Improving Glycemic Control and Insulin Ordering Efficiency for Hospitalized Patients With Diabetes Through Carbohydrate Counting

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Abstract: Glycemic control in hospitalized patients is challenging but important for optimal outcomes. Insulin dosing through carbohydrate counting may address patient, provider, and institutional factors that complicate hospital glycemic management. On two surgical units at a tertiary care teaching hospital, we pilot tested postmeal insulin dosing based on carbohydrate counting (plus basal insulin) rather than the current process of ordering scheduled premeal insulin without knowledge of the patient's consumption. Analysis assessed hyperglycemia, hypoglycemia, insulin orders, and nurse and provider satisfaction and confidence. On general surgery, mean glucose level improved from 188 to 137 mg/dl ($p < .001$). On cardiovascular surgery, mean glucose improved only mildly from 177 to 175 mg/dl ($p < .28$). No hypoglycemia was reported. Efficiency of mealtime insulin dosing improved through reduced average number of insulin orders per meal from 1.1 to 0.09. Process satisfaction improved for providers (preintervention, 60%; postintervention, 100%), general surgery nurses (preintervention, 72%; postintervention, 100%), and cardiovascular surgery nurses (preintervention, 69%; postintervention, 84%). Confidence in insulin dose accuracy improved for providers (preintervention, 50%; postintervention, 100%), general surgery nurses (preintervention, 59%; postintervention, 100%), and cardiovascular surgery nurses (preintervention, 48%; postintervention, 84%). Carbohydrate counting is effective and efficient and improved staff satisfaction and confidence in hospital mealtime insulin dosing.

Review of the Literature

Of hospitalized patients, 38% have hyperglycemia (Umpierrez et al., 2002), and prevalence of hyperglycemia (blood glucose > 180 mg/dl) is 32% to 46% (Cook et al., 2009). Risks associated with neglecting glycemic control are great in the hospital (Moghissi et al., 2009). Suboptimal glycemic control is related to reluctance to use insulin intensively, reliance on sliding scale dosing strategy, and provider fear of inducing hypoglycemia (Moghissi, 2008). Many nutritional factors complicate in-hospital diabetes management (McKnight and Carter, 2008), so experts suggest conservative insulin dosing or postmeal insulin administration (Moghissi, 2008).

Use of the Basal–Bolus Insulin Regimen

In hospitals, basal–bolus regimens are superior to sliding scale insulin regimens on the basis of improved glycemic control, decreased length of stay (McKnight and Carter, 2008; Murphy et al., 2009; Nau et al., 2010; Schnipper et al., 2009; Umpierrez et al., 2007), and low rates of hypoglycemia (Schnipper et al., 2009; Umpierrez et al., 2007).

Carbohydrate counting is widely used in outpatient settings but has not been extensively studied in the hospital setting. Hirose and colleagues (2011) found that use of three different insulin to carbohydrate ratios plus sliding scale was associated with improved glycemic control ($p < .0001$) compared with sliding scale only, without increasing rates of hypoglycemia. In contrast, Dungan and colleagues (2013) found no statistically significant improvement in glycemic control ($p = .26$) and no increase in hypoglycemia ($p = .08$) when fixed mealtime doses were compared with carbohydrate counting.

KeyWords
carbohydrate counting
glycemic control
hospital
mealtime insulin

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Purpose of the Quality Improvement Initiative

The primary aim of this quality improvement project was to improve glycemic control in hospitalized patients with diabetes through a more efficient and safer mealtime insulin dosing system. Project goals were to (1) decrease the number of mealtime insulin orders thereby decreasing the risk of errors in order entry and subsequent adverse patient events, (2) maintain or improve glucose results that reflect mealtime insulin doses (i.e., noon meal, evening meal, and bedtime glucose results), and (3) improve provider and nursing staff confidence and satisfaction in dosing mealtime insulin.

The project compared preintervention and postintervention glucose control through both the current process of mealtime insulin dosing at our large tertiary care teaching hospital in the Midwest United States and a carbohydrate counting intervention.

Methods

A multidisciplinary team reviewed the current mealtime insulin dosing process and developed an alternative dosing strategy to meet the project goals. The new process was pilot tested on two adult hospital units with patients whose diabetes was managed by nurse practitioners and physician assistants of the Diabetes Consulting Service (DCS). To minimize confounding factors, we limited the pilot to patients whose care was managed by DCS staff because of provider expertise in hospital glycemic management. Providers were allowed to determine appropriate basal insulin dosing based on their knowledge and experience. The pilot units were chosen on the basis of differences in types of patients with diabetes and type of meal tray service offered; these differences allowed us to test the new process in a wider variety of patients and settings.

