An Efficiency Evaluation of Protocols for Tight Glycemic Control in Intensive Care Units

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Background The efficiency of protocols for tight glycemic control is uncertain despite their adoption in hospitals.
Objectives To evaluate the efficiency of protocols for tight glycemic control used in intensive care units.
Methods Three separate studies were performed: (1) a third-party observer used a stopwatch to do a time-motion analysis of patients being treated with a protocol for tight glycemic control in 3 intensive care units, (2) charts were retrospectively reviewed to determine the frequency of deviations from the protocol, and (3) a survey assessing satisfaction with and knowledge of the protocol was administered to full-time nurses.
Results Time-motion data were collected for 454 blood glucose determinations from 38 patients cared for by 47 nurses. Mean elapsed times from blood glucose result to therapeutic action were 2.24 (SD, 1.67) minutes for hypoglycemia and 10.65 (SD, 3.24) minutes for hyperglycemia. Mean elapsed time to initiate an insulin infusion was 32.56 (SD, 12.83) minutes. Chart review revealed 734 deviations from the protocol in 75 patients; 57% (n = 418) were deviations from scheduled times for blood glucose measurements. The mean number of deviations was approximately 9 per patient. Of 60 nurses who responded to the workload survey, 42 (70%) indicated that the protocol increased their workload; frequency of blood glucose determinations was the most common reason.
Conclusions Nurses spend substantial time administering protocols for tight glycemic control, and considerable numbers of deviations occur during that process. Further educational efforts and ongoing assessment of the impact of such protocols are needed. (*American Journal of Critical Care.* 2007;16:589-598)

Hyperglycemia and insulin resistance are common in critically ill patients, including patients with no history of diabetes mellitus.[1,2] Elevated blood glucose levels, even a single value obtained at the time of hospital admission, have been associated with adverse outcomes in a variety of critical care settings.[3,4] Recent studies[5-8] have indicated that in critically ill patients, intensive insulin therapy reduces morbidity and mortality more than conventional hyperglycemia management. Intensive insulin therapy also costs less than conventional glycemic management does.[9,10] As a result, the American Association of Clinical Endocrinologists and the American Diabetes Association recently have established guidelines for glycemic targets in hospitalized patients.[11]

Despite the adoption of glycemic targets in hospitals and the increasing number of hospitals that are adopting protocols for tight glycemic control, questions about the implementation and efficiency of these protocols remain unanswered. Glycemic control in the inpatient setting is often suboptimal and is viewed as a secondary concern to other patient care issues.[12] Several different tight glycemic control protocols (TGCPs) have been used in published studies,[5-8] from relatively simple fixed-dose glucose-insulin infusions to more complicated protocols that require frequent testing of blood glucose levels. It is currently unknown if one of these protocols is superior to the others with regard to the effect on clinical outcomes, potential to require increased nursing time, greater expenditures for supplies and equipment, and higher rates of medication errors.

Even a single elevated glucose value at admission is associated with adverse patient outcomes.

The purpose of our study was to evaluate the relative efficiency of TGCPs used in the intensive care units (ICUs) of hospitals in the Omaha, Nebraska, metropolitan area. Study objectives were 3-fold: (1) to conduct a time-motion analysis to determine the amount of time required by nursing staff to administer the TGCP, (2) to perform a retrospective chart review to evaluate the frequency of deviations from the protocol in patients being treated with a TGCP, and (3) to assess nursing satisfaction with the TGCP and the extent of their knowledge about the TGCP by using a survey with both open-ended and multiple-choice questions.

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Methods

Time-Motion Study

A time-motion analysis of patients being treated with a TGCP in 3 hospital ICUs was performed by third-party observers using a stopwatch. Elapsed time was defined as the interval between the time a nurse picked up the point-of-care glucometer and the time activities related to that blood glucose result were completed. Elapsed time was divided into 3 intervals: (1) time required to obtain a blood glucose result by using a handheld point-of-care glucometer, (2) time required to take appropriate therapeutic action based on a blood glucose result, and (3) time to note the blood glucose result (manually or electronically) in the patient's chart.

