Acta Biomed 2021; Vol. 92, N. 1: e2021036 DOI: 10.23750/abm.v92i1.9083

Original article

Optimal Blood Glucose Monitoring Interval for Insulin Infusion in Critically Ill Non-Cardiothoracic Patients: A Pilot Study

Amos Lal[1], Nurul Haque[2], Jennifer Lee[3], Sai Ramya Katta[4], Louise Maranda[5], Susan George[6], Nitin Trivedi[7]

[1]Division of Pulmonary and Critical Care Medicine, Mayo Clinic, Rochester, Minnesota, USA; [2]Department of Medicine, Merit Health River Region Hospital, Vicksburg, Minnesota, USA; [3]Clinical Pharmacy Coordinator, Critical Care, Department of Pharmacy, Saint Vincent Hospital, Worcester, Massachusetts, USA; [4]Department of Internal Medicine, Saint Vincent Hospital, Worcester, Massachusetts, USA; [5]Department of Biostatistics, University of Massachusetts Medical School, Massachusetts, USA; [6]Department of Medicine Performance Improvement Committee, University of Massachusetts Medical School, Saint Vincent Hospital, Worcester, Massachusetts, USA; [7]Department of Medicine, Saint Vincent Hospital; University of Massachusetts Medical School, Worcester, Massachusetts, USA

Abstract

Objective: The American Diabetes Association and the Society of Critical Care Medicine recommend monitoring blood glucose (BG) every 1-2 hours in patients receiving insulin infusion to guide titration of insulin infusion to maintain serum glucose in the target range; however, this is based on weak evidence. We evaluated the compliance of hourly BG monitoring and relation of less frequent BG monitoring to glycemic status. *Materials and Methods:* Retrospective chart review performed on 56 consecutive adult patients who received intravenous insulin infusion for persistent hyperglycemia in the ICU at Saint Vincent Hospital, a tertiary care community hospital an urban setting in Northeast region of USA. The frequency of fingerstick blood glucose (FSBG) readings was reviewed for compliance with hourly FSBG monitoring per protocol and the impact of FSBG testing at different time intervals on the glycemic status. Depending on time interval of FSBG monitoring, the data was divided into three groups: Group A (<90 min), Group B (91-179 min) and Group C (≥180 min). *Results:* The mean age was 69 years (48% were males), 77% patients had preexisting type 2 diabetes mellitus (T2DM). The mean MPM II score was 41. Of the 1411 readings for BG monitoring on insulin infusion, 467 (33%) were in group A, 806 (57%) in group B and 138 (10%) in group C; hourly BG monitoring compliance was 12.6%. The overall glycemic status was similar among all groups. There were 14 (0.99%) hypoglycemic episodes observed. The rate of hypoglycemic episodes was similar in all three groups (p=0.55). *Conclusion:* In patients requiring insulin infusion for sustained hyperglycemia in ICU, the risk of hypoglycemic episodes was not significantly different with less frequent BG monitoring. The compliance to hourly blood glucose monitoring and ICU was variable, and hypoglycemic episodes were similar across the groups despite the variation in monitoring. *Significance of the Study:* The importance of glycemic control in ICU has been well established and it is a resource intensive venture. However, there are no major studies highlighting the most optimal time interval for blood glucose checks in critically ill patients on insulin infusion. With this study we hypothesize that time duration between blood glucose checks can be increased safely without any untoward effects. Our study provides evidence for effective resource management with reducing the time spent with every glucose check and directly translating into high value care.

Keywords: Hyperglycemia, Critically ill, Insulin Infusion, Hypoglycemia, Blood Glucose

Introduction

Intravenous insulin infusion guided by frequent fingerstick blood glucose (FSBG) monitoring is the preferred method of hyperglycemia management in the intensive care unit (ICU). The American Diabetes Association (ADA) and the Society of Critical Care Medicine (SCCM) recommend monitoring FSBG every 1-2 hours in patients receiving insulin infusion to prevent hypoglycemic events by guiding appropriate titration of insulin infusion (1, 2). However, this recommendation is based on expert opinion. To the best of our knowledge, there have been no studies to support 1-2 hourly FSBG testing as the optimal time interval to maintain stable glycemic control in patients receiving intravenous insulin infusion.

Reduced frequency of blood glucose (BG) testing should minimize discomfort from frequent painful finger sticks, reduction of nursing burden and healthcare cost; however, attainment of optimal glycemic status must not be compromised by less frequent FSBG monitoring. The importance of optimal glycemic control in critically ill patients cannot be over-emphasized as both hypoglycemia and hyperglycemia are associated with poor outcomes (3-5). Nonetheless, achieving glycemic goals in critically ill patients is often hard to achieve as the process involves multiple factors including nursing commitment to frequent FSBG checks, implementation of a well developed and tested intravenous insulin infusion protocol and effective resource management.

Although many studies undertake the difficult task to assess the glycemic control in critically ill patients, we were unable to find any studies commenting directly on the compliance of the implemented protocol (5-7). We intended to evaluate the compliance of the current protocol as a measure of current understanding of the nursing staff. This is important, as any change in the protocol directly affects the nursing staff and subsequently translating into patient care issues.

Thus, we aimed to evaluate the compliance with 1 hourly FSBG readings required by our protocol for patients receiving intravenous insulin in the ICU to treat hyperglycemia. In addition, we also studied the relationship of FSBG monitoring intervals with glycemic status.

Materials and Methods

Data Collection Methods

As a part of this pilot study, retrospective data collection and analysis was performed for 56 patients admitted to the ICU from May 1, 2014 through November 30, 2014 who required intravenous insulin infusion for persistent hyperglycemia (two consecutive blood glucose reading ≥180 mg/dL in patients with or without preexisting T2DM). Data was obtained from the chart review through electronic medical records. The insulin infusion protocol used in our ICU was developed after the publication of the NICE-SUGAR trial (8). The glycemic target was 140-180 mg/dL, which was intended to be achieved by insulin infusion rate adjustment based on hourly FSBG readings and not on the basis of rate of change of BG (see Supplement 1 for protocol). Study was approved by institution review board (IRB number 2015-73, July 2th 2015 by Metrowest Medical Center IRB).

Dysglycemic episodes included hypoglycemia (BG values of less than 70 mg/dL) and hyperglycemia (BG values of more than or equal to 180 mg/dL). Inclusion criteria included all the consecutive patients admitted to medical ICU with hyperglycemia requiring insulin infusion for blood glucose control during the study period. Patients with diabetic ketoacidosis, hyperglycemic hyperosmolar states and those admitted to cardiac surgery service were excluded since our ICU has separate treatment protocols for such patients. BG levels were measured using a standard hospital glucometer (StatStrip Xpress©2 Glu, Hospital Glucose Monitoring System, Nova Biomedical Corporation, Waltham, MA, USA). The blood glucose values were automatically transmitted to the electronic medical record system through a glucose meter dock, eliminating any human error of value imputation. Eligible patients were monitored through the ICU stay till the time they required insulin infusion.

Baseline characteristics were obtained including age, sex, ethnicity, history and type of diabetes, body mass index (BMI), and mortality probability model (MPM) II score at ICU admission to estimate the severity of illness. We focused on six clinical interventions including diagnosis of sepsis during the admission, surgical versus medical patient, previous use of insulin, concurrent corticosteroid therapy, renal dysfunction and nutritional status of the patient (fasting state, enteral or parenteral feeding).

Based on the time interval of FSBG testing, the data was divided into three groups: Group A (≤90 min), Group B (91-179 min) and Group C (≥180 min). However, since groups were divided based on frequency of blood glucose testing one patient could fall into more than one groups. For example a single patient can fall into more than one groups based on the frequency of blood glucose monitoring (≤90 min, 91-179 min or ≥180 min) during the course of ICU stay requiring insulin infusion.

Statistical Analysis

Mortality probability model (MPM) II at ICU admission was used to estimate the severity of illness and prognosis. Except where noted, all the clinical data was expressed as means ± standard deviation or as a percentage.

Two way ANOVA was used to calculate any difference in dysglycemic events between groups A, B and C. The data was presented as means ± standard deviation (SD) or medians (with interquartile ranges), unless otherwise indicated. Data analysis was performed using the software Statistical Package for the Social Science (SPSS) version 16 (SPSS Inc. Chicago, IL, USA). *P* <0.05 was considered statistically significant.

Results

A total of 215 patients who were admitted to the ICU and required insulin infusions were screened. Fifty-six patients met the inclusion criteria. All 56 patients were discharged or transferred from the ICU and were not readmitted for the sole purpose of treating hyperglycemia with an insulin infusion during the same hospital admission. Baseline characteristics are shown in **Table 1**, including ICU admission diagnoses and relevant clinical interventions. Mean age was 69.5 years; 48% patients were males, 77% patients had preexisting diabetes and mean MPM II score was 40.7.

TABLE 1. Baseline Characteristics

Characteristic	Study Patients
n	56
Age	69.5 ± 9.5 (SD)
Male Sex	27 (48.2%)
Ethnicity	Caucasian 50 (89.3%)
BMI (kg/m^2)	32.6 ± 9.4
Mortality Probability Model II score (MPM II)	40.7 ± 27.2
History of Diabetes	43 (76.8%)
Type of Diabetes	Type 2 Diabetes (100%)
Clinical Characteristics	
• Sepsis	33 (58.9%)
• Surgical patients	15 (26.8%)
• Previous insulin use	25 (44.6%)
• Corticosteroid therapy	12 (21.4%)
• Renal Dysfunction	
• Nutritional Status	24 (42.9%)
• NPO	31 (55.4%)
• Others (Parenteral, enteral)	25 (44.6%)

Glycemic Control

Of the 1411 time intervals for BG monitoring in 56 patients while on insulin infusion, 467 readings (33%) were in group A (≤90 min), 806 readings (57%) in group B (91-179 min) and 138 readings (10%) in group C (≥180 min); hourly BG monitoring compliance was 12.6% (178/1411). Fourteen (0.99%) of the 1411 readings were in the hypoglycemic range (<70 mg/dL) as defined above. The frequency of hypoglycemic episodes were similar in all three groups (p=0.55) and post hoc analysis between the groups was

not statistically significant. There was a trend of higher hypoglycemic events in Group C (FSBG check ≥180 mins) vs. Group A (FSBG check ≤90 mins) (p= 0.08). The co-efficient of variation for blood glucose (glucose CV %) was 38.79% with standard deviation of ± 70.67 mg/dL for all the patients.

There was a total of 14 patients (no patient had more than 1 episode of hypoglycemia) who experienced hypoglycemic episodes while on insulin infusion combined in all 3 groups (Group A, B and C). Group A had 0.85% (n=4), group B had 0.74% (n=6) and group C had 2.89 % (n=4) readings of hypoglycemia out of 467, 806 and 138 total readings in each group respectively. There was no statistically significant difference in episodes of hypoglycemia comparing three groups, corrected for individual patient using 2 way ANOVA (Figure 1). Cumulative mortality was noted to be 36% (20 of 56 studied patients, expected 40.7% as per MPM II calculations). There was no statistically significant difference among the three groups in terms of mortality or length of stay in the hospital. There was no statistical difference in hypoglycemic events with strict compliance of FSBG monitoring per protocol versus non-compliant (Figure 2).

Effect of Relevant Clinical Variables

During the analysis, we considered six clinically relevant variables namely diagnosis of sepsis during the current ICU admission, whether the patient was a surgical versus medical ICU patient, previous history of insulin use, concomitant corticosteroid therapy, renal dysfunction and nutritional status (nil per oral, enteral nutrition or parenteral nutrition). None of the clinical variables were found to have any correlation between hypoglycemic events and the 3 interval groups of FSBG measurements. Further analysis showed a rapid decline in blood glucose levels in the first 16 hours of starting insulin infusion followed by subsequent stabilization as shown in Figure 3. The rate of change of blood glucose levels (mg/dL/min) followed a similar trend in all three groups. There was no significant difference in FSBG measurement compliance before or after stabilization of blood glucose at 16 hours of insulin infusion.

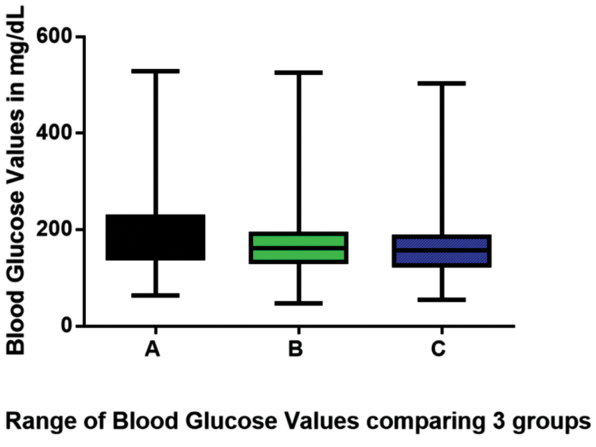

Figure 1. Differences in glycemic episodes (hypoglycemia vs normoglycemia, 70–180 mg/dL) between the three interval groups A (<90 min), B (90-179 min) and C (≥180 min) corrected for individual patient (P value 0.553; 2 way ANOVA).

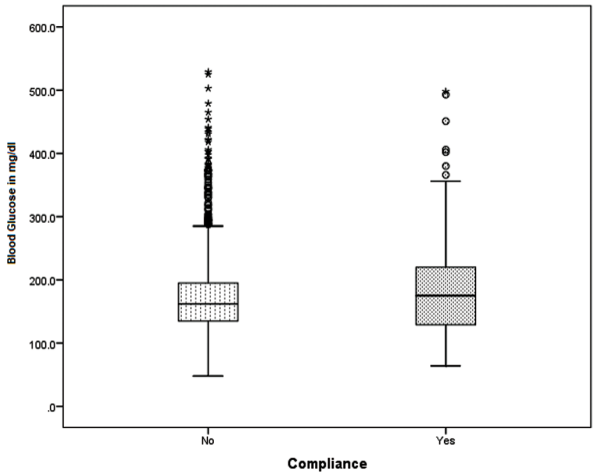

Figure 2. Blood Glucose monitoring strict compliance group (Group A) vs non-compliance group combined (Group B and Group C combined), no statistically significant difference in terms of hypoglycemic episodes.

Discussion

Hyperglycemia in critically ill patients results from increased physiological demands secondary to release of cytokines and counter-regulatory hormones, use of corticosteroids and sympathomimetic drugs which trigger and worsen hyperglycemia by increasing insulin resistance and gluconeogenesis (4, 9). Only 77 percent of our study patients had pre-existing diabetes

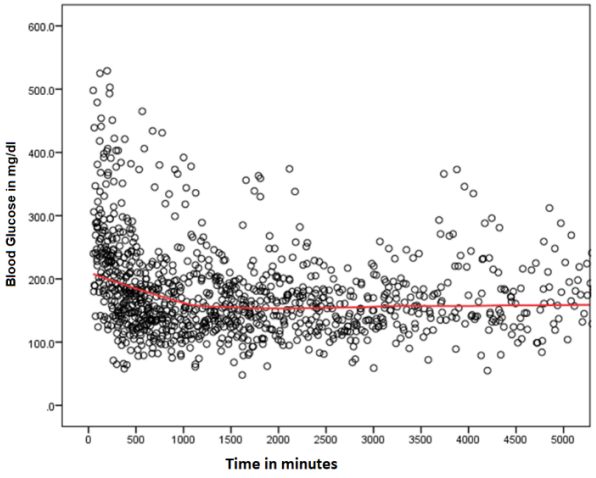

Figure 3. Change in blood glucose (mg/dL) with time in minutes for all patients.

and the rest developed hyperglycemia secondary to the critical illness.

Critical illness-induced dysglycemia (CID), the term proposed for glucose dysregulation (hyperglycemia, hypoglycemia and glucose variability) in critically ill patients, has been linked to poorer outcomes (2, 4, 5, 10-14). Most experts agree with the recommendation to keep the BG between 140-180 mg/dL in critically ill patients. With the advent of increasing use of insulin infusion for hyperglycemia in critically ill patients, continuing education for the healthcare staff and frequent BG monitoring becomes quintessential to ensure patient safety.

Given the rapidity of onset, short duration of action and easy titration, intravenous infusion is the preferred route of insulin administration to keep BG within the target range in critically ill patients. Multiple computerized and paper-based protocols have been validated for use in different settings, and computerized protocols may provide superior glycemic control and improved protocol adherence (15-20). Surprisingly, despite such a wealth of literature, there have been no major clinical trials utilizing insulin infusion that clearly delineate the most appropriate interval for blood glucose checks for patients on intravenous insulin infusion. Consensus recommendation released by Jacobi et al. to check blood glucose every 1-2 hours was based on "very low, quality of evidence" (2). ADA and American Association of Clinical Endocrinologists (AACE) recommend hourly BG checks for patients receiving intravenous insulin therapy, except for patient with stable BG in a desirable range for whom the frequency may be extended to every 2 hours (11). Liberal 4 hourly BG testing frequency increases the risk of hypoglycemia to almost 10% (13, 21, 22).

Our study showed no statistically significant difference in hypoglycemic episodes when the time interval in FSBG monitoring was increased. The insulin infusion protocol established by Goldberg et al., was found to be cumbersome and difficult to implement in our setting as it considers the rate of change as well as absolute glucose values to titrate the dose of insulin infusion (12). In contrast, the protocol developed by and used in our study was based only on absolute blood glucose values to help with the titration of insulin infusion (Supplement 1). Important considerations for implementing a protocol for management of hyperglycemia include glycemic targets, staff motivation in optimizing glycemic control, frequency of blood glucose monitoring and availability of resources for blood glucose checks and documentation.

In our study, the strict compliance with hourly FSBG check (Group A) was only 12.6%. Potential barriers that contributed to the poor compliance were nursing burden in terms of time consumed in FSBG monitoring and adjusting treatment appropriately, healthcare cost including the cost of non-reusable and reusable equipment and indirect cost of nursing time utilized. However these barriers can only be postulated retrospectively since the study was not designed to assess these issues individually.

Commonly encountered barriers to the implementation of an insulin infusion protocol include ambiguity of targets of glycemic control, low nurse-to-patient ratio, practitioner resistance to adopt change, and a lack of organizational and financial support. The time spent on blood glucose monitoring in the ICU setting is often overlooked. Each blood glucose check may require up to 7 minutes by a trained nurse which includes measurement of blood glucose, recording of the measurement, followed by intervention (23). In an ICU with nurse to patient ratio of 1:1.5, and a nurse is actively caring for 2 patients on insulin infusion, she would spend 2 hours out of a 12 hour shift merely on

glucose checks, which could be even greater in ICUs having higher nurse to patient ratio. Thus, safely increasing the time interval between glucose checks without significantly increasing the risk of hypoglycemia can be a point of high value care that will have a huge impact on the healthcare system.

Our study showed no statistically significant difference in hypoglycemic episodes when FSBG checks were done at the intervals of <90 minutes, 90-180 minutes or > 180 minutes. Within the group where FSBG checks were more than180 minutes (Group C), the episodes of hypoglycemia were more frequent than the other two groups and showed a trend towards statistical significance ($p = 0.08$). This may not have reached statistical significance due to the small sample size in our study and may benefit by being studied in larger studies.

Well-tried protocols achieve desirable glycemic control within 3-12 hours, however reported incidence of hypoglycemia may vary from less than 1% to 20% (17, 24). In our study, we found that there was a rapid decline in the BG levels in the first 16 hours, followed by stabilization. However the distribution of hypoglycemic episodes did not follow a pattern and the difference in number of episodes before or after stabilization of blood glucose was not statistically significant. Passarelli et al. commented in their article about a direct correlation with protocol violation and episodes of hypoglycemia (12). Despite the time variation and difference in level of compliance amongst the three study groups, the overall incidence of hypoglycemia was only 0.7%. Hypoglycemia is linked with the risk factors of history of diabetes mellitus, severity of illness, use of ionotropic drugs, renal insufficiency and previous use of insulin (4, 25). In our study, the impact of ongoing sepsis, concurrent use of steroids, renal dysfunction, and current nutritional status, severity of illness and past history of diabetes mellitus were considered; however, there was no statistical correlation found with any of these factors and the risk of hypoglycemia.

Rood et al. introduced the idea of computerized and automated insulin infusion protocol in complex settings such as ICU to improve adherence to the protocol, improve quality of care and reduce the time intensive nature of the process (26). Our institution has introduced a similar model with an insulin infusion calculator to auto-calculate the dose of insulin based on the glucose values and current rate of insulin infusion (units/hour). Moving forward, the ideal insulin infusion protocol would be one that could be integrated into the current electronic medical record system, is user-friendly to the healthcare staff, allows for automated processing of the current blood glucose reading and is able to titrate the dose of insulin accordingly to minimize the human error. Potential caveats to that would be erroneous readings, mechanical errors and varying nutrition or caloric intake of the patient.

Limitations of the study include retrospective data collection from a single center mixed service ICU and poor compliance to hourly blood glucose monitoring. In addition, this was a small sample with exclusion of patients from cardio-thoracic surgery group and those presenting with DKA and hyperglycemic hyperosmolar state. Thus, the results cannot be generalized to all patients receiving insulin infusion for hyperglycemia. We also did not look at effect of our intervention in terms of length of stay and duration of insulin infusion requirement. Effect of vasopressors and steroid use was not studied in this group. Recently the definition of hypoglycemia has been revised to BG values of less than 54 mg/dL, however our results were analyzed keeping in mind the cutoff of 70mg/dL based on previous data.

Conclusion

Despite a lack of strict compliance (12.6%) with hourly blood glucose monitoring in patients receiving insulin infusion to treat hyperglycemia, the risk of hypoglycemic episodes was not significantly different with less frequent BG monitoring. The compliance to hourly blood glucose monitoring and ICU was variable, and hypoglycemic episodes were similar across the groups despite the variation in monitoring.

Conflict of Interest: NT: Speaker bureau Eli Lilly, Novo Nordisk, Sanofi and Janssen. All others authors declare no conflict of interest.

Contributorship Statement: AL: manuscript draft + analysis + literature review + manuscript revision; NH: study design + data collection + manuscript review; JL: data collection + analysis + manuscript review; SRK: data collection + analysis + manuscript review; SVG: literature review + critical review; NT: Conceived the study idea + study design + analysis + critical review

Meetings for Research Presentation: American Association of Clinical Endocrinologists (AACE) Annual Meeting 2016.

References

1. Moghissi ES, Korytkowski MT, DiNardo M, et al. American Association of Clinical Endocrinologists and American Diabetes Association consensus statement on inpatient glycemic control. Endocr Pract. 2009;15(4):353-69.
2. Jacobi J, Bircher N, Krinsley J, et al. Guidelines for the use of an insulin infusion for the management of hyperglycemia in critically ill patients. Crit Care Med. 2012;40(12): 3251-76.
3. Finfer S, Chittock DR, Su SY, et al. Intensive versus conventional glucose control in critically ill patients. N Engl J Med. 2009;360(13):1283-97.
4. Egi M, Furushima N. Glycemic control in acute illness. 2017;70(6):591-5.
5. Goldberg PA, Siegel MD, Sherwin RS, et al. Implementation of a safe and effective insulin infusion protocol in a medical intensive care unit. Diabetes Care. 2004;27(2): 461-7.
6. Beesley SJ, Hirshberg EL, Lanspa MJ. Glucose management in the intensive care unit: are we looking for the right sweet spot? Annals of translational medicine. 2016;4(18):347-.
7. Kar P, Plummer MP, Bellomo R, et al. Liberal Glycemic Control in Critically Ill Patients With Type 2 Diabetes: An Exploratory Study. Crit Care Med. 2016;44(9):1695-703.
8. Finfer S, Liu B, Chittock DR, et al. Hypoglycemia and risk of death in critically ill patients. N Engl J Med. 2012;367(12):1108-18.
9. McCowen KC, Malhotra A, Bistrian BR. Stress-induced hyperglycemia. Crit Care Clin. 2001;17(1):107-24.
10. Klonoff DC. Intensive insulin therapy in critically ill hospitalized patients: making it safe and effective. J Diabetes Sci Technol. 2011;5(3):755-67.
11. Kelly JL. Continuous Insulin Infusion: When, Where, and How? Diabetes Spectr. 2014;27(3):218-23.
12. Passarelli AJ, Gibbs H, Rowden AM, et al. Evaluation of a Nurse-Managed Insulin Infusion Protocol. Diabetes Technology & Therapeutics. 2016;18(2):93-9.
13. Van den Berghe G, Wilmer A, Hermans G, et al. Intensive insulin therapy in the medical ICU. N Engl J Med. 2006;354(5):449-61.
14. van den Berghe G, Wouters P, Weekers F, et al. Intensive insulin therapy in critically ill patients. N Engl J Med. 2001;345(19):1359-67.
15. Lal A, Katta SR, Trivedi N. Closed-Loop Insulin for Glycemic Control in Noncritical Care. The New England journal of medicine. 2018;379(20):1970.
16. Upadhyay J, Trivedi N, Lal A. Risk of Future Type 2 Diabetes Mellitus in Patients Developing Steroid-Induced Hyperglycemia During Hospitalization for Chronic Obstructive Pulmonary Disease Exacerbation. Lung. 2020.
17. Bouw JW, Campbell N, Hull MA, et al. A retrospective cohort study of a nurse-driven computerized insulin infusion program versus a paper-based protocol in critically ill patients. Diabetes Technol Ther. 2012;14(2):125-30.
18. Dortch MJ, Mowery NT, Ozdas A, et al. A computerized insulin infusion titration protocol improves glucose control with less hypoglycemia compared to a manual titration protocol in a trauma intensive care unit. JPEN J Parenter Enteral Nutr. 2008;32(1):18-27.
19. Hoekstra M, Vogelzang M, Verbitskiy E, et al. Health technology assessment review: Computerized glucose regulation in the intensive care unit--how to create artificial control. Crit Care. 2009;13(5):223.
20. Lee J, Fortlage D, Box K, et al. Computerized insulin infusion programs are safe and effective in the burn intensive care unit. J Burn Care Res. 2012;33(3):e114-9.
21. Marvin MR, Inzucchi SE, Besterman BJ. Computerization of the Yale insulin infusion protocol and potential insights into causes of hypoglycemia with intravenous insulin. Diabetes Technol Ther. 2013;15(3):246-52.
22. Olinghouse C. Development of a computerized intravenous insulin application (AutoCal) at Kaiser Permanente Northwest, integrated into Kaiser Permanente Health-Connect: impact on safety and nursing workload. Perm J. 2012;16(3):67-70.
23. Preiser JC, Devos P, Ruiz-Santana S, et al. A prospective randomised multi-centre controlled trial on tight glucose control by intensive insulin therapy in adult intensive care units: the Glucontrol study. Intensive Care Med. 2009;35(10):1738-48.
24. Brunkhorst FM, Engel C, Bloos F, et al. Intensive insulin therapy and pentastarch resuscitation in severe sepsis. N Engl J Med. 2008;358(2):125-39.
25. Lipshutz AK, Gropper MA. Perioperative glycemic control: an evidence-based review. Anesthesiology. 2009;110(2): 408-21.
26. Krikorian A, Ismail-Beigi F, Moghissi ES. Comparisons of different insulin infusion protocols: a review of recent literature. Curr Opin Clin Nutr Metab Care. 2010;13(2): 198-204.
27. Krinsley JS, Grover A. Severe hypoglycemia in critically ill patients: risk factors and outcomes. Crit Care Med. 2007;35(10):2262-7.
28. Lal A, Akhtar J, Ullah A, et al. First Case of Pleural Empyema Caused by Staphylococcus simulans: Review of the Literature. Case Rep Infect Dis. 2018;2018:7831284.
29. Lal A, Akhtar J, Jindal V, et al. Rare Cause of Respiratory Failure: A Twist in the Tale. Annals of the American Thoracic Society. 2018;15(7):880-3.

30. Lal A, Davis MJ, Akhtar J, et al. Serious Cover-Up: Hodgkin's Lymphoma Masked by Organizing Pneumonia. Am J Med. 2018;131(10):1174-7.
31. Sekulic M, Martin S, Lal A, et al. Intravascular Large B-Cell Lymphoma of the Kidney. Kidney Int Rep. 2018;3(6):1501-5.
32. Lal A, Li G, Cubro E, et al. Development and Verification of a Digital Twin Patient Model to Predict Specific Treatment Response During the First 24 Hours of Sepsis. Crit Care Explor. 2020;2(11):e0249.
33. Lal A, Mishra AK, John K, et al. Corticosteroids and Rehabilitation in COVID-19 Survivors. Journal of the Formosan Medical Association. 2020.
34. Rood E, Bosman RJ, van der Spoel JI, et al. Use of a computerized guideline for glucose regulation in the intensive care unit improved both guideline adherence and glucose regulation. J Am Med Inform Assoc. 2005;12(2):172-80.

Correspondence:
Received: 27 November 2020
Accepted: 28 December 2020
Amos Lal, MD, Division of Pulmonary and Critical Care Medicine
200 1St, SW, Mayo Clinic, Rochester,
Minnesota, USA, 55902
Phone: 5083635000
Email: manavamos@gmail.com; Lal.Amos@mayo.edu
ORCID ID: 0000-0002-0021-2033

APPENDIX: SUPPLEMENTARY FILE 1: Institutional Hyperglycemia Management Protocol

Supplementary Material - for review

Saint Vincent Hospital

Hyperglycemia Doctor's Orders for ICU / PCU patients only

Check all that apply. Only items checked will be ordered.
Fill in required information where indicated.

Allergies	Type of Reaction			
	I	II	Intolerant	Other

☐ ALREADY DOCUMENTED ON MEDICATION HISTORY AND ORDER FORM

ALLERGY DEFINITIONS

Type I: Anaphylaxis, angioedema, bronchospasm
Type II and III: Cytopenias, rash, immune complex disorder, vasculitis
Intolerance: Typically adverse effects such as nausea and vomiting

☒ Discontinue all previous insulin and oral anti-diabetic medication orders
☒ Target blood glucose **140 to 180 mg/dL**
☒ Check initial HbA1c level

☐ **REGULAR INSULIN SLIDING SCALE —** administer regular human insulin subcutaneously as follows:
☒ Check blood glucose levels every 6 hours
- Blood glucose less than 70 mg/dL — **Administer 1 ampule (50 mL or 25 gm) of dextrose 50% and call PA/HO**
- Blood glucose level 70 to 180 mg/dL — Nothing
- