ORIGINAL ARTICLE

Insulin Pump and Continuous Glucose Monitor Initiation in Hospitalized Patients with Type 2 Diabetes Mellitus

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Abstract

Background: Insulin pumps and continuous glucose monitoring (CGM) are commonly used by patients with diabetes mellitus in the outpatient setting. The efficacy and safety of initiating inpatient insulin pumps and CGM in the nonintensive care unit setting is unknown.

Materials and Methods: In a prospective pilot study, inpatients with type 2 diabetes were randomized to receive standard subcutaneous basal-bolus insulin and blinded CGM (group 1, $n=5$), insulin pump and blinded CGM (group 2, $n=6$), or insulin pump and nonblinded CGM (group 3, $n=5$). Feasibility, glycemic control, and patient satisfaction were evaluated among groups.

Results: Group 1 had lower mean capillary glucose levels, 144.5 ± 19.5 mg/dL, compared with groups 2 and 3, 191.5 ± 52.3 and 182.7 ± 59.9 mg/dL ($P_{1 \text{ vs. } 2+3} = 0.05$). CGM detected 19 hypoglycemic episodes (glucose <70 mg/dL) among all treatment groups, compared with 12 episodes detected by capillary testing, although not statistically significant. No significant differences were found for the total daily dose of insulin or percentage of time spent below target glucose range (<90 mg/dL), in target glucose range (90–180 mg/dL), or above target glucose range (>180 mg/dL). On the Diabetes Treatment Satisfaction Questionnaire-Change, group 3 reported increased hyperglycemia and decreased hypoglycemia frequency compared with the other two groups, although the differences did not reach statistical significance.

Conclusions: Insulin pump and CGM initiation are feasible during hospitalization, although they are labor intensive. Although insulin pump initiation may not lead to improved glycemic control, there is a trend toward CGM detecting a greater number of hypoglycemic episodes. Larger studies are needed to determine whether use of this technology can lower inpatient morbidity and mortality.

Keywords: Diabetes, Insulin pump, Continuous glucose monitoring, Inpatient.

Introduction

IN THE SETTING of acute illness, concern for hypoglycemia, physician understanding of insulin, and medications modulating insulin resistance,^{1–5} inpatient glycemic control is difficult to achieve. Inpatient glycemic variability worsens patient outcomes.⁶ Hyperglycemia is associated with more frequent postoperative infections,^{7,8} greater morbidity and mortality after stroke,^{9,10} myocardial infarction,¹¹ pneumonia, urinary tract infections,^{12,13} and traumatic brain injury.^{14,15} Profound hypoglycemia is also a risk factor for poor outcomes in hospitalized patients, inciting neurological damage and fatal arrhythmias in patients with preexisting cardiovascular

disease.¹⁶ Many inpatient hypoglycemic episodes are asymptomatic, due to hypoglycemic unawareness or altered mental status induced by medications or acute illness.¹⁷ These findings have led to recommendations for more frequent inpatient glycemic monitoring, especially in patients at high risk for recurrent hypoglycemia.⁵

In the nonintensive care unit (non-ICU), patients with diabetes are typically administered subcutaneous long-acting basal and rapid-acting insulin analogues, based on point-of-care (capillary) glucose monitoring before meals and bedtime or every 6 h in patients who are not receiving oral nutrition.¹⁸ Limited research has been conducted to evaluate alternative insulin administration protocols to better achieve inpatient

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glycemic targets.^{19,20} Numerous publications, primarily reviews and retrospective studies, have evaluated the continued use of outpatient insulin pumps during an acute care hospitalization.^{21–24} To date, few studies have examined insulin pump initiation during an acute care hospitalization.^{25,26} Further, only a limited number of publications have evaluated adjunctive continuous glucose monitoring (CGM) in the non-ICU setting.^{27–31} We hypothesized that inpatient initiation of insulin pump therapy in the non-ICU setting would improve glycemic control, similar to that seen in the outpatient setting.^{32,33} Moreover, we hypothesized that using adjunctive nonblinded CGM would decrease the duration of glycemic excursions, compared with blinded CGM, due to threshold alarm notification, as previously demonstrated for outpatients with type 1 diabetes mellitus (T1DM).³⁴

