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Glycemic control in the ICU: a multicenter survey

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Abstract *Background:* Intensive insulin therapy has recently been shown to decrease morbidity and mortality in the critically ill population in a large randomized clinical trial. *Objective:* To determine the beliefs and attitudes of ICU clinicians about glycemic control. *Design:* Self-administered survey. *Participants:* ICU nurses and physicians in five university-affiliated multidisciplinary ICUs. *Results:* A total of 317 questionnaires were returned from 233 ICU nurses and 84 physicians. The reported clinically important threshold for hypoglycemia was 4 mmol/l (median, IQR 3–4 mmol/l). In non-diabetic patients, the clinically important threshold for hyperglycemia was 10 mmol/l (IQR 9–12 mmol/l); however, nurses had a significantly higher threshold than physicians (difference of 0.52 mmol/l (95% CI 0.09–0.94 mmol/l, P=0.018). In diabetic patients, the clinically important threshold for hyperglycemia was also 10 mmol/l (IQR 10–12 mmol/l), and again nurses had a significantly higher threshold than physicians (0.81 mmol/l, 95% CI 0.29–1.32 mmol/l, P=0.0023). Avoidance of hyperglycemia was judged most important for diabetic patients (87.7%, 95% CI 84.1–91.3%), patients with acute brain injury (84.5%, 95% CI 80.5–88.5%), patients with a recent seizure (74.4%, 95% CI 69.6–79.3%), patients with advanced liver disease (64.0%, 95% CI 58.7–69.3%), and for patients with acute myocardial infarction (64.0%, 95% CI 58.7–69.3%). Physicians expressed more concern than nurses about avoiding hyperglycemia in patients with acute myocardial infarction (P=0.0004). ICU clinicians raised concerns about the accuracy of glucometer measurements in critically ill patients (46.1%, 95% CI 40.5–51.6%). *Conclusions:* Attention to these beliefs and attitudes could enhance the success of future clinical, educational and research efforts to modify clinician behavior and achieve better glycemic control in the ICU setting.

Keywords Glucose · Glucometer · Insulin · Critically ill

Introduction

The adverse consequences of chronic hyperglycemia are well known in patients with diabetes. The Diabetes Control and Complications Trial in which 1441 patients with type I diabetes were enrolled demonstrated that patients randomized to intensive insulin management had significantly less retinopathy, nephropathy and neuropathy compared to those managed conventionally [1]. Similarly, the UK Prospective Diabetes Study of 3867 patients with type II diabetes showed that intensive glucose control with oral hypoglycemic agents or insulin to achieve a target fasting glucose of <6 mmol/l resulted in significantly fewer microvascular complications than conventional management [2].

The adverse consequences of acute hyperglycemia have also been highlighted recently. A meta-analysis of 15 observational studies showed that among patients without diabetes following myocardial infarction, those with glucose values in the range 6.1–8.0 mmol/l had a 3.9-fold (95% CI 2.9–5.4) higher risk of death than patients without diabetes who had lower glucose values [3]. In addition, among diabetic patients with glucose values in the range 10.0–11.0 mmol/l, the risk of death was moderately increased (relative risk 1.7, 95% CI 1.2–2.4). Following stroke, a meta-analysis of 32 observational studies among non-diabetic patients found that acute hyperglycemia (6.1–8.0 mmol/l) was associated with an increased risk of in-hospital mortality (relative risk 3.07, 95% CI 2.50–3.79), and increased risk of poor functional recovery in non-diabetic stroke survivors [4]. To test the hypotheses that outcomes could be improved in patients with lower blood glucose during acute illness, in the DIGAMI study 620 patients with diabetes and myocardial infarction were randomly allocated to intensive metabolic treatment with insulin-glucose infusion followed by multidose insulin treatment or to standard treatment. The investigators found a significant reduction in mortality in the intensive treatment group at 1 year [5], and 3.4 years [6].

During critical illness, stress hyperglycemia is common, due to excessive counter-regulatory hormones (glucocorticoids, catecholamines, growth hormones and glucagon), cytokines, insulin resistance, and pre-existing diabetes. A recent single-center randomized trial of 1548 critically ill patients demonstrated that patients allocated to a target of euglycemia (4.4–6.1 mmol/l) as compared with higher glucose values (10.0–11.1 mmol/l) had a significantly lower ICU and hospital mortality and infectious morbidity, regardless of whether they had diabetes [7].

