol. Fifteen patients were excluded because of the protocol being discontinued within 1 h of ordering. The mean (SD) age was 59.4 (14.3) years; 63.4% of patients were white, and 25.4% were black; and 60.7% were male. Most patients were discharged from surgery floors (68.6%), followed by medicine (13.9%), oncology (10.3%), and neurology (7.2%). The mean (SD) and median (interquartile range [IQR]) times on protocol were 48.5 (52.5) h and 32.1 (49.5) h, respectively.

Performance metrics of the protocol are described in Table 2. When the initial BG level was ≥ 200 mg/dL, the mean (SD) and median (IQR) times to goal BG were 7.1 (3.5) h and 6.6 (4.7) h, respectively. The mean (SD) and median (IQR) BG levels after the goal was achieved were 167 (25) mg/dL and 168 (24) mg/dL, respectively. Forty-four percent of BG values were within the goal range, and 80.3% were within a clinically acceptable range (80–199 mg/dL). Figure 1

TABLE 2. PROTOCOL PERFORMANCE METRICS

	<i>All patients (n = 580)</i>	<i>Orders with initial BG ≥ 200 mg/dL (n = 257)</i>
Initial BG (mg/dL) [mean (SD)]	205 (87)	281 (73)
Number of patients reaching therapeutic target (%)	534 (92.1)	240 (93.4)
Time (h) to BG <180 mg/dL		
Mean (SD)	4.2 (3.9)	7.1 (3.5)
Median (IQR)	2.9 (5.5)	6.6 (4.7)
Rate of decline of BG over first 6 h (mg/dL/h)	NA	16.4 ^a
BG per order after goal achieved for first 72 h (mg/dL)		
Mean (SD)	155 (25)	167 (25)
Median (IQR)	154 (33)	168 (24)
BG values after goal achieved [n (%)]		
<140 mg/dL	2,038/5,486 (37.1)	817/3,016 (27.1)
140–180 mg/dL	2,340/5,486 (42.7)	1,323/3,016 (43.9)
>180 mg/dL	1,108/5,486 (20.2)	876/3,016 (29.0)
>200 mg/dL	639/5,486 (13.2)	539/3,016 (17.9)
80–199 mg/dL	4,739/5,486 (86.4)	2,422/3,016 (80.3)
Mean (SD) daily range of BG (mg/dL)		
0–24 h	94 (77)	143 (74)
24–48 h	81 (77)	92 (62)
48–72 h	77 (80)	95 (89)

^a95% confidence interval, 14.7, 18.1 mg/dL/h.

BG, blood glucose; IQR, interquartile range; NA, not available.

illustrates the performance of the protocol during the first 72 h of insulin infusion.

A random subset of 50 patients was selected to assess adherence to the protocol. Of these, 10 patients were excluded for the following reasons: insulin infusion not initiated ($n = 7$), protocol discontinued within 1 h of initiation ($n = 2$), and age <18 years ($n = 1$). The mean (SD) duration of insulin infusion was 22.4 (18.6) h. Of 773 BG measurements, 621 (80.3%) were measured via POC device, and 152 (19.7%) were measured via arterial sample. The mean protocol violation rate was 23.5 per 100 h of insulin infusion (Table 3). The most common violations included incorrect rate adjustment ($n = 72$, 33.2%), failure to stop the insulin infusion when indicated ($n = 63$, 29%), and more than 2 h between BG checks ($n = 51$, 23.5%).

There were 68 BG measurements <70 mg/dL. Twenty-six BG measurements were excluded because of laboratory error ($n = 19$), defined as discordance with the electronic medical record and resolution without intervention or BG ≥ 70 mg/dL on recheck, or because the hypoglycemic event occurred before the insulin infusion was started ($n = 7$). The percentage of BG readings <70 mg/dL was 0.43% (95% confidence interval [CI], 0.31, 0.58). There were 19 patients with a total of 28 hypoglycemic events in the first 72 h after protocol initiation (Table 3). Seventeen of the 28 hypoglycemic events (60.7%) occurred directly following an aggressive protocol violation. The rate of hypoglycemia in the first 72 h after protocol initiation was 3.2 per 100 patients (95% CI, 1.9, 4.9) and 0.14 events per 100 h (95% CI, 0.09, 0.2). There was one episode of severe hypoglycemia (BG <40 mg/dL) during the study period, which occurred following an aggressive protocol violation.

