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Maria I. Kravchenko

Joshua M. Tate

Philip G. Clerc

Whitney L. Forbes

Morgan C. Gettle

See next page for additional authors

Authors

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IMPACT OF STRUCTURED INSULIN ORDER SETS ON INPATIENT HYPOGLYCEMIA AND GLYCEMIC CONTROL

Maria I. Kravchenko, MD[1]; Joshua M. Tate, MD[1]; Philip G. Clerc, MD[1]; Whitney L. Forbes, PhD[2];
Morgan C. Gettle, MD[3]; Jana L. Wardian, PhD[2]; Jeffrey A. Colburn, MD[1]

ABSTRACT

Objective: In hospitalized patients, glycemic excursions outside recommended glycemic targets have been associated with increased morbidity and mortality. Despite recommendations to avoid use of correctional insulin alone for managing hyperglycemia, this approach remains common. We performed a quality improvement project aimed at both reducing hypoglycemic events and promoting increased use of basal insulin by updating our insulin order sets to reflect clinical practice guideline recommendations.

Methods: Brooke Army Medical Center correctional insulin order sets were modified to reflect higher treatment thresholds and targets, and a basal insulin order was added with a recommended weight-based starting dose. Pre- and postintervention analyses were performed. Patients were included if they were prescribed subcutaneous insulin during their hospital stay. The following outcomes were measured: (*1*) glucose levels, and (*2*) prescriptions for basal insulin.

Results: A significant reduction in hypoglycemia events was noted following the intervention (glucose <70 mg/dL: 9.2% pre-intervention vs. 8.8% postinterven-

tion; glucose <55 mg/dL: 4.2% pre-intervention vs. 2.2% postintervention). When excluding patients that were ordered correctional insulin alone but did not receive a dose, an increase in basal insulin use was seen (50% pre-intervention vs. 61% postintervention). Rates and severity of hyperglycemia (glucose >180 mg/dL) remained unchanged.

Conclusion: The alteration in insulin order set parameters resulted in a significant reduction in hypoglycemia without significant increases in hyperglycemia. Although basal insulin use increased, optimal dosing recommendations were not often utilized. Further interventions are necessary to reduce hyperglycemia. (**Endocr Pract. 2020;26:523-528**)

Abbreviations:
CPOE = computerized provider order entry; **EMR** = electronic medical record; **HbA1c** = hemoglobin A1c; **LOS** = length of stay; **QI** = quality improvement; **SSI** = sliding scale insulin

INTRODUCTION

Diabetes mellitus is one of the most common diseases encountered by health care professionals, affecting over 9% of the population of the United States (1), with manifestations that involve almost every organ in the body. Patients with diabetes are more likely to require hospital admission (2-4) and have more complications and a longer length of stay (LOS) (5-7). Additionally, patients without a prior diagnosis of diabetes may exhibit hyperglycemia during hospitalization (8). Hyperglycemia is strongly associated with adverse outcomes in hospitalized patients, including adverse surgical outcomes, increased LOS, and higher mortality (8-11). While there is a paucity of evidence for reduction in hospital-related mortality, medical therapy

to reduce hyperglycemia has been shown to reduce peri-operative infection rates and improve wound healing (12-14). Any treatment of hyperglycemia must be balanced against the risk of treatment-induced hypoglycemia, which also substantially increases morbidity and mortality and can be more acutely life threatening (15-17). To achieve this equilibrium, the American Diabetes Association, the American Association of Clinical Endocrinologists, and the Endocrine Society have recommended glycemic targets of 100 to 180 mg/dL for most hospitalized patients with diabetes mellitus (18-20).

Insulin has been the mainstay of treatment for inpa-tient hyperglycemia. Particularly, "basal bolus" regimens are recommended by clinical practice guidelines (18-20). Regimens incorporating basal insulin have been shown to be safe and effective (21,22). Despite this wealth of evidence, use of correction dose alone or "sliding scale" insulin (SSI) regimens remains prevalent (23,24). This is primarily due to clinical inertia as well as fear of induc-ing hypoglycemia with long-acting insulin (25). However, SSI regimens are less effective at achieving glycemic targets and demonstrate no difference in hypoglycemia rates (21,26).

Structured insulin order sets, particularly with comput-erized provider order entry (CPOE) in an electronic medi-cal record (EMR), have demonstrated efficacy in improving insulin use patterns and glycemic control when compared to verbal or freestyle handwritten orders (26). In the era of widespread EMR use, insulin order sets with CPOE have become the standard of care in inpatient settings. Evidence is lacking, however, regarding their effect on glycemic management and prescribing patterns in a "real-world" setting.

METHODS

A quality improvement (QI) project was performed by a multidisciplinary team at Brooke Army Medical Center (BAMC), a 425-bed academic military hospital, to improve insulin ordering practices and glycemic manage-ment for adult inpatients with hyperglycemia. The hospi-tal serves active duty military personnel, their families, military retirees, and civilian trauma patients. An EMR is used for all inpatient orders and structured insulin order sets have been in place for many years. However, there is no formal process in place to ensure insulin order sets reflect changing clinical practice guidelines. In addition, the EMR does not have the capability to construct built-in treatment algorithms.

To address inpatient diabetes management within our complex healthcare system, we implemented a supportive mechanism for QI, the Plan-Do-Study-Act (PDSA) meth-od (27). PDSA Cycle 1 implemented two separate targets for intervention: reduction of inpatient hypoglycemia and increasing the prescription of basal insulin as opposed to

SSI regimens alone. During the planning phase, a retro-spective review of inpatient glycemic management within our institution was performed. Six months of data were collected on adult (≥18 years of age) inpatients admit-ted to BAMC medical, surgical, and critical care units for ≥24 hours, who received subcutaneous insulin during their hospital stay. Women admitted to the obstetrics unit were excluded. The collected data included serum glucose, fingerstick blood glucose, time and dose of administered insulin, hemoglobin A1c (HbA1c), and the admitting service. Only patients with a length of stay >24 hours were included, as it was felt that a shorter monitoring time would not accurately represent the impact of any interven-tions. A mean glucose value was recorded for each patient with at least 3 recorded glucose values. To reduce the risk of sampling error, a subanalysis was performed for patients with at least 6 recorded glucose values. An uncontrolled patient stay was defined as a mean glucose value >180 mg/dL, as this is above the glycemic target for clinical practice guidelines (18-20). Hypoglycemia was defined as point-of-care (POC) or serum glucose <70 mg/dL and severe hypoglycemia as POC or serum glucose <55 mg/dL (28). We calculated the percentage of monitored patients who experienced at least one episode of hypoglycemia or severe hypoglycemia over the course of their admission. Insulin regimens were characterized as basal bolus plus correction, basal plus correction, or correction only. The percentage of insulin regimens incorporating basal insulin was calcu-lated for each sampled month. The results of the planning phase (Table 1) showed that the majority of inpatients with hyperglycemia did not meet the glycemic target of 80 to 180 mg/dL. Of additional concern, a higher than expected rate of hypoglycemia was identified.

During the planning phase review, the primary factors identified as contributors to poor management of hyperglycemia were (*1*) overreliance on correction-only insulin regimens or (*2*) suboptimal basal insulin dose for basal plus correction insulin regimens. Possible additional factors identified by house staff and nursing staff includ-ed lack of attention to glucose by providers and lack of knowledge about guideline recommended management. The main factor identified as contributing to hypoglycemia was a very aggressive correctional insulin scale. All insulin correction scales were built to target a glucose value of 100 mg/dL, and no guidance was provided in the order sets to aid the selection of an appropriate correction scale. As a result, patients were receiving correction doses that were higher than physiologically required, such as patients with very mild stress hyperglycemia receiving doses of insulin which subsequently caused hypoglycemia.

Interventions
To improve glycemic control, the insulin order sets for adult medical, surgical, and critical care units were updated. To address hypoglycemia specifically, the correc-

Table 1 Glycemic Control – Pre-intervention				
	Average glucose (mg/dL)	**Percent of patients with any BG out of target range[a]**	**Percent of patients with BG <70 mg/dL**	**Percent of patients with BG <55 mg/dL**
SSI only	176	63	7	2
Basal + SSI	190	83	16	5
Basal/Bolus + SSI	191	90	23	9
Abbreviations: BG = blood glucose; SSI = sliding scale insulin. [a]Target range is 80-180 mg/dL.				

tion insulin protocols were rewritten so that no correction insulin was administered until blood glucose was >180 mg/dL (20). To simplify implementation and increase utilization, one glucose target (150 mg/dL) was provided for all correction insulin and chosen based on clinical practice guideline targets of 100 to 180 mg/dL (18-20). Additionally, comments were added to the EMR order sets which provided guidance regarding the appropriate selection of a correction insulin scale based on the following patient clinical characteristics: age, weight, renal function, and use of glucocorticoids. Since it was expected that these changes would result in increased rates of hyperglycemia, nursing call parameters were added with instructions to contact a provider if three consecutive blood glucose values were >180 mg/dL so that insulin orders could be updated in an expedited fashion.