Thus, emerging evidence suggests that acute hyperglycemia has important adverse short- and long-term consequences for critically ill patients [8]. Accordingly, the overall objective of this survey was to determine those beliefs and attitudes of ICU clinicians about glycemic control for critically ill patients. We sought to understand key factors that can influence the ability to change practice related to glucose management, to aid future clinical, educational and research programs about glycemic control for the critically ill population. The three specific goals were to understand (1) perceived thresholds for clinically important hyperglycemia and hypoglycemia in ICU patients, (2) glucose measurement concerns in the critical care setting, and (3) strategies that clinicians would find most useful to help achieve optimal glucose management in the ICU.

Methods

Instrument development

We generated items for this instrument by reviewing recent literature on glycemic control in critically ill patients. All items generated were reviewed by three investigators (J.M., R.J., D.C.) and formatted to address the three survey objectives. Items were clustered in three domains: (1) thresholds for glucose control, (2) concerns about the use of glucometers for glucose measurement, and (3) strategies for optimal glucose management.

To maximize the accuracy and completeness of data collection, we used closed-ended questions with binary responses. We designed ten-point scales of 1 mmol/l increments to record glucose thresholds for hypoglycemia and hyperglycemia. We used a self-administered rather than interviewer-administered format to maximize the validity of self-reported information [9]. The instrument was pretested by four investigators prior to administration; modifications were made as necessary to optimize clarity of content, format and organization.

Instrument administration

To determine interest in the study, we first administered the instrument at the McMaster University Critical Care Journal Club prior to multicenter distribution. We then surveyed ICU practitioners in five Canadian university-affiliated hospitals in closed multidisciplinary units. A study coordinator administered the survey over three consecutive days at each center. We encouraged participation with verbal prompts [10] by the study coordinator. The survey was conducted in October 2002. Participation was voluntary, data were anonymous, and all responses were kept confidential. This study was approved centrally by the St. Joseph's Hospital Research Ethics Board in Hamilton, Ontario, which waived the need for written consent (please see the Appendix in the ESM).

Analysis

We report means and standard deviations, and medians and interquartile ranges (IQR) where appropriate. We report proportions with 95% confidence limits. We performed *t*-tests to compare continuous variables and used Bonferroni's multiple comparisons of means as appropriate. We used Fisher's Exact Test to test for differences in proportions. We tested for differences in responses between professional groups (nurses and physicians) and among centers. When testing for a center effect among the five participating ICUs, and the difference between residents and attending physicians, we omitted 29 responses obtained at the Journal Club. *P* values <0.05 were considered statistically significant.

Table 1 Centers participating in the survey

	St. Joseph's Healthcare	Hamilton Health Sciences Center (General)	Hamilton Health Sciences Center (McMaster)	Vancouver General Hospital	Queen Elizabeth II Health Sciences Center
Hospital beds (*n*)	422	450	326	590	980
ICU beds (*n*)	15	38	14	23	22
Admissions per year (*n*)	780	2749	601	720	1309
APACHE II score (mean, SD)	18.7 (8.0)	15.5 (6.6)	18.3 (8.3)	22.9 (6.6)	19.7 (7.1)
Type of patients	Medical/surgical, vascular surgery	Medical/surgical, trauma, neurosurgery, cardiac surgery	Medical/surgical, vascular surgery	Medical/surgical, trauma, cardiac surgery	Medical/surgical, neurosurgery
Insulin protocol	No	No	No	No	No
Nutrition protocol	No	No	No	No	No

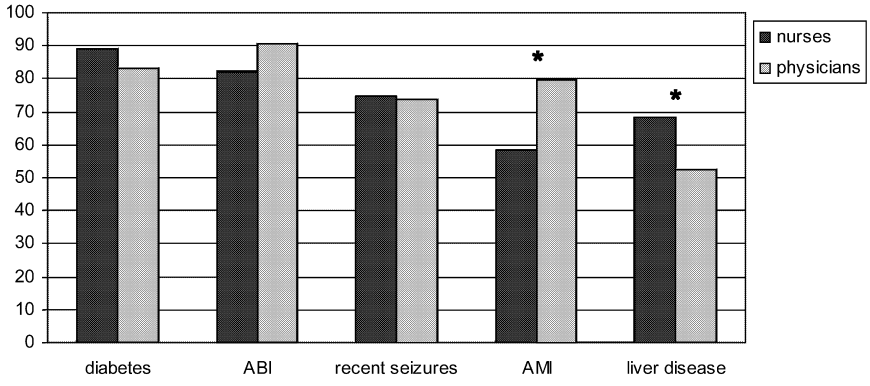

Fig. 1 Subgroups of ICU patients for whom respondents considered the avoidance of hyperglycemia to be important. Physicians were significantly more concerned about hyperglycemia than nurses for patients with acute myocardial infarction ($P<0.001$), and nurses were significantly more concerned about hyperglycemia for patients with severe liver disease ($P=0.012$) (*ABI* acute brain injury, *AMI* acute myocardial infarction)

Results

A total of 317 questionnaires were returned from 233 ICU nurses and 84 physicians in five university-affiliated multidisciplinary mixed ICUs. Participants were from McMaster Critical Care Journal Club ($n=29$), Hamilton Health Sciences Center (General Site) ($n=86$), Hamilton Health Sciences Center (McMaster Site) ($n=25$), St Joseph's Healthcare ($n=42$), Vancouver General Hospital ($n=76$), and Queen Elizabeth Health Sciences Center ($n=59$). We present characteristics of participating ICUs in Table 1.

The clinically important threshold for hypoglycemia reported by respondents was 4 mmol/l (median, IQR 3–4 mmol/l). The clinically important threshold for hyperglycemia in diabetic patients was 10 mmol/l (IQR 10–12 mmol/l), although nurses had a higher threshold than physicians (difference of 0.81 mmol/l (95% CI 0.29–1.32 mmol/l, $P=0.0023$). In non-diabetic patients, the clinically important threshold for hyperglycemia was also 10 mmol/l (IQR 9–12 mmol/l); however, again nurses had a higher threshold than physicians (difference of 0.52 mmol/L (95% CI 0.09–0.94 mmol/l, $P=0.018$). We identified no differences in hypoglycemia or hyperglycemia thresholds across centers, or between residents and attending physicians.

In Fig. 1 we present the subgroups of critically ill patients for whom ICU clinicians believe avoidance of hyperglycemia is important. The population of greatest concern was diabetic patients (87.7%, 95% CI 84.1–91.3%), followed by patients with acute brain injury (84.5%, 95% CI 80.5–88.5%), patients with a recent seizure (74.4%, 95% CI 69.6–79.3%), patients with advanced liver disease (64.0%, 95% CI 58.7–69.3%), and patients with acute myocardial infarction (64.0%, 95% CI 58.7–69.3%). ICU physicians were more likely than nurses to consider avoidance of hyperglycemia important for patients with myocardial infarction (79.8% versus 58.4%, $P<0.001$). ICU physicians were less concerned than nurses about avoidance of hyperglycemia in patients with severe liver disease (52.4% versus 68.2%, $P=0.012$). We found a center effect for two subgroups: patients with acute brain injury ($P=0.023$) and patients with a recent seizure ($P=0.006$). We found no differences between

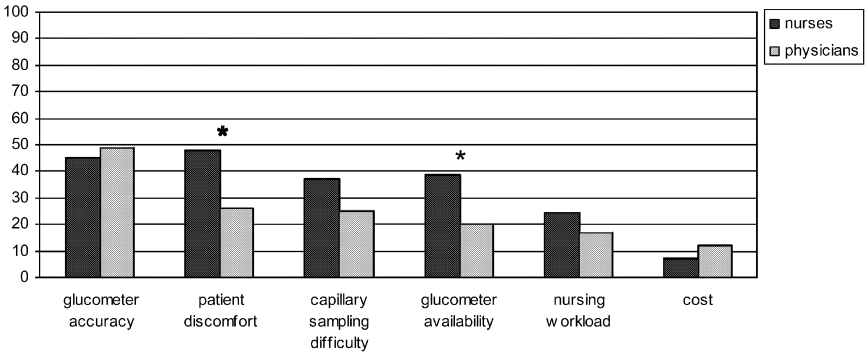

Fig. 2 Concerns expressed by respondents about the use of glucometers in the ICU. Nurses were more concerned than physicians about patient discomfort when obtaining capillary blood (P<0.001), and nurses were more concerned than physicians about lack of availability of glucometers (P=0.002)

