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I, Jennifer Golan , hereby submit this original work as part of the requirements for the degree of Master of Science in Nutrition.

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Consideration of Diet in Inpatient Glycemic Control

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Consideration of Diet in Inpatient Glycemic Control

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by

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ABSTRACT

Background. Although hyperglycemia in hospitalized patients occurs frequently and is associated with morbidity and mortality, its treatment with insulin has been shown to improve clinical outcomes. Safe and effective inpatient glycemic control requires trans-disciplinary expertise that includes dietitians, nurses, pharmacists, and physicians as well as the coordination of care among diverse health care services. Processes related specifically to diet are important because of the key role that food intake plays in the regulation of blood glucose. However, very little is known about the influence of dietary factors on outcomes in hospitalized patients with diabetes.

Objective. This investigation seeks to identify the role of dietary factors in the management of hospitalized patients with diabetes. The overall hypothesis is that glycemic control in hospitalized patients is influenced by the coordination of timing between the consumption of meals, blood glucose measurement, and insulin administration; as well as the amount and composition of meals.

Participants. Eighty-two patients were selected from a general medical ward where meal slips, 24 hour food recalls, the patient medication administration record, and other medical records were used for data collection.

Methods. Insulin administration records for the entire cohort and the cohort receiving scheduled insulin were utilized to examine the timing of insulin administration in relation to the meal and the adjustment of insulin dose based on carbohydrate intake. Twenty four-hour dietary recall was used to assess patient intake and compare calorie and carbohydrate consumption with the amounts ordered, served, and needed.

Results. Data analysis demonstrated that appropriate timing between point of care (POC) glucose measurement and meals was infrequent (28.0%). The smallest deviation in blood glucose level between post-prandial and fasting measurements was observed for the time interval where POC glucose measurement was closest to the corresponding meal, although the difference was not significant when compared with the other time intervals. Analysis of subjects' diet revealed significant differences in mean carbohydrate distribution between breakfast, lunch and dinner (84 ±16 grams, 94 ±19 grams, and 76 ±21 grams respectively [$P<.01$]). The mean value of calories ordered by the physician (2017 ±165) and served by food service (2415 ±447) was higher than the calculated requirement (1792 ±340) (both $p<.01$) and what was eaten by the patient (1685 ±576) (both $p<.01$). However, the amount of calories consumed was similar to what was required ($p=.43$).

Conclusions. Our findings suggest that POC glucose measurement, insulin administration and meal intake are inadequately coordinated in hospitalized patients with diabetes and that this may adversely affect glycemic control. Furthermore, carbohydrate consumption among meals is variable and dietary orders reflect an excessive amount of calories compared to both estimated requirements and what the patient eats. Interventions are warranted that educate health professionals about the nutritional needs for hospitalized patients with diabetes and the associated influence of diet on prandial insulin requirements. Specifically, safe and effective glycemic control with insulin requires systematic and collaborative processes that coordinate all services influencing the care of the hospitalized patient with diabetes.

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INTRODUCTION

Within the last ten years research has demonstrated that hyperglycemia is a common abnormality in hospitalized patients and is associated with increased morbidity, mortality and cost (1-5). Despite controversies focused primarily on what glucose target is ideal during acute illness, there is ample evidence to support the treatment of hyperglycemia in hospitalized patients. However, many health practitioners consistently find it difficult to achieve the targeted inpatient glycemic control that has been recommended by various professional organizations (6-7).

Glucose-lowering trials, particularly those examining the benefits of “tight glycemic control,” have produced mixed findings and as such the glucose target that confers the greatest benefit with the least risk of hypoglycemia is in dispute. While it is unclear if hypoglycemia during hospitalization is a marker or cause of increased mortality, glucose-lowering trials have demonstrated higher rates of hypoglycemia with tight glycemic control (8-9). Furthermore, beyond the potential harm from hypoglycemia per se, the fear of inducing hypoglycemia has been demonstrated to be the leading barrier to implementing inpatient glycemic control practices by clinicians throughout the US (6). As a result, it has become increasingly recognized that to optimize clinical outcomes, hyperglycemia must be treated but with careful avoidance of hypoglycemia.