The time to take appropriate therapeutic action was further stratified into 4 intervals: (1) interval when the blood glucose result was high enough to trigger the initiation of an insulin infusion in patients not receiving an insulin infusion, (2) interval when the blood glucose result exceeded the upper threshold of normal and required an increase in the dosage of a patient's insulin infusion, (3) interval when the blood glucose result was in the therapeutic range and no change in the insulin infusion rate was needed or no change in therapy was indicated, and (4) interval when the blood glucose result indicated hypoglycemia.

Chart Review of TGCP Deviations

Charts of consecutive patients being treated with a TGCP at an ICU in a fourth hospital (level I trauma center) that was not participating in the time-motion study were reviewed retrospectively. Protocol deviations were categorized as follows: (1)

obtaining blood glucose determinations at a time different than the time indicated in the TGCP, (2) administering an insulin dose different from that indicated in the TGCP, and (3) failure to follow any other instructions in the TGCP. Deviations for improper timing were defined as blood glucose determinations obtained more than 15 minutes before or after the appropriately scheduled time. Deviations in administering an accurate insulin dose were defined as administration of any dose other than that calculated or indicated by the TGCP. Deviations in following instructions in the TGCP algorithms included any deviation from instructions in the correct algorithm (Figure 1).

Nursing Survey

Nurses employed full-time in each of the 4 study-affiliated ICUs were asked to complete a survey assessing nurses' satisfaction with the TGCP in use at their institution. The survey also included questions about nurses' experience with the TGCP and the nurses' knowledge of appropriate glycemic targets in critically ill patients. The survey included 10 questions: 7 multiple-choice questions with answers based on a Likert scale and 3 open-ended questions (Figure 2).

Results

Time-Motion Analysis

Demographics and clinical characteristics of the patients included in the time-motion analysis are summarized in Table 1. Time-motion data were collected for 454 blood glucose determinations that were noted electronically or in writing in the medical record. These blood glucose determinations were obtained from 38 patients who were cared for by 47 different nurses during a 30-day period in 2006. A summary of the elapsed times observed in the time-motion study is shown in Figure 3. Of the 454 blood glucose determinations, 188 values were considered normal levels that did not require additional therapeutic action, 188 values were elevated in patients not receiving an insulin infusion and prompted the initiation of an insulin infusion, 240 values were out of the upper target range in patients already receiving an insulin infusion and thus prompted a change in insulin dose, and 8 values were considered to indicate hypoglycemia and necessitated temporary discontinuation of the insulin infusion.

The mean elapsed time from meter pickup to obtaining a blood glucose result from the meter was 5.18 (SD, 1.12) minutes. Elapsed time began with meter pickup and included entering patients' rooms, obtaining a blood sample and placing it into the meter, waiting for the meter to display the result, and reading or noting the result. During this period, nurses would complete other care activities while in the patient's room. The elapsed time from meter pickup to noting a normal blood glucose result (requiring no therapeutic action) in the patient's chart was 19.25 (SD, 2.14) minutes. Included in this time was approximately 5 minutes (mean, 5.17; SD, 3.96) of in-room nursing care activities after the blood glucose result was obtained and almost 9 minutes (mean, 8.90; SD, 5.90) of time after the nurse left the patient's room before the result was entered into the patient's chart or electronic medical record.

> Elapsed time for starting an insulin infusion appeared excessive and included contacting the physician, checking the policy, and waiting for the infusion to be mixed and sent.

The mean time from meter pickup to noting a blood glucose result that indicated hypoglycemia in the patient's chart or electronic medical record was 32.65 (SD, 7.68) minutes. Included in this elapsed time was stopping the insulin infusion, administering glucose, and performing other patient care activities. The greatest part of this time was 19.46 (SD, 8.14) minutes spent in the patients' rooms providing care after stopping the insulin infusion. The elapsed time between obtaining a result that indicated hypoglycemia and adjusting or stopping the insulin infusion was only 2.24 (SD, 1.67) minutes.

The mean elapsed time from meter pickup to noting a blood glucose result that was out of the upper target range in the chart/record of a patient already receiving an insulin infusion was 29.67 minutes. Important components of this elapsed time included 10.65 minutes spent reviewing the chart and the algorithm for insulin infusion in the protocol (and in some instances calling physicians to report the change), 5.40 minutes spent performing routine activities related to patient care, and 8.42 minutes from the time of leaving the patient's room until the result was actually noted in the chart.

> About 9 protocol deviations (time, dose, algorithm) occurred per patient.