To address hyperglycemia specifically, an easily accessible order for insulin glargine was added to all insulin order sets, with a recommended starting dose of 0.2 units/kg body weight. In-person informational briefs were given to medical and surgical residents during their educational conferences, publicizing the changes to the insulin order sets, with recommendations to use basal insulin in all patients with hyperglycemia. An insulin ordering guide was also added to the locally published house staff manual. The former insulin order sets were deleted from the EMR to avoid confusion.

Measures and Analyses

During the 3-month follow-up period, data were collected to assess insulin use patterns, glycemic management, and hypoglycemic episodes. The same criteria were used for inclusion as for the pre-intervention analysis.

Statistical Analysis

All outcomes were analyzed comparing baseline to postintervention. Categorical data were summarized using counts and percentages and analyzed using a chi-squared test. All continuous variables were summarized using means and standard deviations and analyzed using the Kruskal-Wallis test. Significance was established for *P* values <.05.

RESULTS

A total of 1,423 patient hospital-stays were included in the analysis: 697 pre-intervention and 726 postintervention. Average patient age, weight, and LOS were similar in both groups.

Hypoglycemia

Table 2 summarizes the results for hypoglycemia and severe hypoglycemia in the study population. The intervention resulted in significantly less severe hypoglycemia compared to baseline.

Glycemic Control

Overall, no significant change was seen in overall mean glucose or number of patients with hyperglycemia (defined as any glucose >180 mg/dL) after the intervention. However, a significant increase was seen in uncontrolled patient stays, defined by mean glucose >180 mg/dL. Table 3 summarizes the results for glycemic control. A subanalysis was performed for patients that had ≥6 recorded glucose values to reduce the risk of sampling error; the results were not significantly different. Of note, the mean HbA1c was significantly higher in the postintervention group when compared to pre-intervention (8.0% [64 mmol/mol] vs. 7.1% [54 mmol/mol], respectively).

Insulin Use Patterns

Table 4.1 demonstrates the shift in insulin prescribing patterns in the 3 months prior to intervention compared to postintervention, correlated with average HbA1c. A portion of patients on SSI only (22% pre-intervention vs. 38% postintervention) were noted to maintain their blood glucose within range without actually receiving any insulin. Table 4.2 shows insulin prescribing patterns when these patients were excluded from the analysis. Both analyses showed a significant increase in orders for basal insulin.

DISCUSSION

Our QI project demonstrated several important lessons which may be of use for other institutions aiming to

improve inpatient glycemic management. The most valuable outcome of our project was to identify some pitfalls of standardized insulin order sets and to demonstrate a 50% reduction in episodes of severe hypoglycemia by adjusting insulin order sets to fit recommendations with clinical practice guidelines. Additionally, we demonstrated that increased use of basal insulin did not result in higher hypoglycemia rates, addressing one of the main barriers to use of basal insulin in the hospital.

Despite the familiarity of the endocrinology department with current inpatient glycemic targets based on clinical practice guidelines, the insulin order sets, which had been developed by endocrinology staff, did not reflect best evidence–based practices and likely led to the high baseline rates of hypoglycemia in our institution. The previous order set had been in place for several years, predating the less stringent glycemic targets that are currently recommended by clinical practice guidelines. This demon-

Table 2 Hypoglycemia Rates			
	Baseline	**Postintervention**	*P* **value**
Monitored patient-stays	697	726	
Stays with hypoglycemia[a], n (%)	64 (9.18)	64 (8.82)	.73
Stays with severe hypoglycemia, n (%)	29 (4.16)	16 (2.20)	.008
[a]Hypoglycemia was defined as a glucose ≤70 mg/dL; severe hypoglycemia was defined as a glucose ≤55 mg/dL.			

Table 3 Hyperglycemia Rates			
	Baseline	**Postintervention**	*P* **value**
Monitored patient-stays	697	726	
Mean glucose ± SD (mg/dL)	176 ± 46	180 ± 53	
Stays with any hyperglycemia, n (%)	575 (82.50)	584 (80.44)	.145
Uncontrolled patient stays, n (%)	278 (39.89)	323 (44.49)	<.011

Table 4.1 Insulin Prescribing Patterns			
	Baseline	**Postintervention**	**Average HbA1c**
Monitored patient-stays	697	726	
SSI only (%)[a]	388 (56)	352 (48)	6.4% (46 mmol/mol)
Basal ± SSI (%)	197 (28)	209 (29)	8.4% (68 mmol/mol)
Basal/Bolus ± SSI (%)	111 (16)	162 (22)	8.8% (73 mmol/mol)
Bolus ± SSI (%)	1 (<1)	3 (<1)	
Abbreviations: HbA1c = hemoglobin A1c; SSI = sliding scale insulin. [a]*P* value .008 for change in SSI only prescriptions.			