Glycemic control for most acutely ill patients is best achieved through insulin administration (10). According to the meta-analysis of hyperglycemic management studies by Kirk and Oldham this is best accomplished through administration of exogenous insulin which closely mimics normal physiologic insulin activity in the body through three components: basal, nutritional and correctional insulin. However, nutritional insulin, which is given in response to food, is challenging to manage in the hospital setting (11). Providing the correct type and amount of insulin at the proper time is difficult since patient meal times often vary, are interrupted, or are rescheduled (12). In addition to the difficulty of proper insulin administration, Lleva and Inzzucchi (13) found glucose management on the general and medical floors lacking due to several factors including the physician's focus being primarily on the admission diagnosis, the lack of standardized protocols outside of ICU, and irregular nutritional intake. Specifically, the coordination of timing among glucose measurement, insulin administration, and consumption of meals is critical in order to both prevent hypoglycemia and effectively treat hyperglycemia; nevertheless, there has been little research regarding this process and other influences of diet on glycemic control.

The present study used data from patients with diabetes hospitalized on a general medical ward to identify and evaluate dietary factors that influence glycemic control specifically relevant to the timing of meals with insulin administration, as well as the characteristics of the meals consumed. In particular, the study hypothesized that mistiming of insulin administration and glucose measurement was common and that mistiming is associated with hypoglycemia or hyperglycemia. Additional factors that could contribute to poor glycemic control were that the insulin dose is infrequently adjusted based on the amount of food and carbohydrate composition of the meal; that the amount of calories and carbohydrates served to and eaten by the patient would not correspond with what was required; and that insulin was not administered for unscheduled intake of snacks and beverages.

METHODS

Sample

This observational study was conducted at a major, urban university hospital. Patients admitted to the general medical ward for inpatient treatment were given the opportunity to participate in the study. Inclusion criteria included subjects over 18 years of age with no gender or ethnic limitations. All subjects had been diagnosed with either type 1 or type 2 diabetes. Subjects must have been ordered a consistent carbohydrate diet for an entire hospital day and must have received the hospital's standardized protocol for subcutaneous insulin treatment. Intensive care, transplant, neonatal, and obstetric patients were excluded. Patients who received total parenteral nutrition, enteral nutrition, or who were on liquid diets were also excluded. Eighty-two subjects met the inclusion criteria and were enrolled in the study.

Patients with orders for scheduled insulin were selected from the entire cohort (n=35) for separate analysis; they were identified as a subgroup, or hospital population, for which standardized hospital glycemic control practices are expected as part of routine care. Patients receiving "scheduled insulin" were defined as having point-of-care (POC) glucose measurements and scheduled insulin administration prior to each meal (breakfast, lunch and dinner) and at bedtime.

The University of Cincinnati's Institutional Review Board approved the study procedure and all participants provided written informed consent.

Measures

Insulin Administration Timing. The Medication Administration Record (MAR) was used to collect information on the subjects' insulin administration. Insulin type, dosing, and timing were recorded on a standardized form. At the time the study was conducted the MAR pharmacy records consisted of an insulin administration schedule template that was not designed to provide information about the precise time of administration but rather to which meal the insulin dose corresponded. Although this has subsequently been modified, due to insufficient data at the time of the study on precise insulin administration times, the POC glucose measuring time was identified as the surrogate variable for insulin administration time. POC blood glucose and laboratory blood glucose records were obtained from the electric medical record information system used by the hospital.

For the entire cohort, each precise meal time was paired with the closest POC measurement time. The time difference between the meal and POC measurement was calculated. If the POC measurement occurred before the meal, the value was a negative number; if the value occurred after the meal, the value was positive. Properly timed POC glucose measurement and insulin administration were defined as occurring within 0-30 minutes before the meal was consumed.

Insulin Adjustment Based on Amount and Composition of Meal. The MAR for each subject was reviewed to determine if insulin administration was adjusted based on either food consumption or carbohydrate content. Other dietary factors that were measured included the amount of calories and carbohydrates, in grams, required by the patient, ordered by the doctor, served to the patient, and consumed by the patient.

