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Glucose management in a community hospital

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Hyperglycemia;
Inpatient;
Insulin;
Glucose excursion

OBJECTIVES: Diabetes mellitus is a significant risk factor for morbidity and mortality in hospitalized patients. The purpose of this study is to evaluate the treatment of diabetic patients with regard to glucose control.

METHODS: A retrospective inpatient chart review was performed on a sample of 209 patients. Those patients admitted to the hospital who had at least one fasting blood sugar greater than 110 mg/dL during the month of April 2008 were included. This study was approved by the Ohio University and Firelands Regional Medical Center Institutional Review Boards.

RESULTS: Fifty-three percent of hyperglycemic patients had no diagnosis of diabetes before admission. Of those found to be hyperglycemic, no glycemic treatment was offered in 51% of patients. Of the patients who received insulin therapy, almost half (45%) received sliding-scale insulin coverage, with no other treatment offered. Insulin was not titrated in 85% of patients throughout their stay. The mean glucose reading that triggered a change in treatment was 265 mg/dL. Mean average glucose excursion throughout the day was 87 mg/dL.

CONCLUSION: Hyperglycemic management in the inpatient setting has significant room for improvement. Insulin use was titrated too infrequently and often too late to improve patient care. Despite its record of ineffectiveness, the majority of patients in our study received sliding scale insulin as their only insulin therapy. Further research is needed to explore morbidity and mortality associated with the use of sliding scale insulin *versus* basal-bolus insulin, with the goal of achieving improved postprandial glucose control.

Hyperglycemia increases morbidity and mortality in the hospital setting. Decreased immune function, increased oxidative stress, and a procoagulant state are some of the complications that occur because of hyperglycemia.[1] Hyperglycemia without a previous diagnosis of diabetes has been shown to portend a worse prognosis. Umpirerrez et al. evaluated more than 2000 patients with hyperglycemia (regardless of diabetes status) in the hospital setting. Inpatient mortality was 16% in those with newly diagnosed hyperglycemia compared with 3% in those with known diabetes and 1.7% in those with normal glucose.[2] Hospital stay was nine days in patients with newly diagnosed hyperglycemia compared with 5.5 days for those patients with a previous diagnosis of diabetes.[2] Inpatient care of uncontrolled hyperglycemia is associated with a significant rise in cost. Economic burden of diabetes is estimated to be $174 billion, with 50% of these costs attributable to inpatient care. Van den Berghe et al. looked at cost savings from prevention of deep sternal wound infections in cardiac surgery patients. They found that intensive management of hyperglycemia lead to a cost savings of $2613 per patient.[3]

Postprandial hyperglycemia has become a focus of research recently owing to the links between hyperglycemia, increased cardiovascular complications, and death. In the DECODE study, 25,000 patients were followed for seven years after a cardiovascular event. Two-hour postprandial

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hyperglycemia levels was found to have a higher correlation with increased mortality than fasting glucose levels.[4] Control of postprandial hyperglycemia has been shown to improve markers for atherosclerosis. Esposito et al. demonstrated that a reduction in postprandial hyperglycemia in patients with type 2 diabetes was associated with carotid intima media thickness regression.[5]

The current glucose target used in intensive care patients has recently come into question with the NICE-SUGAR study.[6] This was a randomized, controlled trial that studied more than 6000 patients in the intensive care unit. Patients were randomly assigned to either intensive control maintaining serum glucose in the range of 81 to 108 mg/dL or conventional control of <180 mg/dL. The mortality rate was statistically significant, with 27.5% in the intensive group *versus* 24.9% in the conventional group. Hypoglycemia also occurred more frequently in the intensive group, with 6.8% *versus* 0.5%. Because of this study, the American Diabetes Association (ADA) has developed a consensus statement that recommends starting treatment at a threshold of 180 mg/dL and keeping the blood glucose between 140 and 180 mg/dL in intensive care patients. The premeal blood glucose should be kept <140 mg/dL, with a random goal of <180 mg/dL while the patient is in the medical unit.[7]

