



Continuous Glucose Monitoring in the Intensive Care Unit During the COVID-19 Pandemic

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OBJECTIVE

Real-time continuous glucose monitoring (rtCGM) in critically ill hospitalized patients holds promise; however, real-world data are needed.

RESEARCH DESIGN AND METHODS

We placed Dexcom G6 CGM on intensive care unit (ICU) patients at Montefiore Medical Center with confirmed coronavirus disease 2019 (COVID-19) infection and glycemic variability. We analyzed inpatient CGM accuracy using point-of-care (POC) glucose–CGM matched pairs and included patients for analysis regardless of clinical status.

RESULTS

We included 11 patients with CGM: 8 on continuous insulin infusion (CII), 8 on vasopressors, 8 intubated, 4 on high-dose glucocorticoids, 6 on renal replacement therapy, and 2 with anasarca. Accuracy was 12.58% for mean and 6.3% for median absolute relative difference. CGM reduced POC testing by ~60% for patients on CII.

CONCLUSIONS

In this real-world preliminary analysis of rtCGM during critical illness, we demonstrate early feasibility, considerable accuracy, and meaningful reduction in the frequency of POC glucose testing.

The coronavirus disease 2019 (COVID-19) pandemic has highlighted the urgent need to develop innovative care solutions to manage hyperglycemia in hospitalized patients while preserving resources. CGM use in the critically ill patient in the intensive care unit (ICU) offers unique benefits by allowing real-time tracking of glucose levels to detect often unrecognized severe hypo- or hyperglycemic events, while decreasing the high burden of frequent point-of-care (POC) testing during clinically tenuous states and continuous insulin infusion (CII) (1).

Recent studies of real-time (rt)CGM use in non-ICU patients have demonstrated promising results in inpatient settings (2–4). However, these studies excluded critically ill patients. During the pandemic, use of CGM in the ICU could have transformative results in enabling optimized glycemic control, reducing exposure time of staff, and decreasing resource use. Nevertheless, scant data exist on the use of modern rtCGM devices in the ICU.

We implemented CGM in the ICU at Montefiore Medical Center during the COVID-19 pandemic and report our results on the performance and accuracy in a real-world setting. We purposely studied critically ill patients, who received therapies historically excluded from inpatient CGM studies, to provide vital early data on CGM use in the ICU.

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RESEARCH DESIGN AND METHODS

Following the U.S. Food and Drug Administration statement of nonobjection to inpatient CGM use during the pandemic (1,5), hospital leadership allowed clinical use of CGM in the ICU at Montefiore Medical Center. This retrospective analysis of clinical data was approved by the Albert Einstein College of Medicine Institutional Review Board (Bronx, NY).

Patient Eligibility and Selection

Patients were eligible if they had multiple blood glucose readings in the hyperglycemic (>180 mg/dL) or hypoglycemic range (<70 mg/dL) and were hospitalized in the ICU during the COVID-19 pandemic from 1 April to 30 May 2020 at Montefiore Medical Center. Patients remained eligible if they were receiving mechanical ventilation, vasopressors, CII, or renal replacement therapy (RRT). Exclusion criteria involved receiving high-dose ascorbic acid or acetaminophen >4 g/day. Selection of patients was based on requests for CGM placement by hospital staff and review of inclusion/exclusion criteria by an internal inpatient CGM committee (authors S.A., R.L., A.S., and A.L.).

CGM Placement and Documentation

After patient selection, a trained diabetes nurse practitioner or nurse specialist placed a G6 sensor and transmitter onto the patient's abdomen or upper arm in cases of prone positioning. CGM receivers were placed outside of the patient's door for visualization of real-time glucose data.

