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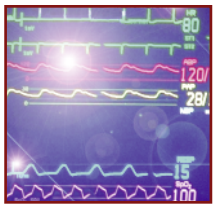

Effect of a Computerized Insulin Dose Calculator on the Process of Glycemic Control

By Cheryl Dumont, RN, PhD, CRNI, and Cheryl Bourguignon, RN, PhD

Background Glycemic control is important to patients' outcomes. However, the process of maintaining glycemic control is risk laden and labor intensive for nurses.
Objectives To examine the effects of using a computerized insulin dose calculator to facilitate management of glycemic control for critically ill cardiac patients.
Methods A prospective randomized controlled trial was conducted with a sample of 300 intensive care patients, 141 randomized to the calculator group and 159 in the control (paper protocol) group. A convenience sample of 44 intensive care nurses responded to a nurse satisfaction survey.
Results A significantly higher percentage of glucose measurements were in the target range in the calculator group than in the control group (70.4% [SD, 15.2%] vs 61.6% [SD, 17.9%], $Z = -4.423$, $P < .001$), and glucose variance was significantly less in the calculator group (35.5 [SD, 18.3] mg/dL vs 42.3 [SD, 21.2] mg/dL, $Z = -3.845$, $P < .001$). Fewer hypoglycemic events occurred in the calculator group (7 vs 18), although this difference was not statistically significant. Nurse satisfaction was higher for the calculator group than for the control group (8.4 [SD, 1.4] vs 4.8 [SD, 2.4], $Z = -5.055$, $P < .001$). Nurses' deviation from the protocol was also less in the calculator group than in the control group.
Conclusions Management of glycemic control and nurse satisfaction were improved with use of the dose calculator. Improving nurses' processes of care may improve nurses' use of time and patient care overall. Studies with larger sample sizes over time are needed to determine these relationships.
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CE 1.0 Hour

Notice to CE enrollees:
A closed-book, multiple-choice examination following this article tests your understanding of the following objectives:

1. Identify the current target glucose concentration for critically ill patients.
2. Describe the use of a computerized insulin-dosing calculator (CIDC) in titrating blood glucose levels in critically ill patients.
3. Discuss potential satisfiers and dissatisfiers in comparing CIDCs to standard written hyperglycemic protocols.

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While medical researchers seek to determine the ideal targets for glucose concentration, nurses struggle to achieve those targets safely. In the past decade, the recommended glucose concentration target for critically ill patients has increased from 80 to 110 mg/dL (to convert to millimoles per liter, multiply by 0.0555) to the currently recommended target of 140 to 180 mg/dL. Targets less than 110 mg/dL are no longer recommended.[1,2] Regardless of the target range, controlling the variability of glucose concentrations within that range is difficult, especially in critically ill patients. The most effective way to provide glucose control in critically ill patients is with an intravenous insulin infusion, but the process of glucose control is costly, labor intensive, and risk laden.[3,4] This study addressed the value of using computer-based technology to assist nurses in the process of glucose control.

Background

Since Van den Berghe and colleagues[5] recommended maintaining glucose concentrations of 80 to 110 mg/dL in intensive care unit (ICU) patients in 2001, there has been much controversy over the best glucose concentration for critically ill patients. In contrast to Van den Berghe's findings, in 2009, the NICE-SUGAR Study Investigators[6] reported an increase in mortality from 24.9% in the conventional glucose control group (≤180 mg/dL) to 27.5% in the tight glucose control group (81-108 mg/dL). In that study, hypoglycemia (≤40 mg/dL) occurred in 6.8% of the tight glucose control group and 0.5% of the conventional control group. Of note, the mean blood glucose concentration in the conventional control group was 142 mg/dL; in previous studies, the conventional groups tended to have much higher glucose concentrations.[6]

Hypoglycemia is an independent risk factor for increased mortality in ICU patients. Krinsley and Grover[7] determined that a single episode of severe hypoglycemia conferred a 2.28 increased risk of mortality (N = 5365, $P < .001$). Egi and colleagues[8] reported that risk of mortality increased nearly 3-fold (N = 4946, $P < .001$) in ICU patients with hypoglycemia. Marik and Preiser[9] did a meta-analysis of 7 randomized controlled studies that included 11 425 patients and found no improvement in 28-day mortality or the incidence of bloodstream infections, nor did they find a reduction in requirements for renal replacement therapy in patients receiving tight glucose control. They did report a significantly higher incidence of hypoglycemia in patients receiving tight glucose control than in patients receiving conventional glucose control.