Dietary Needs. To calculate the caloric needs of each patient we used the Harris Benedict Equation (14). The equation is specific to males and females, using weight (W) in kilograms (kg), height (H) in centimeters, and age (A) in years. The equations are as follows: Resting Energy Expenditure (REE) Women: $655 + (9.6\ W) + (1.7H) – (4.7A)$, REE Men: $66 + (13.7W) + (5H) – (6.8A)$. This equation was used for subjects with BMIs <30. For subjects with a BMI ≥ 30, the Hamwi formula was used to first find desired body weight (DBW) (14). The Hamwi equations are as follows: Women: 100 lbs + 5 lbs for each inch after 5', Men: 106 lbs + 6 lbs for each inch after 5'. The DBW, in pounds, was calculated from this formula and then converted to kilograms. Kilograms were then entered into the formula for adjusted body weight (14). The equations used for adjusted body weight are: Male: [(actual wt – DBW) x 0.32] + DBW, and females: [(actual body wt – DBW) x 0.38] + DBW. This calculation provided the kg which was then used in the Harris Benedict equation. Because all subjects were "confined to bed", the REE calculated for both normal weight and overweight patients was multiplied by a factor of 1.2 (14). For each subject, the caloric need determined by the Harris Benedict equation was used to estimate macronutrient content according to what is considered ideal meal distributions for patients with diabetes at the study hospital (55% carbohydrates, 15% protein, and 30% fat) (15).

Diet Ordered. The computerized physician order sets for insulin present the physician with the choice of total daily calories of either 1900-2100 or 2200-2500. In addition, each subject in the study was ordered a consistent carbohydrate meal plan by the physician, a practice that is encouraged for hospitalized patients with diabetes in order to provide similar amounts of carbohydrates with each meal (6). Patient meal tickets present the amount of carbohydrate (CHO) content as CHO units (15 grams = 1 unit).

Diet Served. The food served to the subject along with the amount of calories and carbohydrate composition ordered by the physician was indicated by the meal ticket found on the subject's tray for each meal (breakfast, lunch, dinner, and snacks). These meal tickets were collected from the previous day for each subject. A diet analysis software program (16) was used to estimate the caloric and carbohydrate values of the food served to the patient for each meal.

Diet Consumed. A 24-hour dietary data collection, the standard method for dietary recall, was performed in order to collect information about what the subject ate the previous day. Because a 3-day recall is not possible in a hospitalized population where length-of-stay is often shorter than 3 days, we used the standard instrument for 24-hour recall which has been demonstrated to be valid and reliable for a cohort of this size (17). The interviewer used the food tray tickets to assist the subject's memory; while reviewing what the subject consumed, subjects were encouraged to add any intake they might have forgotten. The foods listed during the recall were analyzed by a diet analysis software program (16) to obtain calorie and carbohydrate values of the food consumed by the patient at each meal.

Insulin Adjustment Based on Snack Intake

MAR records were checked to see if insulin administration was adjusted based on any snack intake either provided by the hospital or any excess food not included in the hospital meal plan. In addition, MAR records were checked to identify if insulin administration was adjusted based on the carbohydrate content on of the snack.

Twenty-four hour food recalls were compared to the food tray ticket to determine which patients consumed snacks provided by the hospital, and to determine which patients ate food not included in the meal plan.

Analysis

Insulin Administration Timing. For both groups, the entire cohort and the cohort receiving scheduled insulin, the frequency of mistiming was examined. The observations were categorized by meal (breakfast, lunch, dinner) and 30 minute time intervals. Differences between POC blood glucose measurement and meal timing were analyzed descriptively by calculating means and percents of intervals less than or equal to 30 minutes between POC and meal timing. Scheffe's method for multiple comparisons tested the statistical significance between the means of POC glucose measurement and meal timing. The mean and standard deviation of fasting glucose values of each patient ($FGV_{m,}$ FGV_{sd}) were also calculated, and used to obtain 'standardized' deviations of blood glucose from the average value of fasting glucose. A box and whisker plot was drawn to visually compare distributions of percent deviations = 100* [(blood glucose at next meal - FGV_m)/ FGV_{sd}] by 30 minute time intervals, for all meals combined. The medians for each box whisker plot interval were compared using a non-parametric ANOVA called the Kruskal Wallis test.

Insulin Adjustment Based on Amount and Composition of Meal. Means of dietary factors including the amount of calories and carbohydrates needed, ordered, served and eaten by the patients were obtained. Analyses of variance were performed for both calories and carbohydrates in order to test differences among group means, followed by individual paired t-tests. P-values were adjusted for multiple comparisons using the method of Scheffe. Insulin administration dose was not adjusted for carbohydrate consumption eaten or served.