To test our hypothesis, a prospective pilot study was conducted to evaluate the feasibility of initiating insulin pumps and CGM in the non-ICU inpatient setting, to determine whether insulin administration via an insulin pump provides superior glucose control (lower mean glucose, fewer hypoglycemic events) over conventional basal-bolus subcutaneous insulin therapy, and to assess whether using CGM improves glycemic control (decreased glycemic excursion duration, lower mean glucose) compared with traditional capillary glucose monitoring alone.

Materials and Methods

Subjects

Sixteen subjects admitted to the University of Maryland Medical Center were enrolled in the study. Subjects were identified by chart review, referral from the inpatient team caring for the patient, and the inpatient diabetes consultation service. Patients were recruited primarily from cardiovascular services (cardiology, cardiothoracic and vascular surgery). Inclusion criteria included: type 2 diabetes mellitus (T2DM), outpatient insulin prescription, ≥ 18 years old, not pregnant, and anticipated hospital stay greater than 2 days. Exclusion criteria included: T1DM, admission or transfer to the ICU, prescribed only oral diabetes medications before admission, insulin requirements >200 units/day, or current acetaminophen order. If the subject was prescribed both oral diabetes medication and insulin as an outpatient, they were eligible for inclusion in the study.

Subjects were randomized into three different treatment arms. All three groups underwent capillary glucose testing before meals and bedtime if eating or every 6 h if not eating. Group 1 received basal glargine insulin (Lantus, Sanofi Diabetes, Bridgewater, NJ) and preprandial and correction aspart insulin (Novolog, Novo Nordisk, Plainsboro, NJ) before meals and bedtime if eating or every 6 h if not eating with blinded Dexcom CGM (Dexcom, Inc., San Diego, CA). Group 2 received basal and bolus aspart insulin via an OmniPod insulin pump (Insulet Corporation, Billerica, MA) with blinded Dexcom CGM. Group 3 received basal and bolus aspart insulin via an OmniPod insulin pump with nonblinded Dexcom CGM. All three groups used a CGM, although only group 3 had access to real-time CGM data during the study duration. For groups 1 and 2, adjustments in basal and bolus dosing were based on capillary glucose levels. For group 3, adjustments in basal and bolus insulin were based on both capillary glucose and CGM data.

Diet

If eating, subjects were placed on a carbohydrate-controlled diet, with approximately equal carbohydrate content from day-to-day with each meal. Total caloric content was based on nutritionist recommendation. Mealtime menus reported the carbohydrate content of each food item. Using this information, nurses entered the total carbohydrate content into the insulin pump bolus wizard, along with the capillary glucose value, to calculate a mealtime insulin bolus for groups 2 and 3. All subjects were counseled to avoid non-prescribed snacks.

Insulin pump

The OmniPod insulin pump was selected for use as each “pod” is a self-contained pump that is disposable after use, thus abrogating infection control concerns that come with using equipment in multiple patients. The OmniPod pump is programmed by a hand-held Personal Diabetes Manager (PDM).

Before the start of the study, nurses participated in a training session. During the training session, nurses were instructed on how to enter glucose and carbohydrate values into the OmniPod PDM to deliver meal time/correction insulin boluses and how to calibrate the CGM device. After the didactic portion of the training session, all nurses had an opportunity to perform these skills on actual equipment. Staff also received handouts reviewing the training session, in addition to receiving individual training if one of their patients was enrolled in the study. Study investigators were available, either in person or by phone 24 h a day, to answer questions and help resolve technical and mechanical issues.

Nurses administered all insulin pump boluses, using the bolus wizard feature on the pump, incorporating preprandial capillary glucose and anticipated carbohydrate content. Nurses were instructed to remove the pump if a prolonged episode of hypoglycemia occurred that did not resolve using a standardized hypoglycemia protocol.