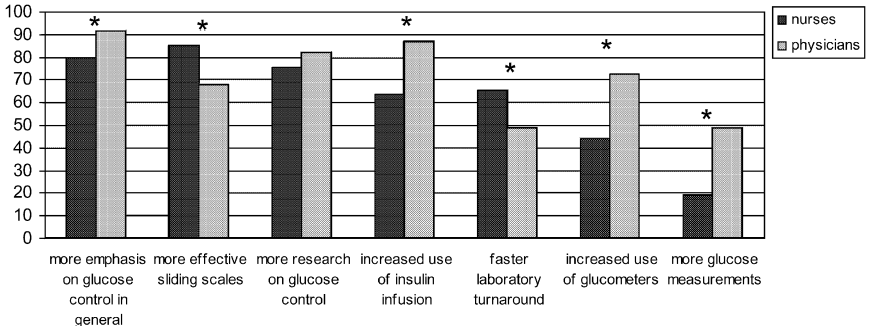

Fig. 3 Strategies endorsed by respondents to help achieve optimal glucose control in critically ill patients. Responses were different between nurses and physicians for all potential solutions except the need for further research

residents and attending physicians in the types of patients for whom clinicians believed avoidance of hyperglycemia was important.

In Fig. 2 we present concerns about the use of glucometers in the ICU. ICU clinicians were most concerned about the inaccuracy of glucometers compared to laboratory measurements (46.1%, 95% CI 40.5–51.6%), patient discomfort when obtaining capillary blood (42.0%, 95% CI 36.5–47.4%), clinician difficulty of obtaining capillary blood (33.8%, 95% CI 28.5–39.0%), availability of glucometers (33.8%, 95% CI 28.5–39.0%), increased nursing workload (22.4%, 95% CI 17.8–27.0%), and cost (8.2%, 95% CI 5.2–11.3%). Responses were similar between nurses and physicians except for two items: nurses were more concerned about patient discomfort when obtaining capillary blood (47.6% versus 26.2%, P<0.001), and nurses were more concerned about lack of availability of glucometers (38.6% versus 20.2%, P=0.002). We found significant differences among centers for each of the foregoing concerns (all P<0.001) except for costs of glucometer use. We found no differences between residents and attending physicians with respect to their concerns about the use of glucometers in the ICU.

ICU clinicians endorsed several strategies to help achieve optimal glucose control in critically ill patients, as presented in Fig. 3. The most frequently reported strategy was placing more importance on optimal glucose control in general (83.0%, 95% CI 78.8–87.1%); physicians endorsed this more often than nurses (91.7 versus 79.8%, P=0.017). More effective insulin sliding scales were also endorsed (80.4%, 95% CI 76.1–84.8%), more often by nurses than physicians (85.0% versus 67.9%, P<0.001). More research on glucose control in the ICU was also considered a useful strategy by ICU clinicians (77.3%, 95% CI 72.6–81.9%), with no difference between professional groups. Increased use of insulin infusions rather than subcutaneous injections was also reported as a potentially useful strategy (70.0%, 95% CI 65.0–75.1%), cited by physicians more often than nurses (86.9% versus 63.9%, P<0.001). Being able to obtain laboratory results more quickly was considered beneficial (61.2%, 95% CI 55.8–66.6%) more frequently by nurses than physicians (65.7% versus 48.8%, P=0.001), and increased use of glucometers was also endorsed (51.4%, 95% CI 45.9–57.0%) more often by physicians than nurses (72.6% versus 43.8%, P=<0.001). Finally, more glucose measurements in general (27.1%, 95% CI 22.2–32.1%) was encouraged by significantly more physicians than nurses (48.8% versus 19.3%, P<0.001). We found significant differences among centers for all of the foregoing strategies (all P<0.001), except for placing more importance on optimal glucose control in general and conducting

more research on glycemic control in the ICU which were endorsed similarly across centers. We found no differences between residents and attending physicians with respect to the strategies they endorsed to help achieve optimal glucose control in critically ill patients.

Discussion

In this multicenter survey, ICU clinicians reported their perception that the clinically important threshold for hyperglycemia for both diabetic and non-diabetic ICU patients was 10 mmol/l. Although the glucose threshold suggested by physicians was significantly lower than that of nurses, the difference of 0.81 mmol/L for diabetic patients, and 0.52 mmol/l for non-diabetic patients may not be clinically important. We conclude that randomized trial evidence showing the benefit of euglycemia on morbidity and mortality for critically ill patients had not decisively influenced practice in these centers [7].