RESULTS

Patient Characteristics

Patient characteristics are presented in Table 1. For the entire cohort (n=82) the majority of the subjects were male. Most subjects were black (53.6%) or white (41.5%). Roughly one quarter of the subjects were overweight and more than half were obese according to BMI calculations. Ninety-seven percent of subjects were diagnosed with type 2 diabetes. For the sub-group of patients receiving scheduled insulin (n=35), the demographic characteristics were similar to the entire cohort.

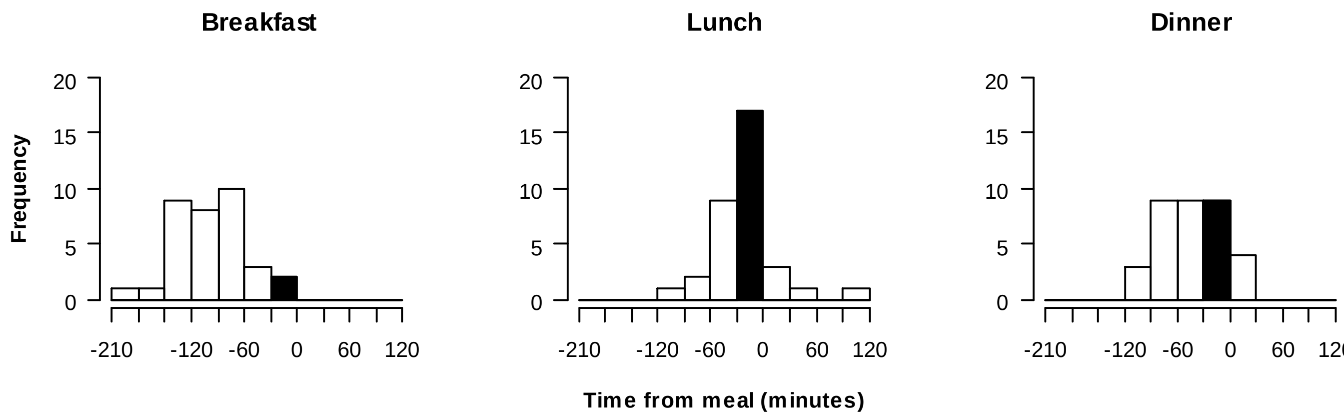
Table 1. Patient Characteristics		
	Entire Cohort (n=82)	
	n	**%**
Sex		
Men	49	59.7
Women	33	40.3
Race		
White, Non-Hispanic	34	41.5
White, Hispanic	2	2.4
African American	44	53.6
Asian	1	1.2
Other	1	1.2
BMI		
<24.9	18	21.9
25 - 29.9	20	24.4
>30	44	53.7
Diabetes Type		
Type 1	2	2.4
Type 2	80	97.5
On Scheduled Insulin	35	42.7
Age (mean, years)		56.7

Timing of POC Blood Glucose Measurement with Meals

For all meals, the cohort receiving scheduled insulin had slightly over one quarter of POC glucose measurements appropriately timed with meals. For breakfast, lunch, and dinner the percent of POC glucose measurement obtained less than 30 minutes before the meal was 5.88, 50.00, and 26.47 respectively. The mean time intervals between POC glucose measurement of all meals were statistically significant different from each other ($p<.05$). The significance between breakfast and lunch was $p<.001$, breakfast and dinner was $p<.001$, and lunch and dinner was $p=0.026$. Figure 1 shows the frequency of POC glucose measurement timing in relation to the meal and demonstrates that appropriate timing of glucose measurement with meals is infrequent for breakfast.

Figure 1

Timing of POC Glucose Measurement and Meals for Subjects Receiving Scheduled Insulin

