Effects of Computerized Decision Support Systems on Blood Glucose Regulation in Critically Ill Surgical Patients

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BACKGROUND: The use of computerized decision support systems (CDSS) in glucose control for critically ill surgical patients has been reported in both diabetic and nondiabetic patients. Prospective studies evaluating its effect on glucose control are, however, lacking. The objective of this study was to evaluate patient-specific computerized IV insulin dosing on blood glucose levels (BGLs) by comparing patients treated pre-CDSS with those treated post-CDSS.

STUDY DESIGN: A prospective study was performed in 4 surgical ICUs and 1 progressive care unit comparing patient data pre- and post-implementation of CDSS. The primary outcomes measures were the impact of the CDSS on glycemic control in this population and on reducing the incidence of severe hypoglycemia.

RESULTS: Data on 1,682 patient admissions were evaluated, which corresponded to 73,290 BGLs post-CDSS compared with 44,972 BGLs pre-CDSS. The percentage of hyperglycemic events improved, with BGLs of >150 mg/dL decreasing by 50% compared with 6-month historical controls during the 18-month study period from July 2010 through December 2011. This was true for all 5 units individually ($p < 0.0001$, by one sample sign test). In addition, severe hypoglycemia (defined as BGL <40 mg/dL) decreased from 1% to 0.05% after implementing CDSS ($p < 0.0001$ by 2-sided binomial test).

CONCLUSIONS: Patients whose BGLs were managed using CDSS were statistically significantly more likely to have a glucose reading under control (<150 mg/dL) than in the 6-month historical controls and to avoid serious hypoglycemia ($p < 0.0001$). (J Am Coll Surg 2013;216:828–835. © 2013 by the American College of Surgeons)

Hyperglycemia on admission or at any time during a patient hospital stay is common and is associated with poor clinical outcomes and mortality in patients with and without a history of diabetes.[1] Research has demonstrated that inpatients with newly diagnosed hyperglycemia have a significantly higher mortality rate and lower functional outcomes than patients with a known history of diabetes or normoglycemia.[1] Patients with medium, high, worsening, and highly variable hyperglycemia have significantly increased ICU length of stay, hospital length of stay, ventilator days, infection rate, and mortality compared with patients with controlled glucose levels ($p < 0.01$).[2]

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Narrowing the range of target blood glucose levels (BGLs) has been shown to decrease morbidity and mortality in the critically ill[3] and is now recommended by numerous organizations, including the American Diabetes Association[4] and the Institute for Healthcare Improvement.[5] These studies have used protocols requiring intensive monitoring of glucose levels (ie, initially every 30 to 60 minutes until BGL stabilizes and then every 4 hours) and numerous IV insulin infusion dose calculations and adjustments.[5] Although tighter glycemic control is becoming the standard of care, it might be associated with hypoglycemia and increased workloads for those managing the blood glucose.[6,7]

In 2011, the American College of Physicians released practice guidelines that stated that the use of intensive insulin therapy (IIT) was associated with excess risk for hypoglycemia in almost all clinical trials; critically ill patients receiving IIT aimed at achieving normoglycemia had the highest occurrence of hypoglycemia (relative rate = 5.32; 95% CI, 4.21–6.73).[8] Although the consequences of hypoglycemia in hospitalized patients are

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Abbreviations and Acronyms
BGL = blood glucose level
CDSS = computerized decision support systems
CMS = Centers for Medicare and Medicaid Services
HAI = health care–associated infection
IIT = intensive insulin therapy
VAP = ventilator-associated pneumonia

unclear, there is some evidence for excess mortality or extended length of stay among patients in the medical ICU experiencing one or more episodes of severe hypoglycemia (BGL <40 mg/dL) related to IIT.[8] Additional studies have suggested that hypoglycemia is associated with an increased risk for dementia in patients with type 2 diabetes and a 2-fold increase in risk for mortality, and that it can induce transient ischemia and catecholamine surges.[8]

In addition to the importance of controlling hyperglycemia on quality of patient care and outcomes, financial considerations are catapulting the control of blood sugars to the forefront in clinical care. According to the Centers for Medicare and Medicaid Services (CMS), poor control of blood sugar for patients with diabetes is considered a potentially preventable complication of care and has been named a targeted measure. In addition, CMS has stressed that poor control of blood sugar could reasonably be prevented through the use of evidence-based guidelines for appropriate hospital inpatient care.[9] Therefore, it seems likely that, in the future, CMS might not provide reimbursement for management of uncontrolled blood sugars, forcing health systems to shoulder the financial burden of extended lengths of stay, infections, etc. Standardized protocols for controlling hyperglycemia are recommended by CMS because they have been found to reduce variation, to increase adherence to evidence-based practices, and to improve clinical outcomes.[10-12] Unfortunately, IV insulin protocols for glycemic control are often complicated, requiring frequent bedside glucose monitoring and repeated complex calculations to titrate insulin doses.[10,13-15] Standardized, nurse-managed paper-based IV insulin protocols are not always associated with optimal results.[10,16] Several studies have reported the successful implementation of clinical computerized decision support systems (CDSS), computer programs that are intended to help health care workers in making decisions.[12,17,18]

In this prospective study, we sought to evaluate the impact of implementing a CDSS on the management of blood glucose in our critically ill surgical patients. The end points of this study of glycemic control before and after implementation of a CDSS were 3-fold. First, we analyzed the effect of the CDSS on glycemic control in this population as a whole and, secondly, the incidence of severe hypoglycemia before and after CDSS. Finally, we evaluated measures of health care–associated infection (HAI) during the study period.

METHODS

Study location and patient population

Carilion Clinic is a not-for-profit health care organization serving nearly 1 million people in southwest Virginia through 7 hospitals, as well as multiple outpatient specialty centers and advanced primary care and specialty practices. The study site is Carilion Roanoke Memorial Hospital, a 763-bed hospital affiliated with Virginia Tech Carilion School of Medicine and Research Institute in Roanoke, VA. Collection of data was prospectively performed in 5 units at Carilion Roanoke Memorial Hospital, including the surgical ICU, the neurotrauma ICU, the thoracic ICU, the cardiac surgical ICU, and the cardiac surgical progressive care unit.

Pre–computerized decision support systems glucose control protocols

On starting the glucose control project, 7 different protocols were identified that could be used in these units. The cardiac surgical ICU routinely used the Portland protocol, a well-accepted and common protocol in use in many cardiac surgical units around the country.[18] Another available method was the standard basal/bolus method of glucose control using a combination of short- and long-acting insulins. The other 5 paper protocols used IV insulin and were managed by the nursing staff. The choice of protocol was at the discretion of the admitting physician. On starting the CDSS, the medical directors of each of the units designated CDSS the standard of practice for any patient needing IV insulin in their unit.

Post–computerized decision support systems

The CDSS (EndoTool; Hospira) that was implemented is a software system designed specifically to customize the insulin dosing to the individual patient, including those with frequently changing requirements. Using mathematical modeling, trends of glucose readings are analyzed to formulate a patient-specific physiologic insulin-dosing curve. Adjustments are automatically made in the dosing curve to minimize episodes of hypoglycemia and to control hyperglycemia. It required a dedicated Citrix server in each unit with an interface with the electronic medical record. On receiving an order for the CDSS, the patient's name and medical record number, along with the patient's weight, creatinine, and initial glucose are entered. It then generates a bolus dose, an infusion rate, and a time to the next blood glucose measurement. There is a built-in