In the past decade, blood glucose targets have increased from 80 to 110 mg/dL to 140 to 180 mg/dL.

Another factor associated with mortality is glucose variability. Ali and colleagues[10] calculated a glucose lability index to represent glucose variability. They reported that patients with sepsis and a high glucose lability index had a hospital mortality rate nearly 5 times greater than the rate in patients with sepsis and a lower glucose lability index (N = 1246, $P < .001$). Krinsley[11] also reported that mortality in ICU patients increased as glucose variability increased, regardless of the patients' mean glucose concentration.

An exact cause and effect relationship between hypoglycemia and glucose variability and patients' outcomes is difficult to determine; regardless, this association has been identified.[12] Egi and colleagues[8] proposed 3 possible explanations for the association between hypoglycemia and poor outcomes. First, hypoglycemia may be a factor of severity of illness, caused by the illness. Second, hypoglycemia may be a biomarker of imminent death, a sign of severity of illness. Third, hypoglycemia may actually be harmful in itself, and in this case, it is important clinically to prevent hypoglycemia. This third explanation highlights the importance of finding ways to decrease the occurrence of hypoglycemic events.

Although association does not confer causality, there are some biologic reasons why hypoglycemia

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and increased glucose variability may have toxic effects. The cellular response to glucose fluctuations is increased oxidative stress. The increased production of oxygen free radicals initiates the inflammatory response and accelerates macrovascular disease. Nerve cells are particularly affected by hypoglycemia. Prolonged or severe hypoglycemia can result in irreversible damage of nerve cells. In addition, the sympathetic response to hypoglycemia may initiate cardiac arrhythmia and/or myocardial compromise.

Hypoglycemia is an independent risk factor for increased mortality in intensive care patients.

Glucose Control Achieved

A benchmark for successful achievement of target glucose levels is difficult to quantify because definitions of glucose target, actual amount of glucose control achieved, hypoglycemia, patients' characteristics, and types of protocols have varied greatly from study to study.[13] For example, successful achievement of target range has been measured as the percentage of "time" in the target range, the percentage of "glucose measurements" in the target range, "mean daily" glucose concentration, and "AM post-op day one" and "post-op day two" glucose concentrations. In a study[14] in which 3 protocols used for patients after cardiac surgery were compared, researchers found that the mean time required to reach a target range of 80 to 110 mg/dL was more than 8 hours and the mean "time" in the target range was at most 46% (SD, 3%). However, time in the target range is a misnomer if glucose is not measured continuously (yet researchers have reported "time" in target range with sampling intervals of 1 to 4 hours).

Computer-based technology may assist in providing more accurate and effective calculations for titration of insulin dosing and may also save nurses time. However, this technology is expensive and in light of the current economic climate, with decreasing reimbursement for care and increasing demand for high-quality, nurses must objectively evaluate the cost-benefit of any new investments.

Glucose fluctuation increases oxidative stress and production of oxygen free radicals initiates the inflammatory response.

When this study was designed in 2008, we knew of no other head-to-head studies in which insulin protocols managed by nurses were compared. In 2009, Blaha and colleagues[14] published a study randomizing 120 patients (40 in each arm) to compare 2 different paper protocols with a computerized protocol. That study[14] demonstrated that the computerized program provided the best glucose control with the least risk of hypoglycemia. This study was also designed to add to the body of knowledge to determine whether a computerized program would facilitate better glucose control and increase satisfaction of nurses with the process of managing glucose control.