The first location, a 19-bed general surgery unit, had a high percentage of patients who were postpartial or complete pancreatectomy. This unit's meal delivery method was on demand in which patients ordered food as desired throughout the day. In the second location, a 37-bed cardiovascular (CV) surgery unit, most patients had type 2 diabetes. This unit had standard meal service with meals delivered at set times each day. Choosing these units allowed for evaluation of the effect of (1) carbohydrate counting on insulin dosing for patients with type 1 and type 2 diabetes and (2) timing of meals on the mealtime insulin dosing process. All patients were receiving basal insulin in addition to mealtime insulin. Patients were not receiving corticosteroids or tube feedings.

A glucose target for the pilot was set for each unit (general surgery, ≤250 mg/dl; CV surgery, ≤200 mg/dl). Because of the assumption that glycemic control may be more variable in patients with new total pancreatectomy and the need to avoid hypoglycemia, the pilot glucose target was set higher for these patients on the general surgery unit. The CV surgery unit target glucose level was based on Surgical Care Improvement Project—Infection-4 criteria, which called for a fasting glucose level ≤200 mg/dl for the first 48 hours postoperatively (The Joint Commission, 2014). The American Association of Clinical Endocrinologists and American Diabetes Association issued a consensus statement that recommended random glucose levels <180 mg/dl in noncritically ill patients, based on expert opinion (Moghissi et al., 2009). New guidelines, issued after the pilot project, continue to suggest this, and thus the pilot data were reviewed with a threshold level of 180 mg/dl (Umpierrez et al., 2012).

Preintervention Process

A current state process flow map that highlighted the roles of patient, DCS provider, food service, health unit coordinator, pharmacy, and nurse was developed, and opportunities for process improvements in the insulin-dosing process were identified. We identified 48 steps (10 decisions and 19 handoffs) required to provide a patient's mealtime insulin dose and determined 18 opportunities for failure. At our institution, the entire process

must be repeated for each dose of mealtime insulin ordered. In the current process, it takes 144 steps per day for a patient to receive three doses of mealtime insulin.

Mealtime Insulin Dosing Strategy

Our institution's mealtime insulin dosing system was complex and the task was burdensome, and it contributed to suboptimal glycemic control in the hospital. The process consisted of the following steps:

- Daily ordering of scheduled doses of mealtime insulin for each of the three meals through computerized provider order entry.
- Mealtime insulin based on each patient's anticipated oral intake rather than actual oral intake.
- Mealtime insulin administered immediately before the patient consumed a meal, creating potential mismatch of the patient's oral intake, and the administered mealtime insulin dose, which could result in hypoglycemia or hyperglycemia.

Providers relied on nursing staff to call for dose adjustment of mealtime insulin when a patient's intake varied.

With this system, providers relied on nursing staff to understand how food intake influences insulin dosing. Nurses were not specifically trained in this component, and thus appropriate nursing interventions were not guaranteed, thereby putting the patient at risk for hyperglycemia or hypoglycemia related to insulin–food mismatch.

Preintervention Data

Glucose values were collected for baseline data from all eligible patients (>18 years of age) who had received basal insulin and scheduled doses of mealtime insulin on the two identified nursing units. Glucose results before the noon meal, the evening meal, and at bedtime were collected. Mean glycemic control on the general surgery unit (mean [*SD*] glucose, 188 [82] mg/dl) was worse than the CV surgery unit (mean [*SD*] glucose, 177 [64] mg/dl). On the general surgery unit, 9% of glucose values were ≥250 mg/dl and 48% were ≥180 mg/dl; on the CV surgery unit, 33% of glucose values were ≥200 mg/dl and 45% were ≥180 mg/dl.

Diabetes Consulting Service providers and nurses were surveyed regarding confidence and satisfaction with the current process for delivering mealtime insulin. The surveys were based on a 4-point Likert scale from *strongly agree* to *strongly disagree* with *strongly agree* and *agree* considered favorable responses. Confidence levels of providers (n = 16) and nurses (general surgery, n = 29; CV surgery, n = 116) were low for accuracy of mealtime insulin dosing with the current method. Satisfaction with the current mealtime insulin process was low among DCS providers and nurses. On the basis of the findings from current state process mapping, glucose results, and survey responses, a new process was designed to address the issues and improve the safety and efficiency of mealtime insulin delivery.