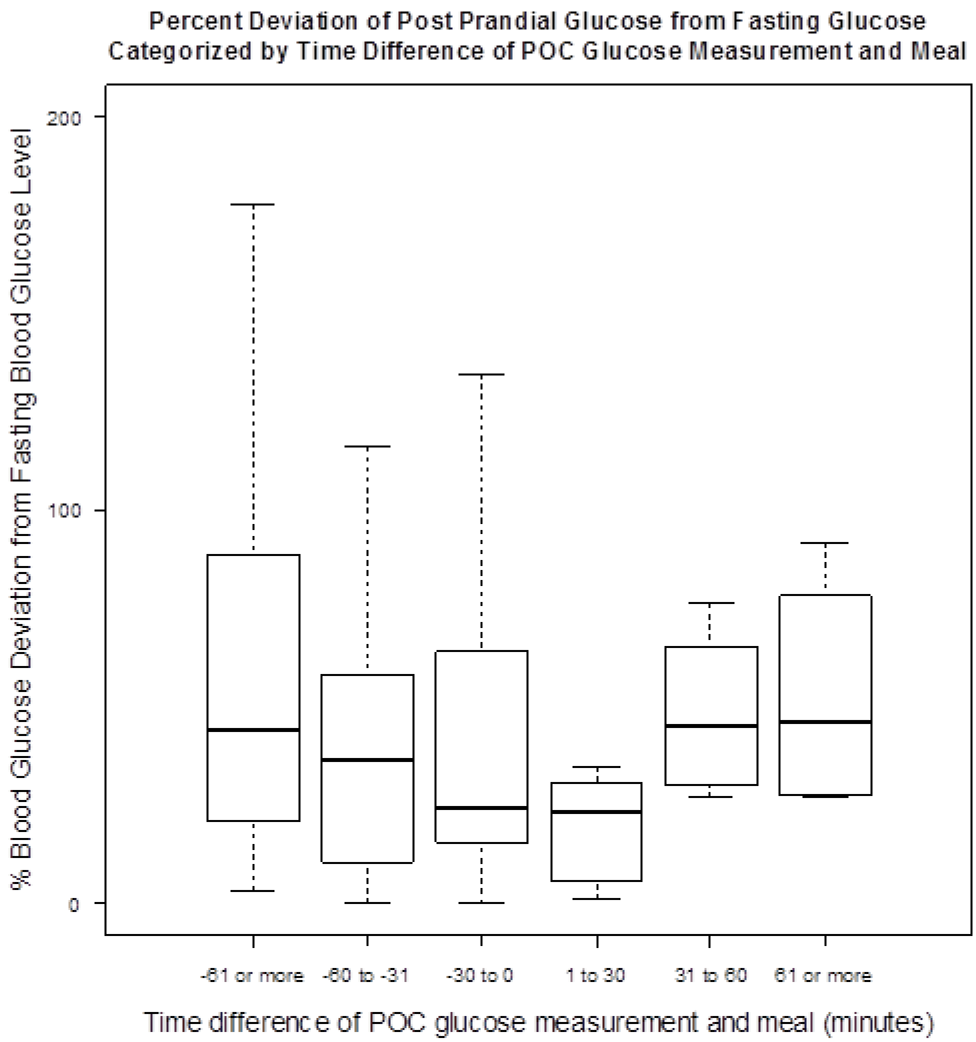


For all meals, the entire cohort had only 28.0% of POC glucose measurements properly timed with the meal. For breakfast, lunch and dinner, the percent of POC glucose measurement obtained less than 30 minutes before the meal was 5.1, 49.4, and 29.5 respectively. The mean time intervals between POC glucose measurement of all meals were statistically significant different from each other ($p<.05$). The significance between breakfast and lunch was $p<.001$, breakfast and dinner was $p<.001$, and lunch and dinner was $p=0.0154$.

Timing of POC Glucose Measurement with Meal and its Relationship to Post-Prandial Blood Glucose level

The cohort receiving scheduled insulin showed for each post-prandial blood glucose level the median percent deviation from fasting blood glucose was 46.4, 34.8, 23.5, 16.7, 28.9, and 91.8 for the following POC glucose measurement time intervals respectively, -61 minutes or more before the meal (n=45),-60 to -31 minutes (n=26), -30 to 0 minutes (n=38), 1 to 30 minutes after the meal (n=13), 31 to 60 minutes (n=8), and 61 minutes or more (n=4). Although, a trend in which the lowest percent deviation of post-prandial from fasting glucose level was observed for the time intervals where POC glucose measurement was closest to the corresponding meal, there was no statistically significant difference between these variables (p=0.29).

Figure 2



The entire cohort showed for each post-prandial blood glucose level, the median percent deviation from fasting blood glucose was 32.2, 28.8, 26.8, 31.0, 23.5, and 56.2 for the following POC glucose measurement time intervals respectively, -61 minutes or more before the meal (n=69),-60 to -31 minutes (n=68), -30 to 0 minutes (n=69), 1 to 30 minutes after the meal (n=23), 31 to 60 minutes (n=2), and 61 minutes or more (n=4). Similar to the cohort receiving scheduled insulin, the lowest percent deviation of post-prandial from fasting glucose level was observed for the time intervals where POC glucose measurement was closest to the corresponding meal, although there was no statistically significant difference between these variables ($p=0.96$).