Purpose

The aim of this study was to determine whether using a computerized insulin-dosing calculator (CIDC; EndoTool, Hospira, Lake Forest, Illinois) rather than the usual paper protocol (modified Portland Protocol) improved the process of blood glucose control in critically ill patients, and improved nurses' satisfaction with the process. The research questions were as follows:

1. Is there a difference in glycemic control (measured by the percentage of blood glucose measurements in the target range, the mean blood glucose concentration in milligrams per deciliter, the time to reach the target glucose range, the variability in blood glucose levels [measured as standard deviation of blood glucose measurements, or BGSD], and number of hypoglycemic events) between the CIDC protocol and the paper protocol?
2. After age, diagnosis of diabetes, number of comorbid conditions, blood glucose level at admission, and use of catecholamines (no/yes) are controlled for, does type of protocol (CIDC protocol vs paper protocol) make a difference in glycemic control?
3. Does nurses' satisfaction with the process of glycemic control differ between the CIDC protocol and the usual paper protocol?

Methods

This prospective, randomized, controlled research study involved an interdisciplinary team of nurses, physicians, and pharmacists. The work was done at Winchester Medical Center in Winchester, Virginia, a 400-bed rural, community, regional referral hospital. Data were collected from April 2008 through January 2009. Approval from the hospital's institutional review board was granted, and consent was obtained from patients.

Study Measures

Protocol Type. The paper protocol had insulin dosing determined by the nurse using the usual standard of care, and the interventional protocol had the dose computed by the nurse using the CIDC.

Before the start of the study, the cardiothoracic surgeons and the nurses met to develop 2 different sets of standing order forms for intravenous insulin:

1 for the CIDC protocol and 1 for the paper protocol. The target goal for blood glucose concentration for surgical ICU patients in this institution at the time of the study was 80 to 150 mg/dL. All parameters such as target range (80-150 mg/dL), hypoglycemia (<60 mg/dL), glucose criteria to start and stop intravenous insulin, insulin concentration (250 units in 250 mL normal saline), and dosing for 50% dextrose solution were the same for both protocols. The difference was the method used to determine the dose for titration of insulin. With the paper protocol, the nurses used written guidelines based on the Portland Protocol to determine how to adjust the insulin infusion after each blood glucose measurement, with the adjustment based on the current measure and insulin dose only. With the CIDC protocol, the nurse entered the glucose reading into the computer and an appropriate dose was calculated by the CIDC program on the basis of the patient's responses to insulin doses in the 4 preceding glucose measurements.

CIDC. The CIDC used in this study was the EndoTool Glucose Management System, a predictive and adaptive software system that calculates the dose of intravenous insulin needed to control blood glucose concentrations in a critical care setting. This type of software, which is compliant with current health insurance privacy rules, calculates the dose of intravenous insulin needed by actively modeling and adapting to individual patient's responses to intravenous insulin. The software uses more that 30 unique algorithms to ensure an extremely low incidence of hypoglycemia, which occurs in less than 0.05% of glucose measurements.[15]

Sample

The samples consisted of critically ill patients and intensive care nurses. The nurses included all had at least 3 months of experience using both the CIDC and paper protocols. A sample of 300 patients was drawn from the patients admitted to the cardiovascular surgical intensive care unit. After a physician had determined that the patient was eligible for intravenous insulin, the patient was randomized to either the CIDC group or the paper protocol group. Randomization was accomplished by the nurse choosing 1 envelope from a stack of white, unmarked, sealed envelopes that contained orders for either the CIDC protocol or the paper protocol. Patients included were cardiac surgery patients. Patients continued receiving intravenous insulin whether in the CIDC group or the paper protocol group until their glucose concentration remained below the upper blood glucose target value for 3 consecutive measurements or the patients were transferred from the intensive care unit. Patients who were not receiving intravenous insulin for at least 4 hours were excluded. Patients who were receiving an insulin infusion because of diabetic ketoacidosis and patients who were primarily medical patients were excluded from the study.

A convenience sample of 44 nurses who had worked with both the CIDC protocol and the paper protocol was obtained 4 months after the study started to assess nurses' satisfaction with the process of glucose control. Each nurse took the survey twice, once for each protocol. These 2 surveys were stapled together to match the respondents, but no names were put on the surveys so as to ensure anonymity.

> The paper protocol for adjusting insulin dose was based on the current blood sugar; computer dosing was based on the 4 preceding blood sugar measurements.

The Nurse Satisfaction Survey

An investigator-developed survey included 2 subscales, 1 measuring satisfaction and 1 measuring the frequency of occurrence of dissatisfiers. Questions were answered on a 10-point scale with opposite anchors. For the subscale of satisfaction, 1 meant very unsatisfied and 10 meant very satisfied. For the subscale of frequency of occurrence of dissatisfiers, 1 meant never and 10 meant very often. Internal reliability was tested with Cronbach α at 0.834 and 0.796 for satisfaction and dissatisfiers, respectively (Table 1).

Nurses' Deviation from the Protocol

Nurses' deviation from the protocol was measured by 2 methods. One was the nurses' perceptions of deviation as measured by a question in the dissatisfier section of the nurse survey. The second method was an actual hand count of the deviations obtained by retrospective chart review; the cases in which the insulin dose did not match the recommended dose for each protocol were counted.

> The groups did not differ in mean blood glucose level, time to reach target, or number of hypoglycemic events.

Procedure

Patients who were scheduled to undergo elective major cardiovascular surgery were identified preoperatively, the study was explained by 1 of the nurse investigators, and written consent was obtained. If patients arrived in an emergent situation, the designated next of kin was approached for consent. It was explained that patients would be enrolled in the study only if their physician determined that

Table 1
Nurse satisfaction survey

Satisfaction with the process of tight glycemic control **Please circle the number that best represents your satisfaction with the ease of use and or your confidence and comfort level with the _____ protocol you are using on a scale of 1 to 10, with 1 being very unsatisfied and 10 being very satisfied.**
1. The time it takes to determine an insulin dose with the paper protocol.
Very unsatisfied 1 2 3 4 5 6 7 8 9 10 Very satisfied
2. The effort to determine an insulin dose with the paper protocol.
Very unsatisfied 1 2 3 4 5 6 7 8 9 10 Very satisfied
3. The safety of the insulin dosing using the paper protocol.
Very unsatisfied 1 2 3 4 5 6 7 8 9 10 Very satisfied
4. The quality of care provided to the patient in relation to glucose control when using the paper protocol.
Very unsatisfied 1 2 3 4 5 6 7 8 9 10 Very satisfied
5. The ease of insulin titration with the paper protocol.
Very unsatisfied 1 2 3 4 5 6 7 8 9 10 Very satisfied
6. The accuracy of the dose–knowing I have it right when I use the paper protocol.
Very unsatisfied 1 2 3 4 5 6 7 8 9 10 Very satisfied
Rate how often the following situations influence whether you follow the _____protocol as ordered
1. Changes in a patient's condition due to changes in vasoactive drugs.
Never 1 2 3 4 5 6 7 8 9 10 Very often
2. The fear of causing hypoglycemia.
Never 1 2 3 4 5 6 7 8 9 10 Very often
3. Changes in patients' feeding, such as starting or stopping tube feedings or total parenteral nutrition.
Never 1 2 3 4 5 6 7 8 9 10 Very often
Rate to what degree does using the _____protocol
4. Require too much nursing judgment.
Never 1 2 3 4 5 6 7 8 9 10 Very often
5. Require too many finger sticks.
Never 1 2 3 4 5 6 7 8 9 10 Very often
6. Cause extreme changes in blood sugar due to protocol dosing guidelines.
Never 1 2 3 4 5 6 7 8 9 10 Very often
7. How often do you deviate from the _____protocol dose recommendation and use your own judgment for insulin dosing?
Never 1 2 3 4 5 6 7 8 9 10 Very often

they needed intravenous insulin. The team of intensive care unit nurses collected data on every glucose measure, the times that the intravenous infusion of insulin was started and stopped, and every deviation from protocol. Data were also collected on patients' characteristics to determine whether the 2 protocol groups differed significantly in any factors that might influence glucose control.

Statistical Analysis

Data were entered into the Statistical Package for Social Sciences 17 (IBM, Armonk, New York).