The elapsed time from picking up the meter to noting a result indicating hyperglycemia in the chart of a patient requiring initiation of an insulin infusion was 51.57 minutes. The largest percentage of this time was spent with the nurse contacting the

DATE	TIME	Adult Insulin Infusion Protocol Page 1 of 2
		1. Discontinue all previous insulin orders (including sliding scale), and all other insulin protocols
		2. Run IV of: ❑ Normal Saline 0.9% to run at ___ml/hr. Use only if pt eating or on TPN, IVF or enteral feed. ❑ Dextrose 5% in Water to run at _____ ml/hr ❑ Dextrose 5% in Water and Normal Saline 0.45% to run at _____ ml/hr
		3. Insulin drip: Regular human insulin 100 units/100 ml 0.9% Normal Saline. Deliver via infusion device, prime the tubing when initiating, and must be changed every 24 hours.
		4. **Titrate Insulin Infusion to Blood Glucose Goal of: (Select One)** __ Regular Control: 80 -180 mg/dl (Recommended for most patients) -- OR -- __ Tight Control (Limited to ICU/CCU): 70-120 mg/dl (Recommended for unstable, critically ill patients e.g., cardiothoracic surgery, receiving glucorticoids or vasopressors or known diabetics on more than 80 units of Insulin daily as an OP). May transfer to floor once patient is stabilized, requiring less Accuchecks
		5. **Begin initial Insulin Infusion with: (Select One)** ❑ Algorithm 1. (recommended for most patients) -- OR -- ❑ Algorithm 2. (Recommended for unstable, critically ill patients e.g., cardiothoracic surgery, receiving glucorticoids or vasopressors or known diabetics on more than 80 units of Insulin daily as an OP).
		Algorithm 1 **BG** / **Units/hr** Less than 70 / Off 70-109 / 0.2 110-119 / 0.5 120-149 / 1 150-179 / 1.5 180-209 / 2 210-239 / 2 240-269 / 3 270-299 / 3 300-329 / 4 330-359 / 4 Greater than 360 / 6 **Algorithm 2** **BG** / **Units/hr** Less than 70 / Off 70-109 / 0.5 110-119 / 1 120-149 / 1.5 150-179 / 2 180-209 / 3 210-239 / 4 240-269 / 5 270-299 / 6 300-329 / 7 330-359 / 8 Greater than 360 / 12 **Algorithm 3** **BG** / **Units/hr** Less than 70 / Off 70-109 / 1 110-119 / 2 120-149 / 3 150-179 / 4 180-209 / 5 210-239 / 6 240-269 / 8 270-299 / 10 300-329 / 12 330-359 / 14 Greater than 360 / 16 **Algorithm 4** **BG** / **Units/hr** Less than 70 / Off 70-109 / 1.5 110-119 / 3 120-149 / 5 150-179 / 7 180-209 / 9 210-239 / 12 240-269 / 16 270-299 / 20 300-329 / 24 330-359 / 28 Greater than 360 / Call MD
		6. When starting Insulin Infusion, begin with hourly capillary (fingerstick) BG Accucheck until ordered goal is obtained. a. If patient **not at goal** and BG **does not** change (decrease) at least 60 mg/dl within one hour, move to next higher Algorithm and notify ordering physician b. For BG that is not at goal after 4 consecutive hours, contact the ordering physician; request a transfer to ICU/CCU and an Endocrine consult.
		7. **Once goal is achieved** and maintained for four consecutive hours, monitor BG as follows: **Regular Control**: Accuchecks every 4 hours given blood glucose is at goal and the patient is clinically stable. Any change in orders for diet, IV rate or composition or the patient becomes clinically unstable; begin again at #6 above, unless ordered differently by the MD. -- OR -- **Tight Control**: Accuchecks every 2 hours. Note: Critically ill patients may require hourly Accuchecks for other reasons even if they have stable BG (e.g., Vasopressor titration)
		8. Notify the ordering physician promptly of: a. Any BG changes up or down greater than 100 mg/dl or any BG greater than 360 mg/dl. b. Whenever patient moves from one Algorithm to another or the infusion is restarted. c. When the patient has received IV Insulin Infusion for 3 days.
		9. Any time BG is between 60 and 70 mg/dl, **stop Insulin infusion** and begin repeating Accuchecks every 30 minutes. a. Once BG is greater than 70 mg/dl X 2 Accuchecks, restart same algorithm and begin again at #6 above. b. For a BG less than 70 within 4 hours after resuming the same algorithm, move to next lower algorithm and begin again at step #6 above. c. For patient already on algorithm 1, contact ordering physician for further orders.
		MD Signature _____ Beeper # _____