Recorded blood glucose values were monitored in real-time by the inpatient CGM committee for validation of sensor and POC glucose readings according to Food and Drug Administration guidelines ($\pm 20\%$ of each other [for blood glucose ≥ 100 mg/dL] or ± 20 mg/dL of each other [for POC blood glucose ≤ 100 mg/dL]) (6,7). Alarm triggers were set to <100 and ≥ 250 mg/dL and 3 mg/dL/min rate of glucose rise or drop. After validation, CGM values were used to monitor glycemic trends, adjust insulin dosing, and alarm for severe hypo- or hyperglycemic events, which triggered confirmatory POC testing. At minimum, once-daily POC measurement was required to ensure maintained CGM validation.

Statistical Analysis

Descriptive data are presented as mean \pm SD for continuous variables (age, HbA_{1c}, time in range) and count (%) for categorical variables (race/ethnicity, diabetes type, comorbidities). We collected CGM and POC glucose matched pairs ($n = 493$) to calculate the mean and median average relative difference (MARD and median ARD %) between measurements. We also calculated the proportion of CGM values within ± 15 , 20, and 30% of POC reference values for glucose levels >100 mg/dL and ± 15 , 20 or 30 mg/dL for POC glucose levels ≤ 100 mg/dL (%15/15, %20/20, %30/30) (8,9). Clarke error grid analysis was used to assess clinical reliability of matched POC-CGM glucose pairs (9).

RESULTS

Overall ($n = 11$), mean age was 56 ± 17 years, six patients were male, and eight belonged to underrepresented racial-ethnic groups (Hispanic or non-Hispanic Black). Six patients had preexisting type 2 diabetes, three had type 1 diabetes, and two had no known diabetes. Mean HbA_{1c} was $8.7 \pm 2.5\%$.

At the time of CGM use, nine patients were on CII, eight received vasopressors, eight were intubated, four received high-dose glucocorticoids, six were on RRT, and two had anasarca.

Median number of days on CGM was 9.0 (3.0–10.0). Mean time in range was $46.1 \pm 15.8\%$, above range was $53.3 \pm 15.8\%$, and below range was $0.6 \pm 0.8\%$. Clarke error grid analysis and MARD are reported in Fig. 1. In sum, 493 paired POC-CGM measurements were used for analysis. Regarding accuracy, MARD and median ARD were 12.58% and 6.3%, respectively. We found 77.7% of values fell within zone A (CGM within 20% of POC), 20.5% zone B ($>20\%$ difference, no incorrect treatment), 0.2% zone C (hyperglycemia or hypoglycemia leading to inappropriate treatment), 1.2% zone D (undetected hypoglycemia or hyperglycemia needing treatment), and 0.4% zone E (hypoglycemia mistaken for hyperglycemia, and vice versa) (Fig. 1).

To calculate reduction in POC testing while using CGM, we calculated the mean number of hours/potential POC tests while on CII versus actual POC tests ($n = 8$ patients). Mean number of hours/potential POC tests on CII was 72.125 h/ ~ 72 tests, compared with mean number of actual

POC tests on CGM of 28, representing an estimated 60% reduction in POC tests during rtCGM use.

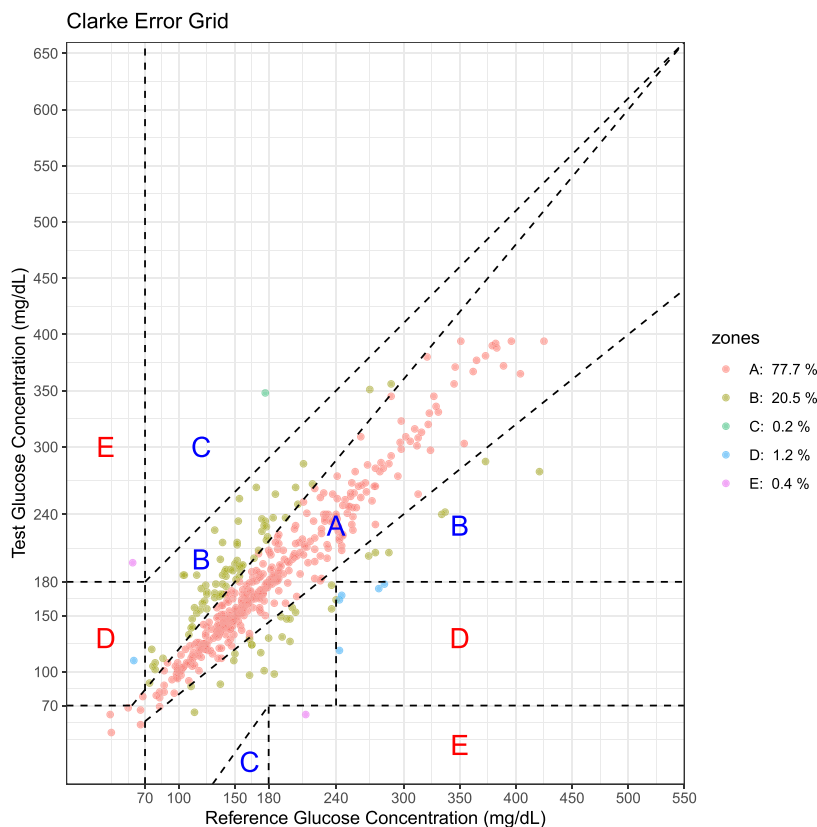
CONCLUSIONS

We present our firsthand real-world experience of rtCGM in the ICU during the COVID-19 pandemic in New York City. Our findings show that use of rtCGM in the ICU setting is feasible, acceptable, and reliable as an adjunctive modality to POC glucose measurements. CGM use resulted in a meaningful reduction in POC testing frequency for patients requiring CII. Overall, our study underscores the great potential of CGM to aid in glucose testing for critically ill patients. While other studies have systematically excluded the sickest patients, we included patients with multiple critical illnesses and therapies, which is a particular strength of our study.

Overall, 98% of all sensor readings had clinically acceptable correlation (zones A + B). Currently, there are few reports of remote monitoring using the G6 device in the ICU. Compared with findings from recent small studies using G6 in medical-surgical patients on hospital floor units (2,10,11), our MARD (12.58%) falls within the range of these reports (9.4–12.8%) (2,10,11). Our accuracy results are even more encouraging given our eligibility criteria including critically ill patients with potentially interfering treatments, compared with prior studies. Nevertheless, concerns remain regarding complete replacement of POC glucose testing with CGM (1,12–14), given that our data reveal several instances of potential failures to detect hypo- or hyperglycemia (zone D) or mistreatment (zone E). Thus, while promising, caution must be exercised in utilizing CGM as the sole modality for glucose testing.

Limitations of our study include its small sample size and observational nature. While inclusion of critically ill patients is a strength and our accuracy results are in line with previous studies excluding sick patients, further studies are required to evaluate CGM safety and accuracy in a larger critically ill population. Differentiation of results by potentially interfering treatments is needed.

In sum, our results provide proof of concept that rtCGM can be used safely and effectively during critical illness, while offering reliable accuracy



n	15/15%	20/20%	30/30%	40/40%	MARD	Median ARD
493	0.708	0.777	0.888	0.953	12.578	6.338

Figure 1—Clarke error grid analysis showing the relationship between CGM and POC glucose values in critically ill patients with COVID-19 ($n = 11$).

and decreasing POC glucose testing frequency. Overall, CGM use in the ICU setting should be further explored as a treatment aid for inpatient diabetes management of the critically ill patient.

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Author Contributions. S.A. and F.J.P. conceptualized the study, researched and analyzed the data, and wrote the manuscript. J.M. input data, researched and analyzed the data, and wrote and reviewed the manuscript. G.M.D. researched and analyzed the data and wrote, reviewed, and edited the manuscript. A.S., A.L., R.L., A.U., and C.P.-G. input and analyzed the data and reviewed and edited the manuscript. G.E.U. reviewed and edited the manuscript. L.P. analyzed the data and reviewed and edited the manuscript. S.A. is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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