Continuous glucose monitoring

All subjects used the Dexcom Seven Plus CGM device, which reported interstitial glucose values every 5 min.³⁵ CGM data were blinded for groups 1 and 2, whereas group 3 used nonblinded CGM data during hospitalization. CGM data from all subjects were used for analysis.

Nurses were extensively counseled on CGM calibration and troubleshooting by study investigators. Although all CGM devices could alarm for mechanical dysfunction, including if CGM calibration occurred less than every 12 h, only group 3 had audible hypoglycemic and hyperglycemic threshold alarms. The hypoglycemic threshold was set to 70 mg/dL; the hyperglycemic threshold was set to 200 mg/dL. All triggered glycemic threshold alarms were confirmed by capillary glucose measurements before initiating treatment. Unless a sensor malfunctioned, a single sensor was used per subject, as data could be collected for up to 7 days. At the end of 7 days, patients remaining in the hospital were transitioned back to standard-of-care basal-bolus insulin managed by the admitting team. The CGM receiver, PDM, and transmitter were cleaned with Cavicide disinfectant before and after each use, whereas the sensor was disposable.

Insulin initiation

The initial inpatient insulin regimen was based on the patient's outpatient regimen. For group 1, 50% of the total outpatient insulin regimen was initially given as glargine insulin, and if eating, the remaining 50% was given as prandial aspart insulin, with one-third given before each meal. Correction aspart insulin was administered based on the total daily insulin requirement. If the patient was known to have significant preadmission hypoglycemia or hyperglycemia, the initial insulin regimen was decreased/increased, respectively, by 10%.

Patients randomized to insulin pumps were started on basal aspart insulin at 40% of their total daily outpatient insulin dose. A lower starting basal insulin dose was used with the pump due to concerns for hypoglycemia that might arise with faster absorption of rapid-acting insulins compared with basal insulins and also more rapid absorption of the smaller hourly volumes of insulin with the pump compared with the larger volumes of insulin for daily long-acting insulin injections. If patients were known to have significant preadmission hypoglycemia or hyperglycemia, the starting dose of basal aspart insulin was 35% or 50%, respectively, of the outpatient dose. Each patient had a single basal rate set for a 24-h duration. Prandial insulin was based on the insulin:carbohydrate ratio (450/total outpatient daily dose of insulin) and insulin sensitivity factor (1500/total outpatient daily dose of insulin).

Insulin titration

Blinding study investigators to each patient's treatment group was not possible due to the study design. To avoid investigator bias, day-to-day insulin titration was handled by the inpatient diabetes consultation team. This team was composed of an attending physician board certified in Endocrinology, Diabetes and Metabolism and an endocrine fellow, neither of whom were study investigators. The consult team received training on the study protocol, specifically the insulin titration protocol, as well as on OmniPod pump and CGM use. Glucose and insulin titration data were reviewed by the investigators during the study on an ongoing basis to ensure that the treatment protocol was followed.

Based on prior publications, all subjects were held to the same glycemic goals during the study, preprandial glucose 90–130 and <180 mg/dL 2 h postmeal.³⁶ Insulin titration occurred daily and as needed. For glucose levels <70 or >250 mg/dL, the diabetes consultation team was notified, and more immediate insulin titration was made. If there was a hypoglycemic episode without clear etiology, the insulin dose was decreased by 10%–20%. If subjects required ≥ 5 units of correction aspart insulin during a 24-h period, the standing dose of insulin (either glargine or aspart) was increased accordingly, depending on the pattern of hyperglycemia. For groups 2 and 3, subjects with hyperglycemia (>250 mg/dL) refractory to two correction boluses received a manual injection of aspart insulin, given at the instruction of the diabetes consultation service, and a new OmniPod pump was inserted to correct for potential catheter kinking/dysfunction.

Data collection

In addition to glucose values and insulin regimen, data on patient demographics (age, gender, race), hospital length of

stay, reason for admission, past medical history, outpatient and inpatient medications, hemoglobin A1c, diabetes complications, diabetes duration, age of onset of diabetes, nutrition status, laboratory results, and insulin pump/CGM alarms were also reviewed. To assess patient satisfaction for each of the treatment arms, the Diabetes Treatment Satisfaction Questionnaire-Change (DTSQc) was administered to subjects at completion of the intervention.^{37,38} DTSQc is a questionnaire that is designed to assess whether a diabetes treatment intervention is deemed satisfactory by the patient. Results are reported on a scale from -3 to $+3$, with negative numbers corresponding to dissatisfaction and positive numbers corresponding to satisfaction.

Results

A total of 16 subjects were enrolled in this pilot study. Five subjects were randomized to group 1, six subjects were randomized to group 2, and five subjects were randomized to group 3 (Table 1). Four subjects dropped out of the study prematurely, disproportionately among the pump groups (three of the four subjects that dropped out). Due to the small sample size, data from the subjects who dropped out of the study were included in the final analysis. One subject from group 2 lost the CGM receiver; therefore, interstitial glucose data were not available to review. Two subjects were transferred to the ICU (one each from groups 1 and 2), resulting in withdrawal from the study. The study population was composed of 81% African Americans, 68% female, mean age 56 ± 12 years with 43% having significant renal impairment (stages 3–5 chronic kidney disease). The mean duration of diabetes was 18 ± 10 years. Five subjects were prescribed oral diabetes medications in addition to insulin as outpatients. Noninsulin diabetes medications were not administered during the study duration. The average total daily dose of insulin among the three groups was not significantly different (Group 1: 33.7 ± 11.8 units vs. Group 2: 27.0 ± 21.5 units vs. Group 3: 38.2 ± 18.8 units, $P = 0.7$).

Subjects in group 1 had a trend toward better baseline outpatient glycemic control compared with the other groups, although not statistically significant, whereas preadmission glycemic control was similar between groups 2 and 3 (HbA1c $7.0\% \pm 0.6\%$ vs. $7.9\% \pm 1.4\%$ and $8.2\% \pm 2.7\%$, $P_{1 \text{ vs. } 2+3} = 0.15$, $P_{2 \text{ vs. } 3} = 0.8$).

Group 1 had the lowest mean capillary glucose value, 144.5 ± 19.5 mg/dL. Groups 2 and 3 had similar mean capillary glucose values, 191.5 ± 52.3 and 182.7 ± 59.9 mg/dL ($P_{1 \text{ vs. } 2+3} = 0.05$) (Table 2). There were no significant differences in the absolute number of hypoglycemic events when comparing groups 2 and 3 or when comparing the groups with blinded CGM (groups 1 and 2) versus unblinded CGM (group 3) based on capillary glucose data or CGM data. However, in all 3 study groups, CGM detected more hypoglycemic episodes (blood glucose <70 mg/dL) than capillary glucose testing. Nonblinded CGM data led to insulin down titration. Seven hypoglycemic episodes were detected exclusively by blinded CGM (groups 1 and 2) and not capillary testing. All hypoglycemic episodes detected by capillary testing were also detected by CGM. None of the subjects experienced clinically significant severe hypoglycemia, defined as loss of consciousness, seizure, or death, with the hypoglycemic episodes detected only by CGM. The percentage of time spent