The protocol violation rate was higher in patients with hypoglycemia compared with the random subset (39.8 per 100 h vs. 23.5 per 100 h; $P = 0.002$). The insulin infusion was not held when indicated more frequently in the group with hypoglycemia compared with the random subset of patients (37.1% of violations vs. 29.0% of violations). Additionally, there were more patients in the hypoglycemic cohort in whom the protocol was not indicated because of extreme hyperglycemia (>400 mg/dL), and a prescriber-managed insulin infusion should have been used (1.3% vs. 0.5%; $P =$ not significant).

The CVSICU accounted for all of the hypoglycemic events in surgical patients and 67.9% of all hypoglycemic events. The CVSICU also had a higher protocol violation rate compared with other units (Table 4) (42.8 vs. 17.6 per 100 h; $P < 0.001$). The odds of hypoglycemia were more than five times higher in the CVSICU compared with other units (odds ratio = 5.2; 95% CI, 1.6, 16.5). The estimated rate of hypoglycemia in the CVSICU was 7.2 per 100 patients (95% CI, 4.0, 11.9) and 0.32 per 100 h (95% CI, 0.19, 0.5).

Discussion

To our knowledge, this is the first published attempt at utilizing SCCM guidelines for evaluation of the quality and safety of insulin infusion protocols. We believe this protocol provides acceptable glucose control with a mean and median BG of 167 mg/dL and 168 mg/dL, respectively. The mean time to achieve target BG was 7.1 h. The time to achieve the goal range in our study is shorter than in previously published

FIG. 1. Performance of the insulin infusion protocol during the first 72 h of insulin infusion.

studies; however, these protocols targeted lower BG goals.^{6–9} A modified Yale protocol with a target BG range of 120–160 mg/dL had a similar median time to achieve goal BG level of 7 h and a mean and median BG level of 156 and 150 mg/dL, respectively.⁶

Although only 43.9% of BG values fell within the target BG range of 140–180 mg/dL after patients reached the goal,

TABLE 3. PROTOCOL VIOLATIONS IN HYPOGLYCEMIC CASES VERSUS RANDOM CONTROLS

	Random controls (n=40)	Hypoglycemic cases (n=19) ^a
Functional unit [n (%)]		
Medicine	2 (5)	2 (10.5)
Neurology	5 (12.5)	2 (10.5)
Oncology	1 (2.5)	1 (5.3)
Surgery	32 (80)	14 (73.7)
Protocol violations per 100 h (mean) ^b	23.5	39.8
Hypoglycemic events [n (%)] ^c	—	28 (100)
Mild	—	14 (50)
Moderate	—	13 (46.4)
Severe	—	1 (3.6)
Number of hypoglycemic events following an aggressive protocol violation	—	17 (60.7)

^aTwo patients had hypoglycemic events during two distinct insulin infusion protocol orders (one in medicine and one in cardiac surgery). Therefore there are 19 patients accounting for 21 insulin infusion protocol orders included in this analysis.

^b $P=0.002$ (random controls vs. hypoglycemic patients).