continued

Figure 1 Protocol for tight glycemic control

continued

DATE	TIME	Adult Insulin Infusion Protocol Page 2 of 2
		10. BG less than 60 mg/dl: a. **Stop Insulin infusion** b. For awake patient - Give Dextrose 50% 25 ml (1/2 amp) IV Push c. For patient that is NOT awake- Give Dextrose 50% 50 ml (1 amp) IV Push d. Recheck BG Accucheck every 30 minutes. For BG less than 60 mg/dl and patient awake. Repeat Dextrose 50% 25 ml (1/2 amp) or for patient not awake repeat Dextrose 50% 50 ml (1 amp) IV Push. e. Once BG is greater than 70 mg/dl X 2 Accuchecks, restart Insulin Infusion, move to next lower algorithm and begin again at step #6 above. f. For patient already on algorithm 1, contact ordering physician for further orders. g. Notify the ordering physician after each dosing of Dextrose 50% given and when Algorithm restarted.
		ADJUSTMENT FOR MEALS and/or BOLUS TUBE FEEDINGS: Once the patient is consuming 50% or more of their last two meals (other than clear liquids) and/or is receiving bolus tube feedings: a. **Increase** the insulin infusion rate **two steps within the same algorithm for one hour and recheck blood glucose.** b. Adjust insulin infusion within same algorithm according to blood glucose level. c. Repeat BG in one hour. d. For **BG between 60 and 70 mg/dl, turn insulin infusion off and go back to step #9. If less than 60 mg/dL go back to step #10**
		MD Signature _____ Beeper # _____

Abbreviations: amp, ampule; BG, blood glucose; CCU, cardiac care unit; ICU, intensive care unit; IV, intravenous infusion; IVF, intravenous fluids; MD, physician; OP, outpatient; pt, patient; TPN, total parenteral nutrition.

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Figure 1

physician, checking the chart and/or TGCP, and waiting for the insulin infusion to be mixed and sent from the pharmacy to the ICU (32.56 minutes).

TGCP Deviations

A total of 75 consecutive patients were treated with a TGCP at a fourth ICU that did not participate in the time-motion study. The protocol in use at this university-affiliated institution's ICU had been adapted from the protocol published by Trence et al.[13] This ICU has 25 beds, and the TGCP had been in place for approximately 4 months. An intensivist medical team is available 24 hours a day, but mandatory consultations are not required. Patients admitted to this ICU have a wide variety of medical, surgical, and trauma diagnoses. Characteristics of this population included a mean age of 63 years, 68% men, 57% surgical cases, and 43% medical cases. Cardiac disease was the most common admitting diagnosis; next were surgery, trauma, and neurological disorders. A history of diabetes was documented in 41% of the patients. After initiation of the TGCP, the patients were followed up for a mean of 20 hours. During this time, 981 blood glucose levels were ordered (range, 9-20 per patient).

A total of 734 deviations from the protocol were documented: 57% (n = 418) were related to deviations in times for scheduled blood glucose readings, 38% (n = 279) were for incorrect insulin doses, and 5% (n = 37) were related to improper execution of the individual algorithm instructions. The mean number of deviations was slightly more than 9 per patient (range, 1-23 per patient). Most patients had deviations in more than a single category. A total of 47% had deviations related to both time and dose, and 39% had deviations in all categories (time, dose, and algorithm). The timing of the blood glucose measurement was the only deviation in 13% of patients, and 1% had a deviation in dose only. Approximately half of the 75 patients achieved their target glycemic control during the 20-hour observation period.

> Forty-two respondents (70%) reported that tight glycemic control increased their workload.

Approximately 75% of all measured blood glucose levels were associated with a protocol deviation. Because of the retrospective nature of this part of the study, we could not determine if any of the deviations resulted in clinically important adverse outcomes for patients. After these results were obtained, hospital administrators implemented a quality improvement initiative and an educational campaign about the use of the TGCP in the ICU at this institution.