Before analysis of the specific aims, descriptive statistics (means, standard deviations for continuous variables, and frequencies and percentages for categorical variables) were calculated for demographic and baseline study variables. Differences in demographic and baseline study variables between protocol types (CIDC vs paper protocol) were tested by using *t* tests for continuous variables that were normally distributed (age and number of comorbid conditions at admission), the Mann-Whitney test for skewed data (body mass index, blood glucose level at admission, and glycosylated hemoglobin), and a χ^2 test for categorical variables. Most of the continuous glycemic control outcomes (mean blood glucose level, variability of blood glucose level [BGSD], and minutes to achieve target) consisted of skewed data; therefore, Mann Whitney tests were used to determine differences between the protocol types. One continuous glycemic control outcome, percentage of blood glucose measurements in the target range, was normally distributed, so a *t* test was used to determine differences between protocol types. A χ^2 test was used to determine differences between the protocol types on hypoglycemic events. On glycemic control outcomes with significant differences between protocol types, hierarchical multiple regression modeling was used to determine if the type of protocol (CIDC protocol vs paper protocol) remained as an individually significant predictor after age, diagnosis of diabetes mellitus, number of comorbid conditions at admission, blood glucose level at admission, and use of catecholamines were controlled for. For the paired data from nurses (who used both the CIDC protocol and the paper protocol), a Wilcoxon matched-pairs signed rank test was used to determine if nurses' satisfaction differed between the 2 protocols.

Results

Characteristics of Patients

The CIDC protocol group (n = 141) and the paper protocol group (n = 159) did not differ significantly in sex, age, body mass index, blood glucose level at admission, glycated hemoglobin percentage, admission diagnosis, presence of a diagnosis of diabetes mellitus, preexisting infection, nutritional status (nothing by mouth vs feeding), propofol use, or infusion of catecholamines concurrently with intravenous insulin (Table 2).

Glycemic Control Outcomes

The 2 protocol groups did not differ significantly in mean blood glucose level (CIDC protocol: 137.8 [SD, 16.3] mg/dL vs paper protocol: 141.1 [SD, 19.8] mg/dL) or mean time to reach target glucose level (CIDC protocol: 3.6 [SD, 2.3] hours vs paper protocol: 3.8 [SD, 2.3] hours). Chi-square results indicated that the 2 protocol groups did not differ significantly in the number of hypoglycemic events of 60 mg/dL or lower (occurred 7 times with the CIDC protocol and 18 times with the paper protocol). Hypoglycemia events of 40 mg/dL or less were too scarce for statistical testing; thus, only descriptive information is provided. With the CIDC protocol, no hypoglycemic events of 40 mg/dL or less occurred, whereas with the paper protocol 2 such events occurred. A significantly higher percentage of blood glucose measurements were in the target range (80-150 mg/dL) for the CIDC group (70.4% [SD, 15.2%]) than for the paper protocol group (61.6% [SD, 17.9%]; $t = 4.605$, $P < .001$). Blood glucose variability, as measured by BGSD, was less with the CIDC protocol (mean 35.5 [SD,

Table 2
Patients' demographics, comorbid conditions, and therapies

Characteristic[a,b]	Paper protocol (n = 159)	Computerized insulin-dosing calculator (n = 141)
Female sex	59 (37.1)	42 (29.8)
Admission diagnosis		
Heart disease	147 (92.5)	133 (94.3)
General surgery	5 (3.1)	5 (3.5)
Medical condition	6 (3.8)	3 (2.1)
Trauma	1 (0.6)	0 (0.0)
Admitted with infection	17 (10.7)	10 (7.1)
Catecholamine therapy	119 (74.8)	109 (77.3)
Propofol therapy	14 (8.8)	15 (10.6)
Nothing by mouth while receiving insulin intravenously	141 (88.7)	119 (84.4)
Diagnosis of diabetes		
None	91 (57.2)	80 (57.6)
Type 1	12 (7.5)	10 (7.2)
Type 2	56 (35.2)	49 (35.3)
Age, mean (SD), y	64.3 (10.3)	64.1 (12.1)
Body mass index,[c] mean (SD)	31.4 (7.8)	30.4 (6.3)
Admission blood glucose, mean (SD), mg/dL[d]	140.9 (60.1)	139.9 (63.2)
Hemoglobin A_{1c}, mean (SD), %	6.9 (1.7); n = 101	7.0 (1.6); n = 79

[a] Unless otherwise indicated, data in the table are expressed as number (percentage).
[b] No characteristic differed significantly between the paper protocol and the computerized insulin-dosing calculator protocol.
[c] Calculated as the weight in kilograms divided by height in meters squared.
[d] Multiply by 0.0555 to convert to millimoles per liter.

Table 3
Hierarchical multiple regression

Models	Blocks	Predictor variables by block	Regression coefficient (SE)	*P* value for regression coefficients	R^2 for each block and for total model
% in target range					
	1	Age and	-0.093 (0.088)	.29	0.008
		diagnosis of diabetes mellitus	-1.178 (2.614)	.65	
	2	No. of comorbid conditions	1.192 (1.343)	.38	0.000
	3	Admission blood glucose (log)[a]	-21.180 (7.352)	.004	0.026
	4	Use of catecholamines	-2.823 (2.296)	.22	0.004
	5	Protocol type	8.831 (1.951)	<.001	0.064
Total model					0.103
Variability of blood glucose (log of BGSD)[a]					
	1	Age and	0.002 (0.001)	.02	0.055
		diagnosis of diabetes mellitus	0.045 (0.029)	.12	
	2	No. of comorbid conditions	-0.009 (0.015)	.56	0.001
	3	Admission blood glucose (log)	0.337 (0.081)	<.001	0.052
	4	Use of catecholamines	0.027 (0.025)	.29	0.003
	5	Protocol type	-0.075 (0.021)	.001	0.036
Total model					0.147

Abbreviations: BGSD, variability of blood glucose (SD of blood glucose); SE, standard error.

[a] Variable log transformed because of skewed data.

18.3] mg/dL) than with the paper protocol (mean 42.3 [SD, 21.2] mg/dL; $Z = -3.845$, $P < .001$).

Multiple Regression Analysis

Because the protocol groups differed significantly in the percentage of glucose measurements in the target range and BGSD, hierarchical multiple regression models were estimated to determine if protocol differences remained after potentially confounding variables (age, diagnosis of diabetes mellitus, number of comorbid conditions at admission, blood glucose level at admission, and use of catecholamines were controlled for. Some variables had a skewed distribution, thus the appropriate transformations were made. Variables were added to the hierarchical regression in blocks in the following order: block 1, age and diagnosis of diabetes mellitus; block 2, number of comorbid conditions at admission; block 3, the log of blood glucose level at admission; block 4, use of catecholamines; and block 5, protocol type (CIDC protocol vs paper protocol).

For the dependent variable of percentage of glucose measurements in the target range, the overall model was significant ($P < .001$) and all the variables combined explained a total of 10.3% ($R^2 = 0.103$ for the total model) of the variance in the percentage of glucose measurements in the target range (see Table 3, which includes the R^2 that is unique for each block as well as for the total model). In block 1, age and diagnosis of diabetes mellitus explained 0.8% ($R^2 = 0.008$, see Table 3) of the variance in the percentage of blood glucose measurements in the target range, which was nonsignificant. In block 2, the number of comorbid conditions at admission did not explain any new amount of the variance. In block 3, the log of the blood glucose level at admission uniquely explained a significant percentage (2.6%) of the variance after age, diagnosis of diabetes mellitus, and number of comorbid conditions were controlled for. In block 4, use of catecholamines uniquely did not explain a significant amount of the variance (0.4%) after age, diagnosis of diabetes mellitus, number of comorbid conditions, and the log of the blood glucose level at admission were controlled for. In block 5, after all the confounding variables were controlled for, protocol group uniquely explained a significant amount of the variance (6.4%).

Of the potentially confounding variables, only blood glucose level at admission was an individually significant predictor ($P < .01$). As blood glucose level at admission increased, the percentage of blood glucose measurements in the target range decreased. After all the confounding variables were controlled for, protocol group remained a significant individual predictor ($P < .001$) of the percentage of glucose measurements in the target range, with the CIDC protocol having 8.831% more blood glucose measurements in the target range than the paper protocol had.

For the dependent variable of BGSD, the overall model was significant ($P < .001$) and all the variables combined explained 14.7% ($R^2 = 0.147$ for the total model of the variance in BGSD. In block 1, age and diagnosis of diabetes mellitus explained a significant amount, 5.5% ($R^2 = 0.055$, see Table 3) of the variance in BGSD. In block 2, the number of comorbid conditions at admission did not uniquely explain a significant amount of the variance (only 0.1%). In block 3, the log of the blood glucose level at admission uniquely explained a significant percentage (5.2%) of the variance after age, diagnosis of diabetes mellitus, and number of comorbid conditions were controlled for. In block 4, use of catecholamines uniquely did not explain a significant amount of the variance (0.3%) after age, diagnosis of diabetes mellitus, number of comorbid conditions, and the log of the blood glucose level at admission were controlled for. In block 5, after all the confounding variables were controlled for, protocol group uniquely explained a significant amount of the variance (3.6%). Of the potentially confounding variables, only age ($P = .02$) and blood glucose level at admission ($P < .001$) were individually significant predictors. As age or blood glucose level at admission increased, BGSD also increased, indicating that blood glucose variability increased as age or blood glucose level at admission increased. After all the confounding variables were controlled for, protocol type remained a significant predictor ($P = .001$) of BGSD, with the CIDC protocol having less blood glucose variability than the paper protocol.

Nurses' Satisfaction

Nurses in the study were mainly female (82.2%), with a mean age of 39.7 (SD, 8.0) years (Table 4). Slightly less than half (46.6%) of the nurses had a bachelor of science degree in nursing or a higher degree, and 26.7% held national certification. On average, the nurses had 15.2 (SD, 8.2) years of nursing experience, with 7.8 (SD, 6.2) years in the intensive care unit.

Table 4
Nurses' demographics (N = 44)

Characteristic	Value
Age, mean (SD), y	39.7 (8.0)
Years in this department, mean (SD)	7.8 (6.2)
Years in nursing, mean (SD)	15.2 (8.2)
Female sex, No. (%)	37 (82.2)
National certification, No. (%)	12 (26.7)
Bachelor of science in nursing or higher, No. (%)	20 (46.6)

Nurses were significantly more satisfied with the CIDC protocol than with the paper protocol. The mean satisfaction with the CIDC was 8.4 (SD, 1.4), whereas the mean satisfaction with the paper protocol was 4.8 (SD, 2.4; Wilcoxon matched pairs, $Z = -5.055$, $P < .001$). The mean frequency of dissatisfiers occurring for the CIDC was 3.9 (SD, 1.8) and for the paper protocol was 6.6 (SD, 1.4; Wilcoxon matched pairs, $Z = -5.597$, $P < .001$). The nurses' perception of how often they needed to deviate from the protocol had a mean of 2.7 (SD, 2.2) for the CIDC and a mean of 7.43 (2.4) for the paper protocol (Wilcoxon matched pairs, $Z = -5.393$, $P < .001$). Data on actual deviations were collected by retrospective chart review and hand count of incidents where the dose charted as given was different than the dose charted as recommended by either protocol. These data demonstrated that nurses had deviated from the CIDC protocol a mean of 0.39 (SD, 1.0) times per patient and from the paper protocol 3.0 (SD, 4.3) times per patient (Mann Whitney test, $Z = -7.671$, $P < .001$).

> A greater percentage of glucose measurements were in the target range and glucose variability was less in the computerized insulin-dosing calculator group.

Limitations

The purpose of this study was to determine whether nurses could facilitate better glucose control using a CIDC and if nurses would find the process easier. The ability to obtain glucose control may have been biased by the fact that more patients in the paper protocol group than in the CIDC protocol group were not receiving nutrition (88.7% vs 84.4%), although this difference was not statistically significant. Some evidence indicates that not receiving nutrition is associated with an increased risk of death in patients undergoing tight glucose control (80-110 mg/dL).[8]

Measurements of glucose level can differ between point-of-care testing and laboratory analysis by

20 mg/dL or more.[15] In the study institution, the point-of-care testing glucometers are routinely calibrated and the accepted difference is 10%. Most of the glucose measurements in this study were from point-of-care testing, but we did not collect data on this or attempt to control for the differences in glucose control related to accuracy of the test. The relatively large sample size and randomization methods should have helped to reduce bias from testing error.