80.3% fell into a clinically acceptable range of 80–199 mg/dL. The percentage of patients within the goal range and clinically acceptable range is similar to that of other protocols reported in the literature. The Yale protocol published in 2004 is the most widely cited insulin infusion protocol in the literature and served as the model for our protocol.⁹ In that publication, 52.5% of BG readings were within the goal range of 100–139 mg/dL after achieving a BG level of <140 mg/dL, and 93% fell into a clinically acceptable range of 80–199 mg/dL. In the revised Yale protocol published in 2012, only 42% of BG values fell within the 120–160 mg/dL target range, and 76% were <180 mg/dL.⁶ In a study by Khalaila et al.⁷ assessing another Yale-derived protocol, 46% of BG readings were within the goal range of 110–149 mg/dL, and 85% fell within a clinically acceptable range of 70–199 mg/dL. This metric can be confounded by frequent BG monitoring for patients that are hyper- or hypoglycemic. We observed four hypoglycemic episodes prior to an insulin infusion being initiated, and seven of 50 randomly selected patients had a BG level of <180 mg/dL without requiring an insulin infusion, so the true percentage of BG values within the goal range for patients actively receiving insulin infusions may be higher.

Our protocol had a low incidence of hypoglycemia of only 3.2 per 100 patients and 0.14 events per 100 h of insulin infusion. Among 595 patients for whom the protocol was ordered, there was only one episode of severe hypoglycemia, and mild hypoglycemic events accounted for 50% of total events, although even mild hypoglycemia has been associated with an increased risk of mortality.¹³ More than 60% of hypoglycemic events occurred in the hour following aggressive protocol violations. This emphasizes the need for double-checks and other redundant systems to minimize the risk for medication errors. It is interesting that there were more patients with antecedent extreme hyperglycemia (BG level of >400 mg/dL) in the cohort of patients who developed hypoglycemia, often due

TABLE 4. PROTOCOL VIOLATIONS IN CARDIAC SURGERY PATIENTS VERSUS ALL OTHER UNITS

	Cardiac surgery (n = 27)	All other units (n = 32)
Functional unit [n (%)]		
Medicine	—	4 (12.5)
Neurology	—	7 (21.9)
Oncology	—	2 (6.2)
Surgery	27 (100)	19 (59.4)
Protocol violations per 100 h (mean)	42.8	17.6 ^a
Hypoglycemic events [n (%)] ^b	19 (67.9)	9 (32.1)
Mild ^c	8 (42.1)	6 (66.7)
Moderate ^d	10 (52.6)	3 (33.3)
Severe ^c	1 (5.3)	0
Number of hypoglycemic events following an aggressive protocol violation ^d	13 (68.4)	4 (44.4)

^a $P < 0.001$ (cardiac surgery vs. other units).

^bOdds ratio = 5.2; 95% confidence interval, 1.6, 16.5; $P = 0.003$.

^c $P =$ not significant.

^dOdds ratio = 7.3; 95% confidence interval, 1.4, 37.7; $P = 0.007$.

to inappropriate initial infusion rates and frequent, aggressive use of bolus doses of insulin. This reinforces the need for a prescriber-managed approach in these patients.

The nurse-managed insulin infusion protocol was instituted to develop a standardized approach to treating hyperglycemia. However, this protocol is nursing resource intensive. Nurses must check BG every hour while patients are on the continuous infusion and take into account current BG, the rate of change in BG, and the current infusion rate to calculate the necessary rate change. When performing these calculations manually there is high risk for error, which may contribute to our high protocol violation rate. Frequency of BG monitoring also accounted for a large proportion of protocol violations. A study by Cyrus et al.¹⁴ demonstrated a higher protocol violation rate of 52.8%; however, this was reported as a percentage of BG measurements rather than standardized per 100 h of insulin infusion. As we were unable to determine whether protocol violations were intentional or unintentional, we cannot predict whether a computerized protocol would decrease our observed violation rate. Computerized insulin infusion protocols such as Glucommander (Glytec, Greenville, SC) have been demonstrated to improve glycemic control, decrease the risk of calculation errors, and can provide reminders for BG checks.^{15–23} A recent study demonstrated a 98.2% adherence rate to the insulin dose prescribed when using the Space GlucoseControl system (B. Braun, Melsungen, Germany).²³ However, errors can still occur in sampling interval, data entry, and pump programming. The ideal integrated system would receive BG data from the glucometer or medical record, calculate the necessary change in infusion rate, and adjust the pump infusion rate without human input.