The use of sliding-scale insulin (SSI), despite its popularity in the hospital, has been proven ineffective for control of hyperglycemia and prevention of hypoglycemia. In a study by Queale et al., the incidence of hyperglycemia was much higher in patients who had SSI added to their regimen as opposed to those with no change in treatment after being admitted. In this study, SSI was not adjusted in about 80% of patients.[8]

The effective use of SSI is to fine-tune an insulin regimen that is already in place; therefore, it is essential to adjust either the SSI coverage or increase the basal and/or bolus insulin regimen frequently. Basal-bolus insulin therapy has been shown to be more effective than SSI. The RABBIT-2 trial evaluated glargine plus glulisine *versus* SSI therapy in non−intensive care patients with type 2 diabetes. A blood glucose target of <140 mg/dL was achieved in 66% of patients in the glargine and glulisine group, compared with 38% of those in the SSI group.[9]

This study assessed management of inpatient hyperglycemia, with respect to the type of treatment, the control of postprandial hyperglycemia, and the adjustment of insulin when glucose is not controlled. It is our hypothesis that SSI is used too frequently, whereas postprandial hyperglycemia and glucose excursions are too high and insulin is not adjusted despite continued hyperglycemia.

Methods

Settings and participants

This inpatient retrospective chart review was completed at Firelands Regional Medical Center in Sandusky, Ohio. Included criteria were patients admitted to the hospital with at least one fasting glucose >110 mg/dL during the month of April 2008. A patient list was generated from a medical record database of patients who had a fasting glucose of >110 mg/dL any time during their hospitalization. Children, outpatients, and patients under observation in the hospital were excluded from the study. This study was approved by the Ohio University and Firelands Regional Medical Center Institutional Review Boards.

Measurements

Electronic medical records were used to obtain the data for this study. Glucose goals of 110 mg/dL fasting and 180 mg/dL random were used to determine glucose control. These values were based on the glucose goal recommendations by the ADA and the American Academy of Clinical Endocrinology (AACE).[10] Patient variables included sex, age, ethnicity, previous diagnosis of diabetes mellitus, insulin use before admission, insulin use during admission, choice of medical unit admission (medical floor *versus* intensive care unit), length of stay, and 30-day readmission rate. The percentage of fasting and random glucose readings at goal was recorded. The number of hypoglycemic events was identified and defined as <80 mg/dL for mild hypoglycemia, and <50 mg/dL for severe hypoglycemia. Postprandial glucose was obtained by the difference in glucose between meals and bedtime. Any glucose excursion that was >50 mg/dL was considered uncontrolled. Daily glucose excursion was gathered by the difference between the highest and lowest glucose levels for one day and then averaged for the length of stay. The physician who initiated and maintained glucose management was recorded and categorized into primary care, cardiology, critical care, surgery, oncology, nephrology, and other. Adjustments to insulin were noted, consisting of the number of times insulin was adjusted, the type of insulin that was adjusted, and the glucose level at which insulin was adjusted. Different types of glycemic treatments were used and separated as SSI only, SSI plus oral, SSI plus basal, SSI plus basal plus prandial, SSI plus 70/30 insulin mix, SSI plus prandial, SSI plus basal plus oral, basal only, SSI plus oral plus 70/30, 70/30 only, and SSI plus exenatide plus oral. Glucose control at discharge was recorded for both fasting and random levels. Other factors that were taken into account were the number of patients who had finger-stick blood sugars performed and patients who received either steroids or total parenteral nutrition at least one time during their hospital stay.

Data analysis

Statistical analysis was obtained through the Ohio University College of Osteopathic Medicine Centers of Osteopathic Research and Education (OU-COM CORE) research office. Cross-table analysis was used to determine whether there was a difference in insulin prescription at discharge in

Table 1 Descriptive statistics on continuous variables

	Minimum	Maximum	Mean/Percentage
Age (years)	20	99	68.7
No diabetes diagnosis before admission			53%
Admission glucose (mg/dL)	36	747	166
Glucose readings at goal			40.5%
Fasting glucose readings at goal			23.3%
Random glucose readings at goal			63.9%
Length of stay (days)	1	33	6.4
Glucose change from breakfast to lunch (mg/dL)	6	254	93
Glucose change from lunch to dinner (mg/dL)	1	272	79
Glucose change from dinner to bedtime (mg/dL)	4	287	89
Time of PPG control (Δ <50 mg/dL)	0%	100%	69%
Average glucose excursion (mg/dL)	10	262	87
Fasting glucose uncontrolled at discharge			71%
Hypoglycemia			1.2%
30-day readmission			19%

patients whose fasting or random glucose was controlled *versus* uncontrolled during the hospitalization. Thirty-day readmission rates were also analyzed to identify whether there were more patients readmitted whose fasting or random glucose was uncontrolled during the hospitalization. Results were considered significant at $p < 0.05$. SSPS version 17 (SPSS, Inc. Chicago, IL) was used for all analyses.

Results

Two-hundred nine patients met criteria for the study. Of the patients selected, 90% were white, 10% were African American, 49% were female, and 51% were male. The average age was 68.7 years. The majority of patients were on the medical floor (87%), whereas 13% were in a critical care setting. The average length of stay was 6.4 days (Table 1).

Primary care physicians, including family physicians and internists, initiated and maintained glucose management 78% of the time. Surgeons were the next largest group of physicians who initiated and maintained management, at 16%.

Mean admission glucose was 166 mg/dL, with a range of 36 to 747 mg/dL. Patients met the fasting goal 23.3% of the time and the random goal 63.9% of the time. At discharge, fasting glucose was uncontrolled in 71% of patients and random glucose was uncontrolled in 41% of patients. The average glucose excursion between breakfast and lunch was 93 mg/dL, between lunch and dinner 79 mg/dL, and between dinner and bedtime 89 mg/dL. Only positive glucose excursions between meals were calculated. Postprandial glucose was controlled in 69% of patients. The average daily glucose excursion at the patient level was 87 mg/dL, with a range of 10 to 262 mg/dl. Mild hypoglycemia occurred in 22 patients, with severe hypoglycemia in only eight patients. Thirty-day readmission occurred in 19% of patients (Table 1).

More than half of the patients in this study (53%) had no previous diagnosis of diabetes (Table 1) and 75% were not taking insulin before admission. Fifty-one percent of the patients in the study were taking no diabetic medications before or during the study, and no insulin was administered in 55% of those patients admitted.

For the patients who received insulin in the hospital, sliding scale was the only insulin used in 45/94 (48%) patients. SSI plus basal insulin was used in 37/94 (39%) patients (Figure 1). Only nine patients were on combination of a SSI, basal, and prandial insulin. Seven of those nine were on a 70/30 mix regimen. Only two patients of the 209 studied (0.9%) were on a true basal, bolus, corrective combination. Twenty-five percent of patients before admission were receiving insulin compared with 31% of patients receiving insulin at discharge.

Insulin was not adjusted in 85% of the patients during their stay. Of the remaining patients, adjustments were made only one time in 18/35 (51%) patients, two times in

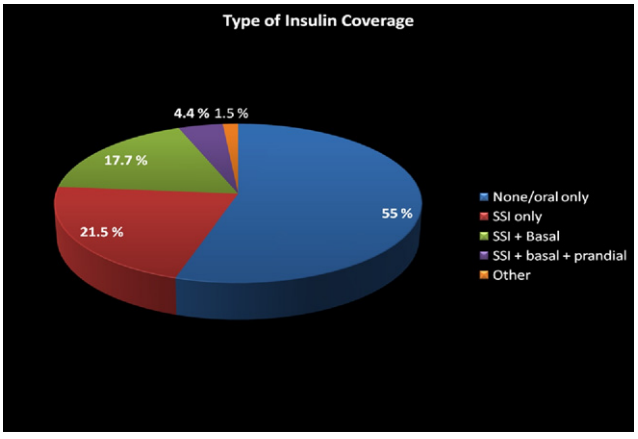

Figure 1 Type of insulin coverage.

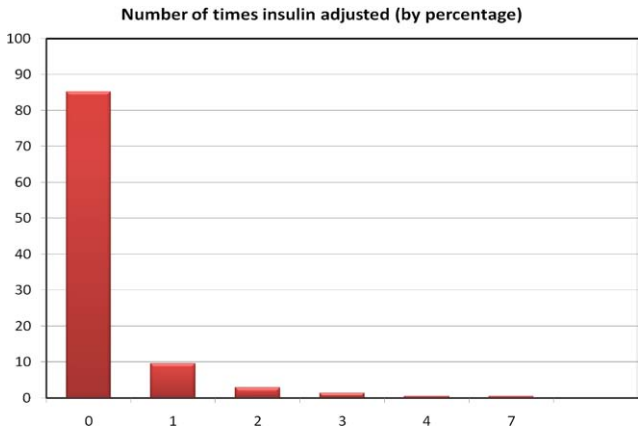

Figure 2 Adjustment of insulin.

6/35 (17%) patients, three times in 2/35 (5.7%) patients, four times in 1/35 (2.9%) patients, and seven times in 1/35 (2.9%) patients (Figure 2). Basal insulin was adjusted the majority of the time and accounted for 72% of the adjustments. SSI was adjusted in only five patients. The glucose level triggering insulin adjustments was an average of 266 mg/dL for basal insulin, 334 mg/dL for prandial insulin, and 262 mg/dL for SSI (Figure 3).

Not all patients in this study had finger-stick blood sugar monitoring before meals and at bedtime. Almost half (49%) of patients had finger-stick blood monitoring as part of their care. Total parenteral nutrition was used in 2% of patients, and steroids were given in 29% of patients at least one time during their hospitalization.

Cross-tabulation analysis was used to determine whether fasting and random euglycemia had any effect on insulin usage at discharge or 30-day readmission rates. When fasting euglycemia was not achieved, 26/85 (31%) patients were receiving insulin at discharge compared with 59/85 (69%) patients who were not placed on insulin at discharge. Eighteen percent of patients in the uncontrolled fasting glucose at discharge group were readmitted within 30 days. This was not statistically significant compared with the patients with controlled fasting glucose at discharge (20%). In the 13 patients who did not achieve random euglycemia

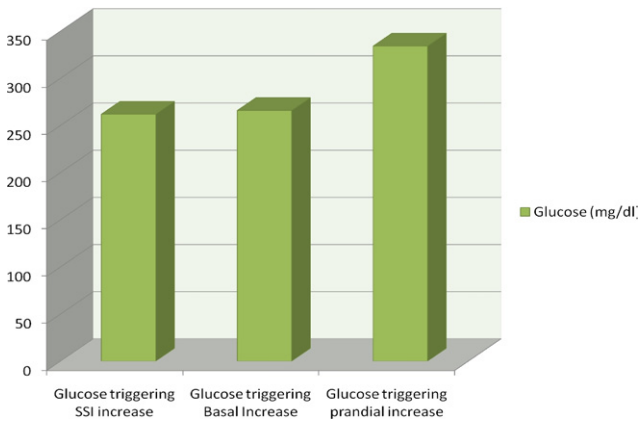

Figure 3 Glucose triggering insulin adjustment.

Table 2 Insulin prescribed at discharge

	No	Yes	Total
Fasting euglycemia			
Not achieved	59	26	85
Achieved	84	39	123
Random euglycemia			
Not achieved	8	5	13
Achieved	90	60	150

at discharge, five (38%) patients were on insulin at discharge compared with eight (62%) patients who were not on insulin. Only 15% of patients with uncontrolled random glucose at discharge were readmitted within 30 days, which was not statistically significant, with a p-value of 0.121 (Tables 2 and 3).

Discussion

In general, glucose goals were not achieved in this study population. Insulin was used predominantly as sliding-scale coverage, which historically has not been effective in achieving improved glucose control. More than half of the patients in the study were hyperglycemic at admission but had no history of diabetes. This is likely a reflection of the common occurrence for patients to find out that they have diabetes when they are admitted to the hospital for another medical illness. Regardless, this group is at high risk for complications and should be treated for hyperglycemia.

Despite 148 (71%) patients having fasting glucose uncontrolled at discharge, only 65 patients were discharged on insulin, with only 13 new initiations of insulin. Only 18% of patients had insulin adjustments while in the hospital, and if there was a treatment adjustment, this occurred only once. This is remarkable given the mean length of stay was six days.

The majority of adjustments were made with basal insulin, whereas only five patients had their sliding-scale insulin adjusted. Therefore, when sliding scale was used, it was used inappropriately because only a minority achieved glucose goals. The most judicious use of sliding-scale insulin is to use the previous day's insulin coverage and add it to the basal or bolus coverage the following day. When adjust-

Table 3 Thirty day readmission

	No	Yes	Total
Fasting euglycemia			
Not achieved	70	15	85
Achieved	98	25	123
Random euglycemia			
Not achieved	11	2	13
Achieved	121	29	150

ments were made, the glucose level was 1.9 to 2.4 times greater than the glucose goals recommended by the ADA. The mean glucose that triggered an adjustment in glucose-lowering treatment was >250 mg/dL, indicating that physicians were waiting too long before responding to hyperglycemia. This may be caused by a lack of recognition of glucose goals, failure to recognize hyperglycemia, lack of confidence in the benefits of tighter glucose control, or choosing to address other problems for the patient.

The NICE SUGAR study was published after the completion of this study, and new recommendations have been made by the AACE and ADA, as stated previously. Even taking into account the new less stringent glucose goals, the glucose levels in this study are still much higher than was seen in the NICE SUGAR routine care group.

Atherosclerosis has been linked to two-hour postprandial glucose control and excessive glucose excursions. Sliding-scale insulin increases this risk because it is a reactive approach causing wide fluctuations in glucose control. This is exemplified by the mean glucose excursions in the patients, found to be 87 mg/dL. Despite the evidence that sliding-scale insulin is ineffective, 52% who were on insulin were given sliding scale alone. Only two patients (0.9%) were on a true basal, bolus, corrective therapy. No insulin was used in 55% of patients.

We were unable to attain statistical significance for the outcomes of insulin prescribed at discharge and 30-day readmission. This was believed to be a result of the small patient population in this study. Despite this, there was evidence demonstrating poor control of hyperglycemia in the hospital, identifying many areas for improvement.

This study has a number of significant limitations. The small number of participants limited power in this study and generalizability of the results. The participants in this study were a heterogeneous population, including patients who were on corticosteroids and total parenteral nutrition; these patients are known to have difficulty with glucose control. Because this was a retrospective chart review, postprandial glucose was obtained by a change in glucose between meals instead of a true two-hour postprandial reading. This may alter the findings because of different time frames between readings in each patient. Only increases in glucose between meals were calculated for analysis.

Summary

Hyperglycemia continues to be poorly controlled in hospitalized patients despite multiple studies showing poor outcomes with ineffective glucose control. Insulin treatment regimens are adjusted infrequently in hospitalized patients. The glucose level triggering adjustment is well beyond that which is recommended by the ADA and AACE. Sliding-scale insulin continues to be relied on as the sole glucose management in the majority of patients and is not adjusted properly when it is used. Glucose control does not seem to be a priority, despite a risk of increased morbidity and mortality. Hyperglycemia does not merely affect a single body system; it causes systemic harm and prevents the healing process. When hyperglycemia is not addressed appropriately, patients may be unnecessarily exposed to possible complications.

Future research is needed to evaluate additional strategies that can be implemented to improve glucose control in the hospital. We need to further explore morbidity and mortality measures in patients on SSI *versus* basal-bolus insulin. Further research should be pursued to determine the effect on patient outcomes of postprandial hyperglycemia in hospitalized patients.

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