TABLE 1. CLINICAL CHARACTERISTICS OF STUDY POPULATION

<i>Trait</i>	<i>Group 1 (basal-bolus insulin), n = 5</i>	<i>Group 2 (pump+blinded CGM), n = 6</i>	<i>Group 3 (pump+nonblinded CGM), n = 5</i>	<i>P^a</i>
Gender, female, %	60	50	60	0.94
Age, years	57.4 ± 15.0	47.3 ± 6.2	61.6 ± 9.0	0.10
Race	100% AA	66.7% AA 33.3% C	100% AA	0.17
T2DM duration, years	18.2 ± 11.4	18.1 ± 8.4	18.4 ± 15.8	1.00
T2DM medication, <i>n</i> (%)				
Insulin alone	4 (80)	2 (33)	5 (100)	1.00
Oral agents+insulin	1 (20)	4 (67)		0.30
Baseline HbA1c, %	7.0 ± 0.6	7.9 ± 1.4	8.2 ± 2.7	0.53
Baseline creatinine, mg/dL	1.52 ± 1.06	3.33 ± 1.93	2.83 ± 1.28	0.25
DM history, <i>n</i> (%)				
Neuropathy	2 (40)	3 (60)	3 (60)	1.00
Retinopathy	2 (40)	1 (17)	2 (40)	0.66
Nephropathy/CKD	2 (40)	2 (33)	3 (60)	0.83
Hypertension	4 (80)	6 (100)	5 (100)	0.63
Hyperlipidemia	3 (60)	5 (83)	4 (80)	0.66
Admission diagnosis, <i>n</i> (%)				
Cardiovascular/Pulmonary	4 (80)	3 (50)	1 (20)	0.22
Renal		2 (33)	2 (40)	0.73
Dermatology	1 (20)			0.63
Ophthalmology		1 (17)		1.00
Hematology			2 (40)	0.17
Endocrine			1 (20)	0.63

^aCompares all three groups.

AA, African American; C, Caucasian; CGM, continuous glucose monitoring; T2DM, type 2 diabetes mellitus.

below target glucose range (<90 mg/dL), in target glucose range (90–180 mg/dL), or above target glucose range (>180 mg/dL) was calculated based on CGM data (Table 3). Due to the small sample size, no significant differences in the percent time spent in each of these glucose ranges were found.

Acetaminophen was administered to subjects in all study groups (10 doses to 2 subjects in group 1, 1 dose in group 2, and 2 doses to 1 subject in group 3) that had the potential to generate falsely elevated interstitial glucose values; however, prominent differences in glucose levels after receiving acetaminophen were not detected.

A similar incidence of pump alarms and pod malfunction requiring replacement occurred in groups 2 and 3. Pump alarms were due to pod catheter occlusions, empty insulin reservoirs, and communication errors between the PDM and pump with a total of 11 alarms between groups 2 and 3. The protocol

prompted nurses to contact study investigators to obtain orders for a subcutaneous insulin injection if the pod could not be replaced immediately; however, the team was only notified once about pod malfunction. All study groups calibrated the CGM at least twice per day, per manufacturer recommendations³⁵ (Table 3). Group 3 experienced more frequent CGM alarms than groups 1 and 2, as expected, since this was the only group that had audible hypoglycemia and hyperglycemia threshold alarms. All three groups experienced calibration and technical alarms. Nurses responded appropriately to hypoglycemia threshold alarms. For other pump and CGM alarms occurring overnight, staff often waited until the next morning to notify the study team, which delayed timely intervention.

Eleven subjects completed the DTSQc to evaluate their perception of treatment efficacy and treatment satisfaction when they finished the study (Supplementary Table S1;

TABLE 2. GLUCOSE RESULTS

	<i>Group 1</i>	<i>Group 2</i>	<i>Group 3</i>
Mean capillary glucose, mg/dL	144.5 ± 19.5	191.5 ± 52.3	182.7 ± 59.9
No. of hypoglycemic events by capillary glucose	3	0	4
No. of hypoglycemic events by CGM	9	4	5

TABLE 3. CONTINUOUS GLUCOSE MONITORING STUDY CHARACTERISTICS

	<i>Group 1</i>	<i>Group 2</i>	<i>Group 3</i>
No. of days CGM used	4.3 ± 2.1	3.6 ± 2.1	4.5 ± 1.0
Calibrations/day	2.9	2.3	4.0
Total number of CGM alarms	9 ^a	3 ^a	13 ^b
% Time below target	7 ± 7	1 ± 3	8 ± 10
% Time in target	75 ± 4	54 ± 37	69 ± 40
% Time above target	18 ± 9	45 ± 36	23 ± 38

^aBlinded CGM alarms: calibration, sensor dysfunction.