Discussion

The value of streamlining nursing care processes is hard to estimate. The cost of a CIDC varies with the manufacturer and number of beds. For this institution, the cost in 2010 was $30 000. The cost of recruiting and training 1 registered nurse is estimated to be as much as $60 000.[16] Nurses were more satisfied with the CIDC and made fewer deviations from the protocol with the CIDC than with the paper protocol. We must ask ourselves: if the nurse is finding it easier to do one process, what other care is the nurse able to provide and what other complications may be avoided? As care becomes increasingly complex, and patients increasingly acutely ill, we must continue to find ways to improve our processes to prevent errors and burnout of nurses. Ultimately, we must do this in the most cost-effective way and evaluate evidence to guide the use of our resources.

Conclusions and Recommendations

The CIDC improved the process of glycemic control among participants in this study, as evidenced by improved levels of satisfaction among nurses, improved percentages of blood glucose measurements in the target range, and decreased variability of blood glucose measurements. Continued medical research is needed to verify the best glucose concentration for specific conditions that patients may have. In the meantime, nurses must continue to evaluate the processes of care and ensure best practice for our patients. In this institution, we determined that use of a computerized dose calculator was best practice for dosing of intravenous insulin.

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CE Test Test ID A1221013: Effect of a Computerized Insulin Dose Calculator on the Process of Glycemic Control.

Learning objectives: 1. Identify the current target glucose concentration for critically ill patients. 2. Describe the use of a computerized insulin-dosing calculator (CIDC) in titrating blood glucose levels in critically ill patients. 3. Discuss potential satisfiers and dissatisfiers in comparing CIDCs to standard written hyperglycemic protocols.

1. Which of the following was determined by the study?
a. A higher percentage of glucose measurements were in therapeutic range in the control group.
b. There was significantly less glucose variance in the control group.
c. There were more nurse deviations from protocol in the computerized insulin-dosing calculator (CIDC) group.
d. There were fewer hypoglycemic events in the CIDC group.

2. Which of the following is the currently recommended target glucose concentration for critical care patients?
a. 80 to 110 mg/dL
b. 110 to 140 mg/dL
c. 140 to 180 mg/dL
d. 150 to 175 mg/dL

3. Which of the following is a possible explanation for poor outcomes associated with hypoglycemia?
a. Hypoglycemia may be the cause of severe illness.
b. Hypoglycemia may be a biomarker of imminent death.
c. Hypoglycemia may prevent severe illness.
d. Hypoglycemia may lower the production of oxygen free radicals.

4. Which of the following is considered an advantage of computer-based technology for titrating insulin dosing?
a. Computerized programs take less time to use than traditional calculations.
b. Computerized programs are less accurate than traditional calculations.
c. Computerized programs are more expensive than traditional calculations.
d. Computerized programs can get higher rates of reimbursement than traditional calculations.

5. Which of the following was a criterion for a patient to be included in the study?
a. The patient received intravenous insulin for at least 4 hours.
b. The patient was admitted with a primary medical diagnosis.
c. The patient was in diabetic ketoacidosis.

6. How many subsets were in the nurse satisfaction survey?
a. 1
b. 2
c. 3
d. 5

7. Cardiovascular surgical patients were enrolled in the study during which of the following times?
a. Preoperatively
b. Intraoperatively
c. Postoperatively
d. In the catheter laboratory

8. Which of the following is true concerning the outcomes of glycemic control in this study?
a. The mean glucose level was higher in the control group.
b. The mean time to achieve target glucose rate was higher in the CIDC group.
c. A higher percentage of blood glucose measures were in the target range in the CIDC group.
d. There was more blood glucose measure variability in the CIDC group.

9. According to the article, the variation between glucose values measured by point-of-care compared to laboratory analysis can be as much as which of the following?
a. 10 mg/dL or less
b. 15 mg/dL or more
c. 20 mg/dL or more
d. Values should be identical

10. Which of the following was true regarding patient demographics in this study?
a. Most of the patients in both groups were diagnosed with type I diabetes.
b. Most of the patients in both groups were diagnosed with type II diabetes.
c. Most of the patients in both groups did not have a diagnosis of diabetes.

11. Which of the following is a safety feature of the CIDC method of calculating insulin titration dosing?
a. It has a faster turnaround time than laboratory analysis.
b. It has a wider therapeutic range than the Portland Protocol.
c. It models a titration dose based on the previous 4 glucose measures.
d. It uses a tighter hypoglycemia treatment range.

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