The CVSICU accounts for the highest volume of insulin infusions at this institution. Nurses on this unit frequently utilize insulin infusions and are also very cognizant of the Surgical Care Improvement Project (SCIP) core measures for

BG control post-cardiac surgery. In the immediate post-operative period most of the patients in the CVSICU in our institution are ordered for another nurse-managed protocol with a goal BG of 100–139 mg/dL; however, patients may be transitioned to the 140–180 mg/dL protocol at other points throughout their hospitalization. It is interesting that this unit had a higher rate of protocol violations and a higher rate of hypoglycemia compared with other units, accounting for nearly 70% of all hypoglycemic episodes observed. We hypothesize that because of external pressures to meet SCIP measures nurses in the CVSICU are more likely to deviate from the protocol, even outside of the perioperative period. Further studies should be performed to determine nursing barriers to adherence with this infusion protocol, including the perceived need to meet nationally recognized quality standards such as the SCIP measures. The higher rate of hypoglycemia could also be impacted by other clinical characteristics of the patient population, such as frequent use of epinephrine, titration of which may lead to changes in insulin requirements not accounted for by the nurse-managed protocol. Further studies should also be performed to identify risk factors for hypoglycemia in cardiac surgery patients.

There are several limitations to this study. First, there is no comparator group to determine if this approach to treating hyperglycemia is superior to another protocol or a non-protocolized approach. Additionally, in this patient population consisting of mostly critically ill and postsurgical patients, many factors impact BG such as changing rates and formulations of enteral and parenteral nutrition, the use of corticosteroids or epinephrine, and administration of dextrose-containing intravenous fluids. Caution should be exercised when applying our results to a different population. Due to limitations of documentation of the electronic medical record, we were unable to determine the frequency of alternate site testing (i.e., testing at sites other than the fingertip) of POC BG.

In order to include a large number of patients, each patient chart was not reviewed to determine adherence to the protocol. We have extrapolated the protocol violation rate in a random subset to the entire population, but the true violation rate is unknown. Additionally, 20% of these randomly selected patients were excluded from the protocol adherence analysis for various reasons as described. We were also unable to determine in this study if protocol violations were intentional or unintentional. The performance metrics of the protocol must be taken into context with our high protocol violation rate. We were unable to determine the precise time at which the insulin infusion was started or stopped. Because we did not account for the time between ordering the protocol and starting the infusion, the reported time to achieve the goal BG may be falsely high. We also did not characterize total insulin exposure or exposure to dextrose-containing solutions. Notably, seven patients in the random subset of 50 patients never received insulin while ordered for this protocol. Because we did not have data regarding these patients' comorbidities, we are unable to compare BG control between patients with and without diabetes. Finally, we do not report clinical outcomes associated with use of the insulin infusion protocol.

Conclusions

We describe an infusion protocol designed to maintain BG within a range of 140–180 mg/dL and the first attempt at

utilizing the SCCM guidelines for evaluation of the quality and safety insulin infusion protocols. This protocol had a very low rate of hypoglycemia and achieved adequate BG control within the clinically acceptable range of 80–199 mg/dL but failed to achieve the SCCM target of <150 mg/dL and had a low percentage of BG values within the target range of 140–180 mg/dL. There are currently no accepted benchmarking data for metrics recommended by national organizations, and we suggest that other institutions use the performance characteristics described here to compare the quality and safety of other protocols.¹ The rate of protocol violations was higher in patients with hypoglycemia, emphasizing the need for implementation of safety measures, double checks, and the potential utilization of clinical decision support tools when managing patients on continuous insulin infusions. Protocol violations and hypoglycemic events were also more frequent in the CVSICU. Further investigation should be conducted to determine barriers to following the protocol, including perceived need for tight BG control, as well as risk factors for hypoglycemia in this patient population.

Author Disclosure Statement

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