^bNonblinded CGM alarms: calibration, sensor dysfunction, glycemic threshold.

Supplementary Data are available at <http://online.liebertpub.com/doi/suppl/10.1089/dia.2017.0250>). Subjects from all three groups reported equivalent treatment convenience. Although not achieving statistical significance, groups 2 and 3 were less likely to want to continue their current treatment compared with group 1. In addition, there were trends toward group 3 feeling as if they were spending more time hyperglycemic than with their home treatment regimen compared with groups 1 and 2.

Discussion

During our study, insulin pump use did not provide superior glucose control over conventional basal-bolus subcutaneous insulin therapy. Inpatient pump initiation was labor intensive and technically challenging, possibly limiting glycemic benefits. Further, the small number enrolled in the study may have impacted our findings. Some studies of hospitalized patients with type 2 diabetes have demonstrated that fixed meal time insulin dosing, compared with flexible dosing based on carbohydrate content, leads to equivalent glycemic control,³⁹ whereas others have shown that flexible insulin dosing may increase the frequency of preprandial hypoglycemia.⁴⁰ In our study, carbohydrate counting did not lead to increased hypoglycemia frequency, nor did it improve glycemic outcomes.

Currently, the Endocrine Society does not recommend inpatient CGM use due to insufficient evidence for accuracy and safety.⁴¹ However, expert opinion suggests that CGM may be appropriate for specific high-risk groups, such as patients with cardiovascular disease in the non-ICU setting.⁴² In our study, CGM detected more occult hypoglycemia episodes than capillary glucose testing, validating the results of prior inpatient CGM studies.^{27–29} Contrary to outpatient studies demonstrating glycemic benefit,^{43,44} inpatient non-blinded CGM use did not result in decreased mean glucose compared with blinded CGM in our study. Generally, outpatient CGM studies last for several months; however, we only used inpatient CGM for a maximal duration of 7 days. The absence of improved glucose levels may be due to the short duration of CGM use, which may not provide adequate time to titrate insulin appropriately. Other barriers to improved inpatient glycemic control include changes to clinical status, medication regimen, diet, and activity level.

Hypoglycemia occurs frequently in hospitalized patients receiving insulin.⁴⁵ Moreover, hospitalized diabetes patients with hypoglycemia have a higher mortality rate (OR 1.07; 95% CI 1.02–1.11) and a longer length of stay than diabetic patients without hypoglycemia.⁴⁶ Groups 2 and 3 experienced fewer total hypoglycemic episodes (Table 2). We speculate that the lower rate of hypoglycemia occurred in the setting of personalized mealtime and correction boluses, based on individualized calculations of carbohydrate ratios and sensitivity factors, in addition to increased hyperglycemia noted during study duration. In contrast, group 1 experienced more hypoglycemic episodes (Table 2), which may have contributed to a lower mean glucose. In addition, group 1 had the lowest baseline A1c (Table 1). Since insulin dosing for all three groups was based on their home dose of insulin, the lower baseline A1c seen in group 1 may have also modulated our findings.

The results from the DTSQc did not achieve statistical significance, whereas the results from the questionnaire still provide valuable insight into patient acceptance of CGM and

insulin pumps while hospitalized. Although capillary hypoglycemia and hyperglycemia frequency was similar among all groups, group 3 was likely more aware of glycemic excursions due to the threshold alarms, audible once interstitial glucose was <70 or >200 mg/dL. Subjects reported equivalent treatment convenience in each study arm; however, since each group did not cross over to the other arms of the study, individual subjects did not compare treatment modalities. The lower satisfaction noted in groups 2 and 3 may be due to the difficulty of initiating an insulin pump and/or CGM device during hospitalization and associated frequent alarms (11 pump alarms and 25 CGM alarms; Table 3). These alarms occurred in the context of hospitalized patients with multiple comorbidities, diagnostic testing, and other disruptions, likely contributing to alarm fatigue.

