EVALUATION OF NURSING WORK EFFORT AND PERCEPTIONS ABOUT BLOOD GLUCOSE TESTING IN TIGHT GLYCEMIC CONTROL

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- **BACKGROUND** Tight glycemic control is important in critically ill patients and involves insulin infusions and monitoring of blood glucose levels. Hourly measurements of blood glucose levels and adjustments of intravenous insulin doses require additional work by nurses.
- **OBJECTIVES** To evaluate the nursing work incurred with and nursing perceptions about tight glycemic control and blood glucose monitoring.
- **METHODS** A variety of intensive care units were studied. Surveys were used to gain information about nurses’ perceptions. Time-in-motion observations were used to determine the time taken to measure blood glucose levels and adjust insulin doses.
- **RESULTS** Nurses thought that tight glycemic control was important and that the work associated with it was substantial. Nurses thought that easier and automated forms of blood glucose monitoring are needed. They preferred using an arterial catheter to obtain blood samples to avoid excessive finger sticks. The total number of blood glucose measurements was 77,954. The mean time taken for hourly blood glucose monitoring and adjustment of insulin doses was 4.72 minutes. The estimated costs of time spent on glycemic control during a 1-year period were $182,488 for nurses’ salaries and $58,500 for supplies.
- **CONCLUSIONS** Although most nurses endorse tight glycemic control, the work associated with it is burdensome and costly. Because up to 2 hours might be required for tight glycemic control for a single patient in a 24-hour period, the costs in time and money are high. Easier clinical methods for monitoring blood glucose levels are needed. (American Journal of Critical Care. 2006;15:370-377)

Glycemic control has emerged as a critical clinical management strategy in critically ill adults, primarily because a growing body of evidence during the past decade has indicated that elevated blood glucose levels are associated with adverse outcomes and that controlling blood glucose levels within more normal ranges yields more positive outcomes. Hyperglycemia in critically ill patients is associated with higher rates of sternal wound infections, nosocomial infections, mortality, and other clinically relevant complications. The detrimental impact of hyperglycemia on postoperative infections also has been recognized. Tighter glycemic control has been associated with decreases in complications, infections, length of stay, morbidity, and mortality in a variety of clinical settings and populations. Additionally, glycemic control has resulted in a reduction of other adverse clinical events associated with critical illness, such as renal failure, bloodstream infections, and prolonged ventilatory support. With the advent of this knowledge, initiatives to control blood glucose levels have developed in many critical care units across the United States and the world.

Clinical strategies to maintain a euglycemic state during critical illness involve frequent monitoring of
blood glucose levels and use of intravenous insulin infusions to control glucose levels within strict ranges. Many and varied protocols are used to maintain more normal blood glucose levels. However, 2 elements are common in most protocols: frequent (hourly or more often) measurements of blood glucose levels and careful adjustment of intravenous insulin doses to achieve normal blood glucose levels. This process is used to achieve a patient’s targeted blood glucose levels within the shortest time possible in a safe manner, thereby limiting the duration of hyperglycemia. Initial and subsequent measures of blood glucose levels depend on the patient’s response to therapy and are crucial for glycemic control and detection of hypoglycemia.

Studies on the implementation of strategies for glycemic control have focused mostly on the impact of the strategies on patients’ outcomes, process compliance, safety, and effectiveness. In some of the studies, comments were solicited from nurses about barriers to glycemic control. In a pilot study in the spring of 2005 on the safety, compliance, and effectiveness of a new set of standardized physician orders for intravenous insulin infusion, nurses were asked to make comments or suggestions about the order set and processes for glycemic control. Nurses indicated that once they understood the value of controlling blood glucose levels, they were willing to use the protocols, but an increase in work and time was required for blood glucose monitoring and adjustments to insulin doses. During this process of implementation, more point-of-care (POC) blood glucose monitors were required to accommodate the increase in the number of blood glucose assays required.

**Tight glycemic control reduces complications, infections, length of stay, morbidity, and mortality.**

In previous cost analyses of POC measurements of blood glucose levels, the time required to perform the measurements was used to gauge the costs of the monitoring. Greendyke reported that POC blood glucose testing took about 5 minutes of nursing time. Lee-Lewandrowski et al estimated that the time required was between 3 and 5 minutes. Both of these studies were done more than 10 years ago and mostly involved regular medical surgical units or a hospital system. In a review of the literature, I found no studies that specifically addressed the current costs and nursing work associated with measuring blood glucose levels or estimated costs and nursing work associated with tight glycemic control in critical care. Implementation of strategies for tight glycemic control in critical care requires an increased commitment of time and effort by nurses. Because of the large number of hourly assessments and measurements required for most critically ill patients, the addition of another test and adjustment of therapy increase the work effort for nurses in an already work-intensive environment.

**Costs and nursing work associated with blood sugar testing and tight glycemic control are unknown.**

Critical care nurses perform many assessments, measurements, documentations, and therapies on an hourly and ongoing basis, including monitoring hemodynamic parameters, oxygenation, and ventilation; adjusting vasoactive drugs; and providing care to patients. Thus, adding frequent measurements of blood glucose levels and adjustments in intravenous insulin doses results in an increase in nurses’ workload. Most insulin infusions are started by nurses and maintained by intensive care unit staff. For glycemic control initiatives to be effective and safe, understanding the effect of adding these procedures to nursing work is crucial. Because of the shortage of critical care nurses and the need for temporary personnel, any means of controlling workload and ensuring patients’ safety is important.

Tighter glycemic control requires changes in clinical behaviors and use of resources. Intravenous administration of insulin is a mainstay of treatment used to treat hyperglycemia in critically ill patients, mostly because of the rapid onset action of the drug, the rapid rate of response to the treatment, and more predictable dosing, given abnormalities in circulation in many critically ill patients. Historically, critical care nurses have been most familiar with intravenous insulin therapy used to treat hyperglycemic emergencies, such as diabetic ketoacidosis and hyperglycemic hyperosmolar syndrome. As tight glycemic control has become more prevalent, more nurses are becoming familiar with intravenous administration of insulin, and this trend has influenced care delivery in critically ill patients.

The timing for blood glucose monitoring for ultimate glycemic control is not an exact science, and changes in blood glucose levels can vary widely in critically ill patients. Blood glucose levels can change quickly in response to intravenous administration of insulin and to other factors that promote hyperglycemia, such as the stress response to illness; administration of catecholamine drugs, steroids, or
intravenous solutions containing glucose; surgery; and enteral and parenteral nutrition. Blood glucose monitoring during infusion of intravenous insulin is typically performed hourly during major adjustments in the dose of insulin to a preset target range. The frequency may be increased during adjustment in doses of catecholamine-type drugs and during other rapidly changing clinical states. Once a patient’s blood glucose level is stabilized within an acceptable range for several hours, usually the monitoring can be reduced to every 2 to 4 hours.

Nursing knowledge and clinical behaviors have been changed as a result of the use of tight glycemic control. Because more patients than before are receiving intravenous insulin infusions, nurses must be able to understand and implement protocols for glycemic control, which can be complex and difficult to understand. Additional documentation is also required during tight glycemic control for recording the results of blood glucose monitoring, response to treatment, rate of infusion of insulin, and administration of medications. With certain populations of patients, nurses are commonly assigned to more than one patient receiving insulin infusions, posing an additional burden. Nurses are also required to have POC education and competency verification on an annual basis and to be able to perform quality control testing.

The purpose of the study reported here was to evaluate the impact of hourly blood glucose monitoring and adjustment of intravenous insulin infusions in terms of nursing work and nurses’ perceptions. The specific aims were to estimate the financial impact of blood glucose monitoring required for glycemic control, understand nurses’ perceptions of blood glucose monitoring and tight glycemic control, and determine the amount of time required to monitor blood glucose levels and adjust doses of intravenous insulin.

The following research questions were addressed in the study:

- What is the mean time required to perform POC measurement of blood glucose levels?
- What are the preferred sites for obtaining blood samples for measurements of blood glucose levels?
- What are nurses’ perceptions of performing frequent POC measurements of blood glucose levels for tight glycemic control?
- What is the potential financial impact of tight glycemic control?

Methods

The study was observational and exploratory; a time-in-motion and survey design was used. Direct observations were made to evaluate the time taken to measure blood glucose levels and adjust doses of intravenous insulin. Surveys were used to ascertain nurses’ perceptions of blood glucose monitoring. The study was approved by the nursing research committee and the institutional review board.

Setting and Sample

The study site was a level I trauma center in the Southeastern United States. The study was done in medical, surgical, neurosurgical, and burn/trauma intensive care units; coronary care units; and areas for recovery from open heart surgery. The total number of beds was 58. The intensive care units and areas for recovery from open heart surgery were the ones most involved in the intravenous insulin initiative at the time of the study. The sample included registered nurses from those units who agreed to participate in the study and who typically were assigned 2 critically ill patients. A total of 122 nurses were employed in these units during the study period.

At the medical center, a widespread performance improvement initiative, the Systemwide Undertaking for Glycemic Achievable Results (the SUGAR project), included the use of strategies for tight glycemic control in critical care and the development of protocols for infusion of intravenous insulin. The infusion protocols included hourly POC blood glucose monitoring during acute management phases of glycemic control, with subsequent reduction in monitoring once a patient’s blood glucose level stabilized within a target range, usually 4.4 to 6.1 mmol/L (80-110 mg/dL). Implementation of the initiatives included intensive education, and studies were done to determine the safety and efficacy of the strategies. At the time of the study reported here, the newly revised initiative for intravenous insulin therapy had been under way for approximately 10 months. All patients in the critical care units had blood glucose monitoring at least every 6 hours per unit protocol to determine the need for glycemic control.

Procedures

Nurses were recruited during staff meetings and through information passed along by nursing operations managers, assistant nurse managers, and unit-based educators. Surveys were distributed to all 122 registered nurses in the study units. The nurses were told that participation in the study was voluntary, that the responses were anonymous, and that completion of the survey implied consent. The medical center’s nursing research committee reviewed the survey for content, structure, and face validity and provided recommendations. One section of the survey consisted of 7 questions with answers based on a 5-point Likert scale.
about the respondent’s feelings about blood glucose monitoring and glycemic control. A second section had a list of specific statements with the instructions to check the statements consistent with the respondent’s feelings about blood glucose monitoring during tight glycemic control. The third section was open-ended and allowed for individual comments related to the research questions.

The POC testing coordinator provided data on the number of POC blood glucose and quality control measurements performed in the study units during the 12 months preceding the study. Nursing operations managers for the units provided the mean salary for registered nurses in the respective units. The materials management department provided the costs for materials for blood glucose monitoring.

Nurses were asked about their willingness to be observed and timed while performing a scheduled measurement of blood glucose level and making adjustments in intravenous insulin therapy. A checklist of 32 steps that might be done during this process was used during observation. The checklist included 3 methods for obtaining blood samples for determination of glucose levels: arterial catheter, finger stick, and central venous catheter. A stopwatch was used to time nurses while they performed the procedures. The starting point was obtaining the equipment for monitoring; the end point was documenting on a manual flow sheet the adjustments made.

The medical center required other documentation on each patient’s computerized medical record, including intravenous insulin dosing regimens and results of blood glucose tests. Because the nurses recorded these data and many other items in the computerized records at the nurses’ convenience during various times of the shift, the time required for the computer documentation was not included in the study. For an estimated time of 5 minutes for completion of blood glucose monitoring, an analysis indicated that at least 10 observations would be required to detect a difference of 1 SD at 80% power.

Results

Survey Results

A total of 66 nurses completed the survey, for an overall response rate of 54%. The response rates were 63% for units in which intravenous insulin therapy was regularly performed and 17% for a unit that had just recently implemented intensive glycemic control.

Nurses’ Rating on Likert Scale. The responses to the 7 questions in the first section of the survey are summarized in Table 1. For each statement, a score of 3 indicated moderate agreement with the statement.

Scores greater than 3 indicated stronger agreement, and scores less than 3 indicated less agreement. According to the scores, the nurses generally strongly agreed that glycemic control was important. They reported moderate agreement with the statement that hourly measurement of blood glucose levels was too much work for bedside nurses. The respondents were concerned about multiple finger sticks and strongly agreed that automation of blood glucose measurement would make glycemic control easier.

Nurses’ Responses to Specific Statements. The responses to the 10 specific statements are given in Table 2. Nurses continued to indicate that too much work was involved in the procedures required for tight glycemic control. A total of 86% indicated that an easier or more automated form of measurement was needed, and 76% indicated that they would be willing to devote an intravenous access for that purpose.

### Table 1 Survey responses ranking statements about glycemic control procedures (n = 66)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Response*</th>
</tr>
</thead>
<tbody>
<tr>
<td>I believe that keeping blood glucose levels in the normal range (4.4-6.1 mmol/L [80-110 mg/dL]) really makes a difference in patients’ outcomes</td>
<td>4.32 0.96 5</td>
</tr>
<tr>
<td>Having to perform hourly bedside blood glucose testing is a barrier for glycemic control</td>
<td>1.96 1.82 2</td>
</tr>
<tr>
<td>I don’t mind doing hourly blood glucose measurements for intravenous insulin therapy</td>
<td>2.18 1.68 2</td>
</tr>
<tr>
<td>I believe that performing hourly blood glucose measurements for glycemic control is too much work for the bedside nurse</td>
<td>2.98 1.66 3</td>
</tr>
<tr>
<td>I would prefer that my patient is not on the intravenous insulin infusion orders in the intensive care unit</td>
<td>2.38 1.78 2</td>
</tr>
<tr>
<td>I am concerned about the many finger sticks performed for measurements of blood glucose levels</td>
<td>3.73 1.43 4</td>
</tr>
<tr>
<td>If I had an automated way to get blood glucose readings, it would make glycemic control easier</td>
<td>4.83 0.54 5</td>
</tr>
</tbody>
</table>

* Based on a 5-point Likert scale, where 3 indicated moderate agreement.
A total of 90% indicated that a registered nurse usually performs blood glucose monitoring during administration of infusions of intravenous insulin. A total of 44% reported that they used an arterial catheter and finger sticks to obtain blood samples for glucose testing; 35% used both of those plus a central venous catheter; and 18% predominantly used finger sticks. Sixty-four of the nurses responded to the question about which site they preferred to use to obtain blood samples for testing. An arterial catheter was the preferred site for 49 respondents (77%). The reasons for this choice varied: 29 (59%) preferred it because fewer finger sticks were needed; 14 (29%) because they thought blood loss was less than with other sites; 12 (24%) because they thought it was easier than other sites; and 2 (4%) because they thought using an arterial catheter reduced the risk of infection. A total of 13 respondents (20%) preferred using finger sticks because that method was easier (54%) and resulted in less blood loss (23%). Only 2 respondents preferred to obtain blood samples via a central venous catheter.

Open-ended Section. The responses of the nurses in the open-ended part of the survey included their perceptions of glycemic control procedures and were wide and varied. Many respondents completed a full page of discussion, including positive and negative comments. Themes were generated from the responses and were placed into 5 categories: good for patients’ care, concern about effects on patients, work effort, monitoring issues, and comments on the protocol for intravenous insulin therapy. Table 3 summarizes key areas of responses. Only a single respondent did not think that tight glycemic control was important. The findings from this section of the survey further substantiated the responses on the other sections and broadened understanding of nurses’ perceptions.

Observational Results

A total of 21 nurse observations were conducted in 4 of the 6 units during the nurses’ usual times for measuring blood glucose levels and adjusting insulin doses. The range of times was 3.13 minutes 22 seconds to 8.15 minutes 53 seconds, with a mean of 4.72 minutes (SD 1.13, median 4.67). Some of the longer times involved finding blood glucose monitors, troubleshooting the monitoring device, and obtaining measurements in patients with isolation precautions. In some of the shorter times, some of the potential steps were omitted, such as hand hygiene or wearing gloves, and other shortcuts were taken.

Financial Results

The number of POC blood glucose tests done in the study units from September 2004 through August 2005 was 77,954 and had increased steadily as the intravenous insulin initiative grew. The mean time for performing blood glucose testing and making adjustments in intravenous insulin therapy and the nurses’ mean salary plus benefits were used to estimate the approximate costs for tight glycemic control procedures for the 1-year period. The estimated cost of nursing salary for this purpose was $182,488. The time for entering insulin dosing data in the computerized medical record was not included because all measurements did not include adjustments in intravenous insulin.

Table 2: Survey responses to statements about perceptions of glycemic control (n = 66)

<table>
<thead>
<tr>
<th>Statement/question</th>
<th>Respondents</th>
<th>%</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Too much work</td>
<td>24</td>
<td>24</td>
<td>16</td>
</tr>
<tr>
<td>Takes too much time</td>
<td>44</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>Is a waste of time</td>
<td>6</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Easier if automated</td>
<td>85</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>Like doing it</td>
<td>1.5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Is not difficult to do</td>
<td>38</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Normal part of patients’ care</td>
<td>45</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Should be done by someone other than a nurse</td>
<td>15</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Willing to dedicate an intravenous catheter for measurement if automated and displayed</td>
<td>76</td>
<td>50</td>
<td></td>
</tr>
</tbody>
</table>

A total of 90% indicated that a registered nurse usually performs blood glucose monitoring during administration of infusions of intravenous insulin. A total of 44% reported that they used an arterial catheter and finger sticks to obtain blood samples for glucose testing; 35% used both of those plus a central venous catheter; and 18% predominantly used finger sticks. Sixty-four of the nurses responded to the question about which site they preferred to use to obtain blood samples for testing. An arterial catheter was the preferred site for 49 respondents (77%). The reasons for this choice varied: 29 (59%) preferred it because fewer finger sticks were needed; 14 (29%) because they thought blood loss was less than with other sites; 12 (24%) because they thought it was easier than other sites; and 2 (4%) because they thought using an arterial catheter reduced the risk of infection. A total of 13 respondents (20%) preferred using finger sticks because that method was easier (54%) and resulted in less blood loss (23%). Only 2 respondents preferred to obtain blood samples via a central venous catheter.
approximately $50,670. During the same period, 10,631 quality control tests were performed in the study units, with an approximate cost of $5800. This amount does not include the costs for time to perform quality control tests, because they are performed by various personnel and were not measured in this study. Docking of the POC device to download blood glucose values typically is done twice per 24-hour period and is usually performed by the clinical technician and was not included as part of this study. Other costs associated with annual competency training for POC blood glucose analysis required by all nurses were estimated. The estimated cost for this training was at $5446 annually for the nurses in the unit. In this study, the costs for the POC coordinators and educators assigned were not included.

### Costs to achieve tight glycemic control, in both dollars and nursing time, are considerable.

**Discussion**

The study had a number of limitations. For example, it was not a comprehensive evaluation of the financial impact of glycemic control; however, the calculated estimates indicate that the costs associated with tight glycemic control are not trivial. The salary costs might have been somewhat overestimated or underestimated, because all POC blood glucose tests done in the unit during the whole year were included. Clinical technicians may have done some tests, and some patients were not receiving insulin infusions. However, conservative estimates for nurses’ salary, time, training, and supplies for the critical care units for 1 year totaled nearly $250,000. If a patient has hourly blood glucose monitoring during tight glycemic control, nearly 2 hours of direct nursing time is spent monitoring blood glucose levels and making adjustments in insulin therapy for 1 patient alone per day.