Table 4.2 Insulin Prescribing Pattern Excluding Patients Who Maintained Blood Glucose Within Range Without Receiving Insulin			
	Baseline	**Postintervention**	**Average HbA1c**
Monitored patient-stays	612	594	
SSI only (%)[a]	303 (50)	220 (37)	6.7% (50 mmol/mol)
Basal ± SSI (%)	197 (32)	209 (35)	8.4% (68 mmol/mol)
Basal/Bolus ± SSI (%)	111 (18)	162 (26)	8.8% (73 mmol/mol)
Bolus ± SSI (%)	1 (<1)	3 (<1)	
Abbreviations: HbA1c = hemoglobin A1c; SSI = sliding scale insulin. [a]*P* value .005 for change in SSI only prescriptions.			

strates the need to regularly re-evaluate existing structured order sets. Our QI project revealed a disconnect between clinical practice guidelines (which recommend a glucose threshold for insulin utilization and a premeal and random glucose target range) and CPOE functionality of correction insulin order sets (which ideally provide a more specific glucose target as a basis for correction insulin doses). We have demonstrated that a correction insulin glucose target of 150 mg/dL may be more favorable than 100 mg/dL for minimizing hypoglycemia in the inpatient setting, and any resultant increase in hyperglycemia would be better managed by increasing utilization of basal insulin. It is likely that the improvement in hypoglycemia rates was directly related to the changes in insulin order sets, but we recognize that the design of our intervention does not confer the causality that could be attributed in a randomized controlled trial. We did not account for patient variables which may have confounded the rate of hypoglycemia, such as time spent nil per os, personal history of gastric bypass, or development of acute kidney injury. However, it is of interest that the rate of adherence to the new order set by house staff approached 100%, with the sole exception being patients admitted to the bariatric surgery service, for whom a custom insulin protocol is utilized. Exclusion of bariatric surgery patients did not affect the final results. The educational efforts conducted at the same time would not be expected to reduce hypoglycemia rates, since the education was primarily focused on increasing the use of basal insulin.

The intervention did significantly improve basal insulin prescribing patterns, with an additional 12% of patients with hyperglycemia receiving basal insulin after the intervention. In contrast to previous studies investigating the use of structured insulin order sets (21,26), our intervention did not result in any improvement in glycemic control; in fact, the number of patient-stays with a mean glucose >180 mg/dL actually increased. The majority of patients did not meet glycemic targets. There are several possible explanations for this finding. First, although the majority of patients were receiving basal insulin after the intervention, 65% of patients were not receiving at least the minimum recommended dose of 0.2 units/kg. This suggests that many providers remain uncomfortable with prescribing even the minimum recommended basal insulin dose in the inpatient setting. Second, a lack of titration was seen, with many patients receiving the same dose of insulin throughout their stay despite glucose values remaining above target range. Third, we did not control for variables that may have confounded hyperglycemia, such as steroid use, prescribed diet, infections, and postoperative status. Finally, we did note that the average HbA1c was significantly higher in the postintervention group, indicating that the patients admitted during this time period had worse glycemic control at baseline. This could potentially confound the results by masking any improvement in hyperglycemia due to insulin prescribing changes. However, we would expect this effect to be most prominent during the first 24 hours of admission, and all included patients had a LOS >24 hours. Moreover, the subanalysis of patients with at least 6 blood glucose readings showed identical results.

A significant proportion of patients who were ordered correctional insulin never received any insulin due to absence of significant hyperglycemia. This increases the burden on nursing staff due to the frequency of glucose checks and the documentation requirements. Consideration of decreased frequency of glucose monitoring in patients without hypoglycemia or hyperglycemia after 24 hours may be a potential target for a future process improvement project.

Ultimately, structured insulin order sets aligned with clinical practice guidelines, even with prescribing prompts, were not sufficient to achieve recommended glycemic targets. Previous studies have demonstrated additional value in utilizing an EMR-based treatment algorithm (26), but our EMR is not able to support this capability. However, in institutions whose prescribing systems allow integration of algorithms, this is likely to be more effective in managing hyperglycemia. For other institutions that do not support this capability, we suggest that a review of insulin order sets may be useful.

CONCLUSION

Minor alterations in insulin order set parameters resulted in a significant reduction in hypoglycemia without a significant increase in hyperglycemia. Further interventions are necessary to reduce hyperglycemia. Periodic review of existing insulin order sets is a simple method to improve inpatient glycemic control.

DISCLOSURE

The authors have no multiplicity of interest to disclose. The view(s) expressed herein are those of the author(s) and do not reflect the official policy or position of Brooke Army Medical Center, the U.S. Army Medical Department, the U.S. Army Office of the Surgeon General, the Department of the Army, the Department of the Air Force, or the Department of Defense or the U.S. Government.

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