Limitations

Based on power calculations, the goal for recruitment was to enroll 15 patients into each arm of the study. We experienced significant difficulty recruiting subjects for our study. We recruited acutely ill inpatient T2DM subjects who were highly comorbid. Many patients were already overwhelmed by their acute illness and did not want to add another medical variable to their hospital stay. Other factors that played a role in recruitment were short hospital stays (inclusion criteria were anticipated hospital stay of ≥ 2 days), transfer to the ICU, and use of acetaminophen. As a result of the small numbers, our ability to identify statistically significant differences among the three groups was limited. Thus, it is possible that where trends were identified, statistical significance might have been achieved with larger numbers.

Although this pilot study demonstrates feasibility, multiple limitations were identified, many of which were related to difficulties experienced by patients and staff unfamiliar with this technology. In the nonresearch inpatient setting, insulin pumps and CGM are used only in patients (or surrogates present 24 h a day) who have their own insulin pumps or CGM, are awake and alert, and are able to demonstrate adequate skills to independently manage these devices.⁴⁷ As demonstrated in this study, initiating insulin pumps and CGM in hospitalized patients with type 2 diabetes without previous experience with either device is labor intensive. In a real-world setting, because of lack of experience, a staff member with expertise in their utilization would need to be available 24 h a day, either by phone or in the hospital, to assist with troubleshooting whenever problems arise.

We relied heavily on the nursing staff, not the acutely ill patients, to manage the insulin pump and CGM devices. Study investigators trained all involved nurses in the study on how to enter glucose levels into the PDM and CGM devices, how to give an insulin bolus via the pump, and how to troubleshoot the insulin pump and CGM. Our nursing staff was not explicitly trained on how to carbohydrate count; however, meals provided by nutrition services had comprehensive carbohydrate content available to staff. Despite having this information, nursing reported difficulty with carbohydrate counting, not knowing whether patients would eat the entire meal, leading to concerns for hypoglycemia and also for hyperglycemia when patients purchased snacks from the cafeteria. Most nurses had never taken care of hospitalized patients with an insulin pump or CGM device; thus, caring

for patients with these devices increased the complexity of their day-to-day nursing responsibilities. This is in contrast to the extensive outpatient diabetes education that patients receive before starting insulin pump therapy.⁴⁸

Teams caring for study subjects were asked to avoid prescribing acetaminophen, whereas subjects in all three groups still received the drug. Acetaminophen administration can falsely elevate interstitial glucose values when using the Dexcom Seven Plus CGM device.⁴⁹ Prior publication demonstrated a 61 mg/dL difference between capillary and interstitial glucose 2 h after receiving acetaminophen.⁵⁰ If inpatient CGM becomes widely used in hospitalized patients, providers will need education on avoiding acetaminophen to be able to reliably use CGM data for treatment decisions.

Future Studies

Since completing this pilot study, more sophisticated CGM and insulin pumps have come on the market. These advances include improvements in sensor accuracy, data collection and glucose analysis features, and communication between sensors and insulin pumps, allowing for hybrid closed-loop systems. These tools have the potential to transform inpatient diabetes care and will need further study to assess their feasibility and impact on inpatient diabetes management.

Summary

We studied insulin pump and CGM initiation in highly comorbid, non-ICU T2DM hospitalized patients without previous experience with either device as a means to improve inpatient glycemic control. Even though insulin pump and CGM initiation are possible during hospitalization, diabetes management is labor intensive. Although there were multiple limitations during our pilot study, improved hypoglycemia detection with the use of inpatient CGM was seen and is consistent with findings from other inpatient studies.^{27–29} Larger studies are needed to determine whether use of this technology can lower inpatient morbidity and mortality.

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Author Disclosure Statement

E.K.S. received research supplies from Dexcom for conducting inpatient studies. No competing financial interests exist for D.L.L., K.A.R., or K.D.S.

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