Nursing Survey

A total of 220 full-time nurses at the 4 ICUs were sent a copy of the survey. A total of 75 surveys (34%) were completed and returned (Table 2). Among the respondents, 45 (60%) had been in practice more than 5 years, and 31 (41%) had practiced more

Please consider your complete experience in using the insulin infusion protocol at your hospital.

Circle the best response.

1.	I have been practicing as an ICU nurse for:	Less than 1 year	1 to 2 years	3 to 4 years	5 to 9 years	10 years or more
2.	I would characterize my experience in using the insulin infusion protocol to obtain and maintain patients at near normal glucose levels as follows:	None	Limited (fewer than 5 patients)	Average (5 to 19 patients)	Substantial (20 to 49 patients)	Extensive (50 patients or more)
3.	The insulin infusion protocol in my ICU is effective in controlling *hyperglycemia*?	Strongly disagree	Disagree	No opinion	Agree	Strongly agree
4.	The insulin infusion protocol in my ICU is effective in preventing *hypoglycemia*?	Strongly disagree	Disagree	No opinion	Agree	Strongly agree
5.	The insulin infusion protocol in my hospital is easy to administer.	Strongly disagree	Disagree	No opinion	Agree	Strongly agree

Please complete the following questions:

6. How has using the insulin infusion protocol increased or decreased your workload?

_____

_____

7. What area of the insulin infusion protocol is most difficult for you to administer? (Mark only one answer)

a. Glucose monitoring
b. Determining insulin infusion rates
c. Adjusting insulin rates
d. Charting insulin and glucose data
e. Communicating with physicians regarding glucose management
f. Other (explain):

_____

_____

8. In addition to those items listed in question #7 above, what other obstacles do you face in getting patients to their glucose targets?

_____

_____

9. What do you feel is the most common source of error when executing the insulin infusion protocol? (Mark only one answer)

a. Problems with glucose measurements
b. Problems calculating insulin doses
c. Problems with insulin concentrations
d. Problems with insulin infusion rates
e. Other (explain):

_____

_____

10. What do you believe is the optimal glucose range for the patients that you treat in your clinical setting?

_____

_____

Abbreviation: ICU, intensive care unit.

Figure 2 Nursing Satisfaction Survey

than 10 years. A total of 39 respondents (52%) had used a TGCP in more than 20 patients. A total of 55 respondents (73%) agreed that the protocol was effective in controlling hyperglycemia, and 44 (59%) agreed that the protocol was not associated with excess risk of hypoglycemia. A total of 42 respondents (56%) agreed that the protocol was easy to administer; 27 (36%) disagreed and indicated that the TGCP was difficult to administer.

A total of 60 nurses responded to the question about the effect of the TGCP on nursing workload (Table 3). Of these, 42 (70%) indicated that the TGCP increased their workload, and 24 of the 42 (57%) indicated that the increased workload was due to the increased frequency of monitoring blood glucose. Of the 13 nurses (22%) who reported a reduction in workload, 10 (77%) indicated that the TGCP reduced the need to call physicians. A total of 66 nurses responded to the question about the most difficult part of the TGCP to administer. Responses, which were not limited to a single choice, included frequent glucose monitoring in 27%, communication with physicians about blood glucose management in 21%, and determining the appropriate insulin infusion rate in 18%.

Table 1
Clinical characteristics and demographics of patients (N = 38) in the time-motion study

Characteristic	Value	
Age, mean (SD), y	63.9 (11.2)	
Sex, No. (%) of patients		
Men	22	(58)
Women	16	(42)
Ethnic background, No. (%) of patients		
White	28	(74)
African American	7	(18)
Latino	3	(8)
Primary diagnosis, No. (%) of patients		
Surgical	20	(53)
Medical	18	(47)
Diabetes mellitus, No. (%) of patients	19	(50)
No. of intensive care units	3	
No. of nurses	47	
No. of blood glucose measurements	454	

Other obstacles cited that interfered with achievement of glucose targets included the following: the algorithm did not work or was too complicated (32%); the use of other medications, including total parenteral nutrition, adversely influenced blood