Evaluation of System Barriers and Solutions to Carbohydrate Counting

An alternative mealtime insulin dosing strategy ideally would provide several improvements as follows:

- Elimination of requirement to issue a separate mealtime insulin order for each meal, thereby decreasing the frequency of order entry and profiling and reducing risk of error within the ordering process.
- Assurance that insulin doses would more accurately reflect food consumed because doses would be based on actual oral intake. Thus, glycemic control should be improved without a subsequent increase in hypoglycemia.
- Reduction in phone calls from nurses to providers to adjust the insulin dose on the basis of quantity of food consumed, which likely would increase provider and nurse satisfaction with the process.

After development of the process flow map, potential failures and methods to prevent these failures were identified (Table 1).

The new process involved ordering a rapid-acting insulin dose through a standardized paper-based order set that included options of 10 different insulin to carbohydrate ratios for meals, ranging from 1:30 to 1:1, and providing insulin immediately after the patient finished a meal. A paper-based order set was used to prevent access of the order set to nonpilot areas until the process and order set could be tested. The following system modifications were necessary to implement the new process:

- Method to print amount of carbohydrate contained in each food item on meal tray ticket. Total carbohydrate summation on meal tray ticket was deemed insufficient for this process.
- Order set to allow providers to order insulin to carbohydrate ratio for mealtime insulin based on carbohydrates consumed.

Table 1. Potential System Failures and Recommended Interventions

Potential for System Failures	Recommended Interventions
Meal tray removed from patient room before nurse calculates carbohydrates consumed by patient	Green reminder sign posted in patient room informing staff that carbohydrate counting is ordered and nurse should remove meal tray Green patient education material reminding patient to use call button to alert nurse to remove meal tray Nurse, nursing assistant, and patient/family education about tray removal
Miscalculation of a dose of mealtime insulin	Calculation of total carbohydrates consumed completed by nurse only Insulin dose verification by a second nurse Maximum insulin dose range contained in medication profile
Carbohydrate information inadvertently not included on meal tray ticket or patient consumes nonhospital food	Nurse contacts DCS provider who has a resource that lists carbohydrate content of hospital foods and nonhospital foods (e.g., CalorieKing Wellness Solutions, Inc; www.calorieking.com)
Concern about insulin stacking if rapid-acting insulin was given between meals for carbohydrate-containing snacks	Insulin coverage for between-meal snacks was not included in order set Nurse is required to call provider for separate insulin order for high-carbohydrate snacks
Variations in ordering and order entry	Preprinted order set has checkboxes of possible insulin to carbohydrate ratios Education is given to pharmacy staff, DCS providers, and nursing staff

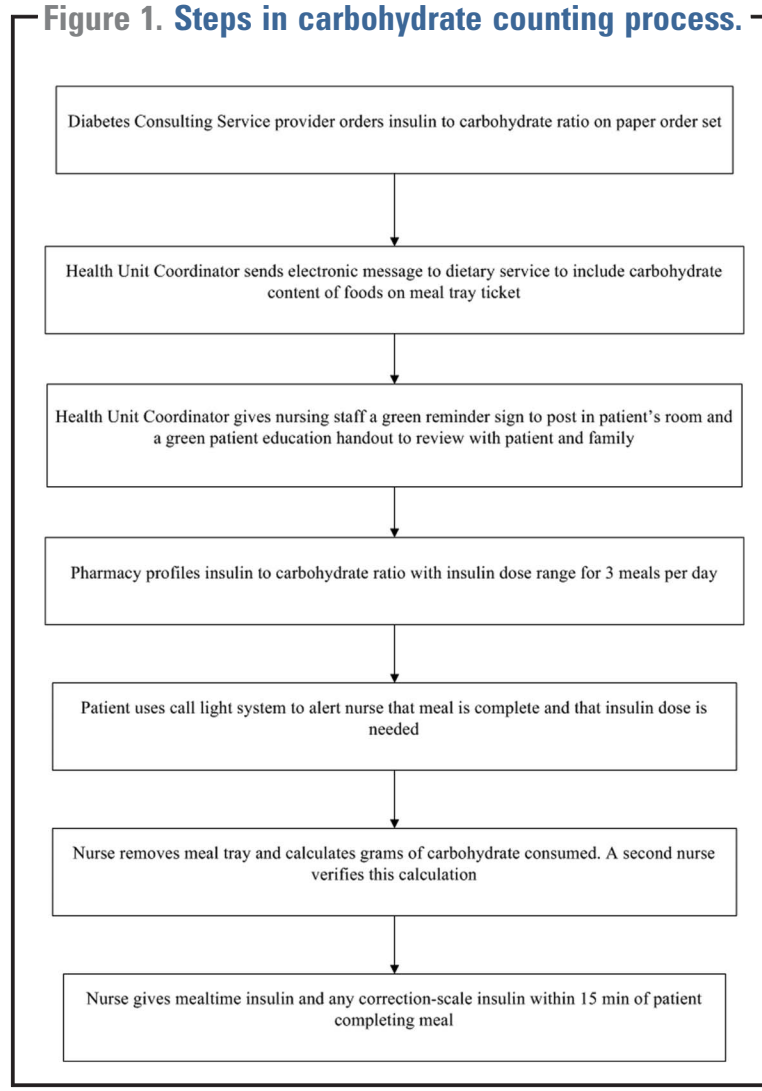
DCS, Diabetes Consulting Service.

- Revision of insulin profiling process to display insulin to carbohydrate ratio and dose range for each mealtime insulin order.

The process for carbohydrate counting is outlined in Figure 1.

When mealtime insulin orders were deemed necessary, the DCS provider completed an order set indicating an insulin to carbohydrate ratio for the patient. The patient's type of diabetes and insulin sensitivity was considered when mealtime insulin was ordered. In general, treatment was started with a ratio of 1 unit insulin to 15 g carbohydrate. A safety check in the form of a maximum dose range was profiled to cover carbohydrate consumption of up to 120 g per meal. Between-meal snacks were not covered with the insulin to carbohydrate ratio because of hypoglycemia concerns related to insulin stacking. To further minimize hypoglycemia risk, nurses were instructed to round down both total carbohydrate consumed (in grams) and the calculated insulin dose (units) to the nearest whole number. Insulin to carbohydrate ratios did not require a daily renewal order. However, if a change to the insulin to carbohydrate ratio was desired, the provider generated a new order.

Figure 1. Steps in carbohydrate counting process.



Results

Reduction in Number of Orders Issued

The initial process of ordering scheduled doses of mealtime insulin was streamlined, and the number of insulin orders was decreased. Process steps for each mealtime insulin order were reduced per order change from 48 (10 decisions and 19 handoffs) to 40 (4 decisions and 11 handoffs). For example, when the patient ate 10 meals throughout a hospital stay, the baseline process required 480 steps because our institution required a separate order for each meal. For these same 10 meals, the pilot process required 40 steps if the order of insulin to carbohydrate ratio was not adjusted. The number of insulin orders per meal was reduced from 1.1 (baseline) to 0.09 (pilot) if the insulin to carbohydrate ratio was not adjusted throughout the hospital stay. The large reduction in number of orders has the potential to decrease the risk of medication errors related to order entry and profiling. Efficiency, based on time required of DCS providers, pharmacists, and nursing staff to write, process, and follow up on orders, should be improved also, although this was not measured directly.

Glucose Control Postintervention Data

Improvements in glycemic control without increased hypoglycemia were noted on both pilot units (Table 2). On the general surgery nursing unit, mean glucose value improved from 188 mg/dl

Table 2. Baseline and Postintervention Glucose Values

Metric	General Surgery Cohort* Baseline (n = 13)	General Surgery Cohort* Postintervention (n = 10)	p	Cardiovascular Surgery Cohort† Baseline (n = 39)	Cardiovascular Surgery Cohort† Postintervention (n = 66)	p
Glucose, mean (*SD*)	188 (82)	137 (42)	<.001	177 (64)	175 (60)	<.28
Glucose, median	178	129		169	169	
≥250 mg/dl, %	9 (n = 98 tests)	1 (n = 116 tests)				
≥200 mg/dl, %				33 (n = 479 tests)	30 (n = 684 tests)	
≥180 mg/dl, %	48 (n = 98 tests)	16 (n = 116 tests)		45 (n = 479 tests)	42 (n = 684 tests)	
≤60 mg/dl, %	1 (n = 98 tests)	0 (n = 116 tests)		0 (n = 479 tests)	0 (n = 684 tests)	

*Patients have type 1 or type 2 diabetes mellitus and receive on-demand meals.
†Patients have type 2 diabetes mellitus and receive standard meal tray delivery.

(baseline) to 137 mg/dl (postintervention) ($p < .001$), percentage of glucose ≥250 mg/dl improved from 9% to 1%, and percentage of glucose ≥180 mg/dl improved from 48% to 16%. On the CV surgery nursing unit, mean glucose value improved from 177 mg/dl (baseline) to 175 mg/dl (postintervention) ($p < .28$), percentage of glucose ≥200 mg/dl improved from 33% to 30%, and percentage of glucose ≥180 mg/dl improved from 45% to 42%. No increase in hypoglycemia occurred in either patient population.

Provider and Nursing Staff Confidence and Satisfaction Data

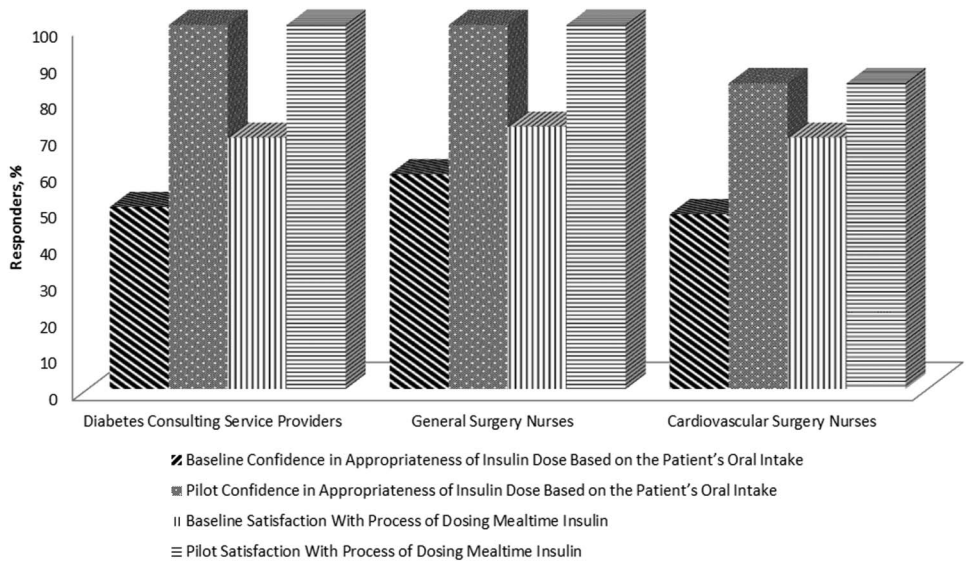
The confidence of DCS providers (n = 10) and nurses (general surgery, n = 13; CV surgery, n = 64) improved in the accuracy of mealtime insulin dosing with carbohydrate counting (Fig. 2). Satisfaction with the new mealtime insulin process also improved among DCS providers and nurses (Fig. 2).

Several changes were made postimplementation to improve glucose results. Nursing staff were instructed to round both total carbohydrate (in grams) consumed and calculated insulin dose to the nearest whole number using general rounding principles (vs. automatic rounding down). In addition, feedback was provided to nursing staff about the importance of obtaining glucose results at least 3 to 4 hours after carbohydrate intake. Glucose levels checked within 3 hours of previous meal were contributing to hyperglycemia and had potential to affect patient safety if a postprandial glucose level measured too soon after a meal was corrected with insulin.

Discussion

This project demonstrated improved glycemic control among general surgery patients, reduction in mealtime insulin orders, and improved provider and nurse confidence in and satisfaction with mealtime insulin dosing on the basis of the insulin to carbohydrate ratio. The project team hypothesized that glucose control would improve also in the CV surgery unit, which did not show improved control. Most patients undergoing cardiac surgery in this pilot had type 2 diabetes. Type 2 diabetes is marked by insulin resistance and decreased activity of endogenous and exogenously administered insulin (Burant and Young, 2012). The initial insulin to carbohydrate ratios used likely were not intense enough for these patients with inherent insulin resistance and thus resulted in a less profound improvement in glycemic control. A result of the project was that the recommended initial insulin to carbohydrate ratio for CV surgery patients should begin at 1 unit of insulin to 10 g of carbohydrate consumed versus 1 unit to 15 g. In addition, more intensive insulin to carbohydrate ratios were added to the order set to more effectively treat patients with insulin resistance.