Insulin Adjustment Based on Amount and Composition of Meal

In reviewing the documentation for insulin administration the only insulin changes noted were those related to a dose being held related to low blood glucose value or when the patient refused the scheduled dose. There were no documented dosing adjustments related to food intake, therefore, statistical analysis was unnecessary due to lack of documentation.

Calorie and carbohydrate composition of patient meals. Table two shows averaged over all meals, an excess of 225 and 623 calories, were ordered and served respectively when compared to calculated needs [both ($p<.01$)]. However, subjects consumed 730 calories fewer than served ($p<.01$), and the amount of calories eaten were similar to what was needed ($p=.43$). In respect to carbohydrate composition, patients were ordered 31 more grams, and served 37 more grams, than needed [both ($p<.01$)]. On average, the patients consumed 33 grams fewer than needed ($p<.01$) and, the amount of carbohydrate ordered were similar to what was served ($p=.89$). Although, dietary orders for all subjects included “consistent carbohydrate” composition for each meal, there were significant discrepancies in grams of carbohydrates to patients at breakfast, lunch and dinner ($p<.01$).

Table 2. Calorie and Carbohydrate Diet Composition				
	Need	**Ordered**	**Served**	**Eaten**
All Meals				
Calories[a]	1792 (±340)	2017 (±165)	2415 (±447)	1685 (±576)
Carbohydrates (g) [b]	246 (±47)	277 (±23)	283 (±44)	213 (±66)
Carbohydrates (g) by meal [c]				
Breakfast	71 (±16)	81 (±5)	84 (±16)	63 (±25)
Lunch	73 (±16)	83 (±9)	94 (±19)	69 (±28)
Dinner	75 (±17)	85 (±7)	76 (±21)	57 (±25)

[a] Total calories - means were significantly different ($p<0.01$) except for eaten and need.

[b] Total carbohydrates - means were significantly different ($p<0.01$) except ordered and served.

[c] Carbodyrates by meal - means were significantly different ($p<0.01$) for B, L, D served

Intake of Snacks and Beverages

Eighty out of 82 patients received nighttime snacks in accordance with the hospital consistent carbohydrate meal plan. Six patients ate more than one snack during the day, and 3 had snacks outside of the hospital meal plan. Insulin records showed no adjustment was made for carbohydrate content of the snacks, or for the three snacks not provided by the hospital.

DISCUSSION

This research furthers the knowledge of diabetes care in non-critically ill patients. Lleva and Inzucchi show regimens using basal insulin combined with premeal and supplemental insulin that maintain blood glucose levels of 140 mg/dL for before meals and 180 mg/dL for random checks are effective for glycemic control in the hospital (13). Taking these guidelines one step further, this study showed the timing of the insulin administration is just as important as the type and dosage of insulin given to the patients. Breakfast had the least number of properly timed POC glucose checks for both groups. This might be due to shift changes for nurses and patient care assistants occurring during this time. Lunch was the most properly timed meal of the three, but still had a large number of mistimings since only 50 percent of checks occurred within the proper time. All meals demonstrated appropriate timing of POC glucose measurement and meal was infrequent. This supports the research of Freeland et al which found 84% of the time patients were not given rapid-acting insulin within 10 minutes before or after the morning meal (18). For each meal the means of POC glucose measurement timing and meal time were statistically significant from each other, showing the inconsistency of POC glucose measurement checks among the hospital staff. Procedures need to be introduced to correct POC glucose measurement so the point of care is within 30 minutes of the meal, especially for the group receiving scheduled insulin.

The box-whisker-plots provide insight into the correct timing of insulin administration in order to maintain proper blood glucose levels. Although, not statistically significant, the lowest percent deviation of glucose value from fasting glucose value was observed during the time interval of glucose check within 30 minutes of meal, both before and after for the scheduled insulin group. Within this time frame could lie the best time to administer insulin so as to have glucose values fall within a proper range. Corby et al found in adults with type 1 diabetes, rapid-acting insulin administered 20 minutes prior to the meal was more effective at controlling post prandial glucose compared to insulin given just before the meal or 20 minutes after (19).

The results for insulin adjustment based on amount and composition of meal, showed the amount of food the patient ate was not taken into account for insulin administration. It appears that nursing administered insulin to those patients receiving scheduled insulin regardless of the amount of food eaten by the patient. Not regulating this could result in hypoglycemia for the patient if insulin is given and no food is eaten or hyperglycemia if not enough insulin is given to cover the amount of food eaten. Guidelines should be implemented to ensure insulin administration is in accordance to food consumed. Also, since the calories and grams of carbohydrates needed, ordered, served and eaten were statistically significant from one another, this shows the need for more coordination among the hospital staff in ordering and administering proper diabetic meals. The amount of calories ordered by the physician and served by food service was higher than calculated needs. However, the calories the patients consumed compared to what they required was not statistically different. This may be a reflection of patients' self-regulation of energy intake, however, the over-serving of each patient still needs to be addressed for economic reasons. This supports the findings of Moghissi et al (6) which found diabetic programs that have specified glycemic targets will have more costs attributable to an increase in time needed from physicians, nurses, pharmacists, and dietitians in the short term but will ultimately provide long-term cost-savings due to improved clinical outcomes.

In addition, although the patients were on a consistent carbohydrate meal plan the grams carbohydrates served at each meal was significantly different, showing the need for coordination within the food service department of the hospital. For this population, the majority of who have type 2 diabetes and are insulin resistant, a difference of 25 g of carbohydrates can reflect very different insulin requirements.

Snack consumption of patients show very few snacks eaten outside of food provided by the hospital. This is fortunate since insulin was not given to cover these outside snacks. Snack guidelines should be developed either banning the consumption of outside snacks or having a way to alert the nurses so they can provide adequate insulin to cover the carbohydrate content of the snack.

All of these results show the need for coordination among the hospital staff, including doctors, nurses, dietitians, and food service, in order to provide proper, standardized diabetes care.

Flanagan et al found a dedicated inpatient care team decreased the length of hospital stay for patients with diabetes (20). Doctors and dietitians need to work together in order to provide the correct meal plan for diabetes patients. Food service needs to follow strict guidelines to make sure the amount of food, especially carbohydrates are correctly served to patients, and nurses should check glucose and administer insulin in the proper time frame. Any errors in ordering the diet, serving the food, checking blood glucose levels, and administering insulin could result in poor glycemic control. Further research should focus on strategies to coordinate all health care professionals responsible for diabetes care to see if that coordination results in more managed glycemic targets.

This study does have limitations. Using POC glucose measurement timing in place of insulin administration timing, does not allow use of the most precise timing values. Further research should use insulin administration time instead of POC glucose measurement time for associations between insulin administration and blood glucose levels.

CONCLUSION

The present study shows point-of-care glucose measurement, insulin administration and meal intake are inadequately coordinated in hospitalized patients with diabetes and this may adversely affect glycemic control. Standards of care should be implemented for insulin administration practices especially for breakfast since shift change often occurs during this time. Documentation processes for insulin administration should be changed to require the exact time of insulin administration time to be recorded instead of having the nurses simply sign off on specific times. Also, interventions that are patient-centered and involve patient participation as they are able may prove to be among the most effective in inpatient diabetes care.

Standardized procedures should also be implemented regarding the dietary intake of each diabetes patient. Basic education of physicians regarding diet prescription and food service workers should be applied to ensure meals contain the proper calorie and "consistent carbohydrate" amount for patient since an excessive amount of calories and carbohydrates are ordered and served to patients compared to estimated requirements and actual intake. Coordination of dietary intake of hospitalized patients with diabetes could improve glycemic control.

Several systems-level changes have taken place following our study that may improve the coordination of insulin administration with meals. First, a "room-service" system of meal delivery has been implemented throughout the hospital which requires collaboration between food services, nursing and physicians to achieve proper insulin timing with meal consumption. Furthermore, as patients request their breakfast later in the morning than the previously determined early morning timeframe, patients are less likely to require insulin at times overlapping with the staff change in shifts. Second, the Medication Administration Record (MAR) was revised so that printed times for prandial insulin administration reads, "breakfast", "lunch", and "dinner" rather than 07:30, 12:00, and 17:00. This prevents the conflict in decision-making that nurses would face when deciding between whether insulin should be given as marked in the MAR or in relation to meal consumption. Finally, bedtime snacks were omitted from the patient's meal plan, since newer insulin is used to control blood sugar. This insulin does not need a bed time snack to ensure blood sugar levels do not drop overnight. Therefore, patients were getting additional carbohydrates with the evening snack, possibly resulting in hyperglycemia.

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