We asked ICU clinicians about subgroups of critically ill patients for whom avoidance of hyperglycemia was particularly important. Respondents reported concern about patients with diabetes (88%), acute brain injury (85%), recent seizures (74%) and advanced liver disease (64%). Surprisingly, the patients of least concern were those with acute myocardial infarction (64%), despite results of the DIGAMI trial showing the mortality benefit of maintaining glucose in the range 7–10.9 mmol/l for patients with cardiac ischemia [5]. We also identified discipline-specific differences which may reflect knowledge base and training; for example, physicians expressed more concern for patients with acute myocardial infarction than did nurses (80% versus 58%). Reasons for lack of concern about hyperglycemia in patients with acute myocardial infarction may be due to lack of awareness of key randomized trials such as DIGAMI [5], or underappreciation of the prevalence of impaired glucose tolerance in such patients [11].

Our results highlight the importance that ICU clinicians give to optimal glucose management, given myriad competing priorities in critical care medicine, and offer insights into ways we might improve current management. ICU clinicians believe that greater emphasis on optimal glucose control is necessary (83%). Both nurses and physicians called for further research on glucose control (77%). Generally, in terms of improving current strategies, clinicians called for more effective insulin delivery and glucose monitoring, raising the option of insulin nomograms [12]. Increased use of insulin infusions and glucometers was endorsed by most clinicians, with physicians more strongly favoring these strategies. Others expressed concern about the accuracy of glucometer measurement in the ICU setting, highlighting the need to examine the limits of agreement between laboratory glucose measures and glucometers [13, 14], and the reliability of glucometer measures taken on the same sample.

We used evidence from several randomized trials to conduct this survey, suggesting that a self-administered format yields more valid self-reports than interviewer administered questionnaires [9], and that closed-ended formats yield more complete and valid demographic data than open-ended formats [15]. We also used strategies that have been shown to increase mail survey response rates, such as selection of a survey topic of current interest to participants, administration of a short survey, and conducting this survey on behalf of a university rather than a hospital [16]. We invited participation from both nurses and physicians, reflecting the key role that nurses have in managing glucose in the ICU. We surveyed five teaching institutions in Canada, and believe that our findings apply to similar institutions.

There were several limitations to this study. The first was the universal caveat of all surveys—that stated practice may not reflect actual practice. Second, our method of administration did not allow for calculation of precise response rates. However, interest in this topic is currently high, and our open invitation to participate led to a large sample size, yielding narrow confidence intervals around many estimates. We did not elicit views about glycemic control for all subgroups such as patients with septic shock. This survey was not designed to elicit reasons why ICU clinicians have different thresholds for clinically important hypoglycemia or hyperglycemia; in-depth interviews would be most suitable for this purpose. Finally, we included only five ICUs. Our findings are not generalizable to ICUs currently using an insulin protocol designed to achieve specific target glucose levels.

In summary, a recent randomized trial in a relatively homogeneous group of critically ill patients suggests that euglycemia is associated with lower morbidity and mortality than higher levels of glucose. This work follows a consistent body of evidence about the importance of euglycemia in other acute settings. Nevertheless, clinicians in our multicenter survey did not consistently report application of this evidence in practice. We believe that lack of clinician awareness of the recent ICU trial [7] is an unlikely explanation for our findings; however, other plausible explanations include the short time since publication of this trial, uncertainty about the generalizability of these results to non-cardiac surgery patients or patients with short durations of ICU stay, familiarity with the challenges of trying to achieve euglycemia in the ICU, entrenched practice patterns, concern about unrecognized hypoglycemia in critically ill patients, and a desire for more confirmatory evidence. Moreover, changing clinician behavior does not follow passive dissemination of information; it is most effective following interactive education, reminders, audit and feedback, and actively implemented, locally developed guidelines and protocols, as summarized in systematic reviews of behavior change

strategies [17]. Furthermore, integrated education and development of strategies to improve glycemic control may be more effective when done collaboratively in an interdisciplinary manner than within disciplines in parallel, given the uniquely multidisciplinary approach to care in the ICU.

Meanwhile, pending the completion of future randomized trials in heterogeneous ICU populations, to shift metabolic management toward tighter glucose control requires attention to clinicians' beliefs and attitudes. Addressing the issues we identified in this survey could enhance the success of future clinical, educational and research efforts to modify practitioner behavior and achieve euglycemia, thereby potentially improving the outcomes for critically ill patients.

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