Other limitations were excluding the time taken to document insulin administration in the computerized medical record, the time spent on performing quality control tests, and the time required to dock the POC device to download blood glucose values.
Finally, a small sample size was used for the observation of time taken to perform blood glucose monitoring (n=21).

While conducting this study, I was often present in the critical care units. Many unsolicited comments were made by nurses when approached about participating in the study. For example, nurses said that although they knew glycemic control was probably important, maintaining glycemic control with a usual patient assignment was difficult. Some nurses said that they try to keep their patients off intravenous insulin if at all possible.

In a recent pilot study by Bland et al, nurses indicated that the work associated with caring for 2 patients treated according to the protocol was taxing and that they felt they could not meet all the requirements for the patients’ care for that assignment. This finding was consistent with comments made by nurses in my study. One solution offered by nurses in the study by Bland et al and in this study was to reduce the frequency of blood glucose measurements, particularly once the blood glucose level has stabilized at the target rate.

Although this strategy would reduce nursing work time, if the intervals between blood glucose measurements were extended, opportunities to establish tighter glycemic control might be missed, and control of hyperglycemia might be inconsistent, and hypoglycemic events might be missed. In the same study by Bland et al, nurses preferred obtaining blood samples from arterial catheters to avoid excessive trauma caused by frequent finger sticks. These findings also were supported by the findings in my study. A total of 59% of nurses in my study preferred using an arterial catheter to avoid multiple finger sticks, and 29% preferred using one to avoid unnecessary blood loss.

In my study, nurses indicated that an easier or automated method of blood glucose monitoring was desired. Technology is advancing in the area of continuous blood glucose monitoring in an acute care setting. Goldberg et al evaluated the efficacy and safety of a continuous blood glucose monitoring system generally used for outpatient control of diabetes in a medical intensive care unit. Their results indicated that the use of continuous blood glucose monitoring had clinically acceptable accuracy and that modification of its use might have applications in critical care and tight glycemic control. When continuous monitoring is used, some of the barriers to tight glycemic control can be addressed, including a decrease in nursing workload associated with measurement of blood glucose levels, a method to detect and provide notification of unacceptable changes in blood glucose levels, and timely intervention with insulin infusions. Goldberg et al remarked that future studies should incorporate use of real-time measurements of blood glucose levels and evaluations of the impact of such measurements on glycemic control in critical care areas.

Conclusions and Recommendations

Findings from this study indicated that nurses appreciate the need for glycemic control and think that such control is good for patients’ care. They also recognize the increased work effort associated with maintaining tight glycemic control. When nurses are assigned patients to care for, the additional effort required for tight glycemic control should be weighed as well as the acuity of the patients’ illness. In addition, the time required for administration of intravenous insulin could be limited by more aggressive implementation of subcutaneous basal and prandial insulin administration once a patient’s blood glucose level has stabilized within normal ranges during infusion of intravenous insulin at low rates.

Financial costs and time allotment associated with glycemic control in critical care are substantial. Some improvements in costs might be realized if patients’ outcomes are improved and the length of stay is reduced as a result of glycemic control.

Future technological advances and studies are needed to evaluate the use of automated, continuous, and/or noninvasive blood glucose monitoring and the impact of such monitoring on glycemic control in critical care. If monitoring devices that require less nursing time and effort to determine blood glucose levels are used, possibly more timely interventions can be made and nurses can spend time on other critical activities.

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REFERENCES


Evaluation of Nursing Work Effort and Perceptions About Blood Glucose Testing in Tight Glycemic Control
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