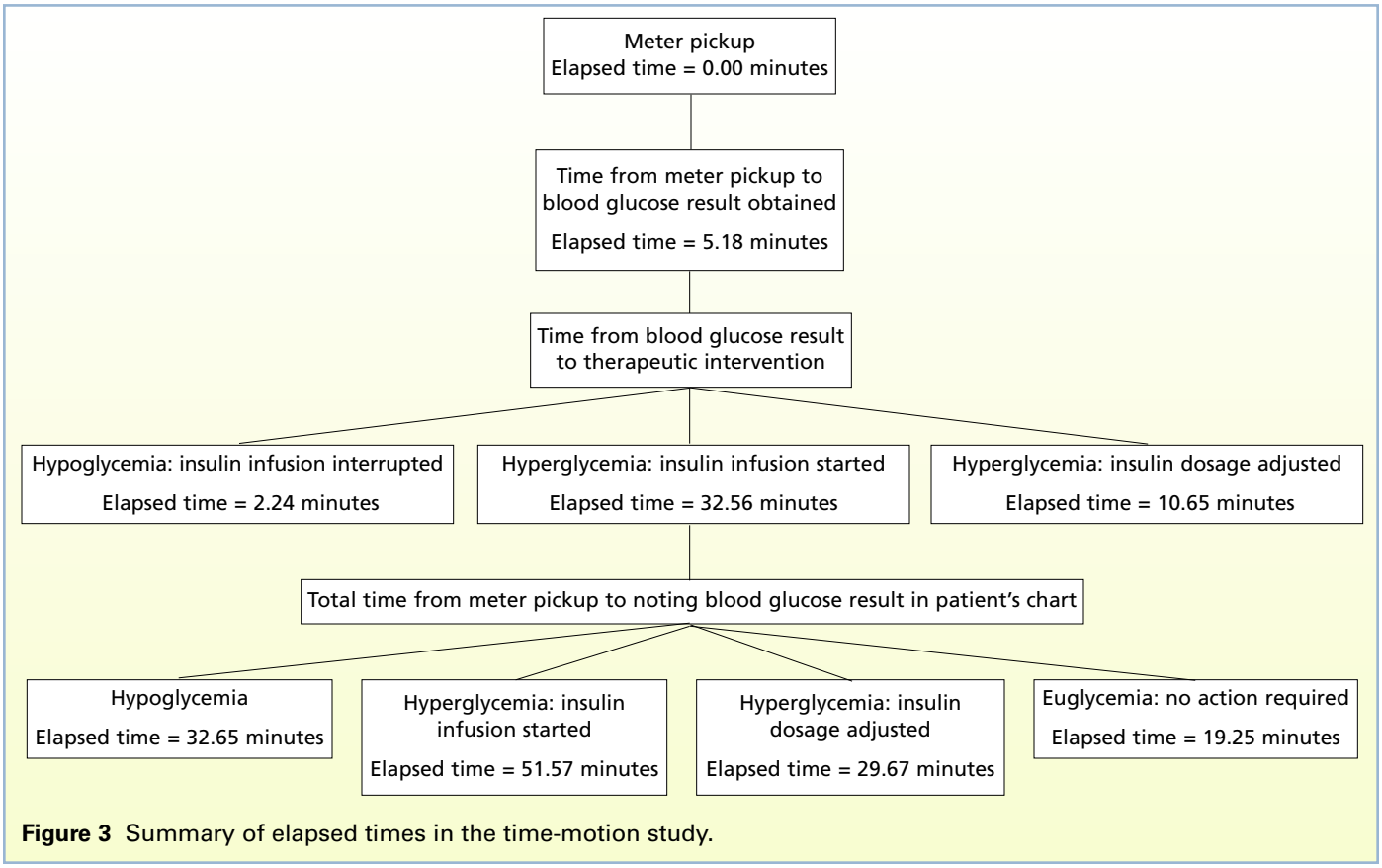

Figure 3 Summary of elapsed times in the time-motion study.

Table 2
Results of survey of full-time intensive care nurses about the protocol for tight glycemic control

Question	No. of respondents	% of respondents[a]
Years in practice		
<1	7	9
1-2	14	19
3-4	9	12
5-9	14	19
≥10	31	41
Experience with protocol		
None	0	0
<5 patients	12	16
5-19 patients	24	32
20-49 patients	23	32
≥50 patients	16	21
Protocol effective in controlling hyperglycemia		
Strongly disagree	2	3
Disagree	11	15
No opinion	7	9
Agree	47	63
Strongly agree	8	11
Protocol effective in preventing hypoglycemia		
Strongly disagree	4	5
Disagree	20	27
No opinion	7	9
Agree	38	51
Strongly agree	6	8
Protocol easy to administer		
Strongly disagree	3	4
Disagree	24	32
No opinion	6	8
Agree	39	52
Strongly agree	3	4

[a] Because of rounding, percentages do not all total 100.

Table 3
Responses of 60 nurses to the survey question about the effect of the protocol for tight glycemic control on workload

Reason for response	Increased workload	Decreased workload	No change
No. of blood glucose checks	24	0	0
No reason given	7	3	5
No. of phone calls	4	10	0
Patients eating/receiving tube feedings	4	0	0
Patient complaints	1	0	0
Protocol too complicated	1	0	0
Dosage adjustments	1	0	0
Total responses, No. (%)	**42 (70)**	**13 (22)**	**5 (8)**

glucose measurements (19%); and patients who were eating or receiving tube feedings had blood glucose levels that were difficult to control (19%). A total of 38% of the respondents identified problems with the insulin infusion rate as the most common source of error with the TGCP.

When nurses were asked about the optimal blood glucose range in the critical care setting, 22 different blood glucose ranges were specified. The most common response, offered by 35% of respondents, was 70 to 150 mg/dL (to convert to millimoles per liter, multiply by 0.0555). A total of 56% of the respondents stated that the minimum blood glucose goal should be 70 mg/dL, and 74% indicated that the maximal blood glucose goal should be between 120 and 150 mg/dL.

Discussion

Studies[5-10] published to date indicate that tight glycemic control improves outcomes and reduces the cost of care in critically ill patients. As a result, a growing number of hospitals are implementing TGCPs in their ICUs. Relatively little has been published on how implementing a TGCP affects nurses' workloads. The number of patients receiving insulin infusions is substantially higher in ICUs where a TGCP has been implemented than in other ICUs. This increase in the number of patients receiving insulin infusions and the requirement of frequent (every 1-2 hours) blood glucose monitoring could increase nurses' workload. In our study, times required to carry out various phases of a TGCP were recorded, nurses were surveyed to assess attitudes and experience with a TGCP, and charts were reviewed retrospectively to assess the frequency and types of protocol deviations that occurred during administration of a TGCP. This study is the first comprehensive evaluation designed to assess the efficiency of using TGCPs in ICUs.

Elapsed times (Figure 3) to achieve various milestones in the TGCP observed in the ICUs in our study seem quite long for what may have been assumed to be relatively simple tasks. The elapsed time from meter pickup to obtaining a blood glucose result from the glucometer was slightly more than 5 minutes. However, a number of activities occurred during this time, including meter startup, moving from the nurse's station into a patient's room, obtaining a blood sample from the patient, and placing the blood sample into the glucometer. In addition, once the blood sample was placed into the glucometer, nurses would often take care of the patient's other care needs while waiting for the blood glucose result to appear on the readout of the meter. Similar observations were made during other intervals of elapsed time.

The time from obtaining a normal blood glucose value until the time that the result was actually noted

in the medical record was slightly greater than 19 minutes. It obviously does not take this amount of time to perform this task, but nurses performed other activities during this time before actually entering the result in the medical record, often entering the result at the same time that other medical information was being noted in the chart. The elapsed time from obtaining a blood glucose reading that indicated hypoglycemia to the time of therapeutic intervention (ie, stopping the insulin infusion) was slightly greater than 2 minutes.

Elapsed times for certain milestones did seem excessive. For example, an elapsed time of almost 33 minutes to start an insulin infusion seems excessive. Most of the elapsed time was spent waiting for insulin infusions to be delivered from the pharmacy. Efforts to reduce the time required for the pharmacy to provide an insulin infusion seem warranted. One other elapsed time that seemed excessive was the time to increase an insulin infusion dose in response to a blood glucose reading indicating hyperglycemia. The elapsed time of almost 11 minutes after obtaining a result indicating hyperglycemia should be shorter. Most of the time spent during this time interval was used to review the medical chart and to calculate the new insulin infusion dose on the basis of the TGCP. Calculating insulin doses was listed as a cause of difficulty in administering a TGCP in the survey, so attempts to simplify dose calculations seem worthwhile.

Determining whether most of the times observed during the time-motion analysis should be considered within the accepted standard of practice is difficult. In the only other published study[14] of times to achieve milestones during administration of a TGCP in an ICU, the mean time to obtain a blood glucose result and change the insulin infusion was only 4.7 minutes (range, 3.1-8.2). The clinical importance of this finding, which is a full 10 minutes shorter than our time to adjust an insulin infusion, is uncertain. In the study by Aragon,[14] only 21 timed blood glucose observations were evaluated in 4 different ICUs. No other information was provided about these observations. It is not certain how many different nurses were involved in the measurements, how many patients were included in the analysis, how long a patient had been receiving an insulin infusion when samples were being collected, or at what time intervals (every 1 hour or every 4 hours) the samples were being collected. Isolated observations made in what could be construed as "staged" timing events certainly would produce results different from the elapsed times for samples being collected longitudinally during the routine course of patient care in a busy ICU, as in our study.

In our time-motion analysis, attempts were made to observe nurses during 12-hour blocks of time per patient, during which the blood samples for glucose testing were collected. This approach included the impact of shift change, nurses' leaving the unit for breaks and meals, and the usual variations in the intensity of care that occur over a long period. Additional time-motion analyses performed in a fashion similar to the one we used must be done to determine the optimal times for achieving the various milestones in administering a TGCP in an ICU.

The survey results we collected on nurses' attitudes about workload related to administration of a TGCP in an ICU were generally similar to the findings of Aragon.[14] In our survey, which included 75 respondents, 74% of the nurses thought that their TGCP was effective in controlling hyperglycemia and 59% agreed that the TGCP was not associated with hypoglycemia, but only 56% agreed that the TGCP was easy to administer. Of the 60 nurses who responded to a question about the impact of the TGCP on nursing workload, 42 (70%) indicated that TGCP increased their workload. Of those 42, 24 indicated that the number of blood glucose determinations was the primary reason for the increased workload.

In the Aragon survey,[14] in which nurses were asked questions that differed slightly from ours about the use of TGCP, 49 of 66 respondents (74%) indicated that the TGCP took too much time, was too much work, or was a waste of time. The data from the survey by Aragon also indicated that the frequency of blood glucose determinations was a major source of increased workload. In addition, the need to obtain blood via finger sticks was an obstacle. In the Aragon study, a substantial percentage of nurses indicated a desire to use arterial catheters or central venous catheters to collect blood rather than collecting blood via finger sticks. A total of 76% percent of the nurses in the Aragon study also indicated that they would be willing to dedicate an intravenous catheter to blood glucose measurements.

> Much of the elapsed time in treating hyperglycemia was spent calculating new insulin infusion doses from the protocol.

Communication with physicians and difficulty using the TGCPs in patients receiving oral or intravenous feedings were some of the more common problems identified by our respondents. As previously mentioned, calculating insulin infusion doses also was a problem with the TGCPs. Problems with

the insulin infusion rate were identified as the most common source of error with a TGCP. These obstacles could be lessened by improved education about TGCP administration and/or by altering or adjusting the TGCP.

Perhaps one of the most surprising findings of our efficiency evaluation was the high number of deviations from the protocol. Clearly, a mean of approximately 9 deviations per patient represents substandard care. Because the times for blood glucose determinations were outside the accepted range of ±15 minutes more than 75% of the time, perhaps the nurses simply did not appreciate the importance of the TGCP. Although the reasons for the excessive number of protocol deviations cannot be determined, the TGCP had been in place for only 4 months when the chart review took place. After the results of the chart review were disseminated, nursing administrators (in the unit where the deviations occurred) initiated an ongoing education and training program for nurses that focused on administration of the TGCP. The high rate of protocol deviations seems consistent with the finding that most survey respondents could not state the optimal blood glucose range used in the TGCP.

Conclusion and Recommendations

Both the time-motion analysis and the responses to the nursing survey indicate that substantial nursing time is involved in the administration of a TGCP. In addition, a substantial number of protocol deviations occurred during administration of a TGCP. Additional educational efforts and refinements in TGCP administration are needed. Methods designed to simplify TGCPs and to streamline documentation of health information should be implemented. Ongoing assessment of the effect of TGCPs on nurses' workloads also should be done.

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