Figure 2. Confidence in appropriateness of insulin dose based on the patient's oral intake and satisfaction with process of dosing mealtime insulin.



Another possible explanation for this outcome could be that the CV surgery units have meals delivered at the same time each day compared with on-demand meals for the general surgery unit. Breakfast and lunch standard tray times on CV surgery did not allow for a non-postprandial glucose value (i.e., ≥3 hours after eating) before lunch because of the times when meal trays arrived. Therefore, nursing staff were educated on postponing the noon glucose test as late as possible to avoid postprandial results. Elevated noon glucose values could also indicate that CV surgery patients have increased insulin resistance in the morning, similar to patients with gestational diabetes (Reader, 2012). The order set was modified to allow different insulin to carbohydrate ratios to be ordered for separate meals, to increase flexibility for providers and compensate for patients with increased insulin resistance with the morning meal.

Increased flexibility in ordering up to 10 separate insulin to carbohydrate ratios may have contributed to improved glycemic control in our quality improvement project compared with results of the study on carbohydrate counting (Dungan et al., 2013). In addition, our sample was limited to two surgical units; medical patients were not evaluated.

Reduction in the number of steps to ordering mealtime insulin and the number of orders per meal opportunity can have great implications for patient safety in the hospital setting. Providers are challenged with managing multiple different tasks to meet patient needs. Any reduction in the number of orders written and processed reduces opportunity for errors and increases efficiency. In addition, the project team hypothesized that the reduction in number of orders per meal opportunity has a role in the increased satisfaction of providers and nurses in the new process.

Nursing confidence in the accuracy of insulin doses on the CV surgery unit did not improve as dramatically as expected. The smaller improvement in glycemic control in the CV surgery unit likely resulted in less confidence in the effectiveness of this insulin dosing strategy.

Implications for Practice

Our project was successful largely because of the following:

1. Available resources for modifying meal tray tickets to include the carbohydrate content of each food item so that the information is available to nurses at the point of care.
2. Diabetes Consulting Service providers, who are experts in diabetes management and are familiar with insulin management. Additional background information regarding insulin dosing based on insulin to carbohydrate ratios may be required for institutions without an expert diabetes service.
3. Formal education for every nurse on the pilot units and the presence of an onsite resource during implementation. Patient data were reviewed in real time to ensure timely feedback for nurses and DCS providers. Feedback was solicited and progress updates were provided throughout the pilot.

Potential barriers to implementing the carbohydrate counting process throughout the hospital include the training required for all nurses and validation of the competence of the non-DCS provider in ordering appropriate insulin to carbohydrate ratios. Nurse competency also needs to be measured. The process is likely to be more successful with implementation of an electronic order set that provides an automatic message to the dietary service to include carbohydrate content on meal tickets. The order set should be modified to allow for ordering insulin to carbohydrate ratios to cover snacks in selected patients. Development of a Web-based calculator for nurses to determine the dose of mealtime insulin on the basis of the order and the grams of carbohydrate consumed would limit dose calculation errors, improve efficiency, and have potential to improve patient safety further. Monitoring the effectiveness of the intervention is labor intensive, and development of an automated report based on the electronic medical record would be helpful.

The basal–bolus insulin program is recognized as a superior treatment in diabetes management (McKnight and Carter, 2008; Murphy et al., 2009; Nau et al., 2010; Schnipper et al., 2009; Umpierrez et al., 2007, 2011). However, a limitation of this project is that only mealtime insulin doses and glucose test results were evaluated. Accuracy of the basal insulin dose was not evaluated, and insufficient basal insulin may contribute to hyperglycemia. Other confounding factors, such as individual endogenous stress response and any subsequent illness during hospitalization, also would contribute to glycemic results but are difficult to control and measure.

In summary, our institution saw reduction in mealtime insulin orders for patients with diabetes, improvement in glycemic control in general surgery patients, and improved provider and nurse confidence and satisfaction with mealtime insulin dosing after initiation of a mealtime insulin ordering process grounded in an insulin to carbohydrate ratio. These study outcomes have potential implications for patient safety, provider and nursing satisfaction, and efficiency in the complex hospital setting, where glycemic control is important but challenging. Further study regarding the use of insulin to carbohydrate dosing in diverse patient populations is recommended to ensure that this therapy is appropriate for widespread inpatient use.

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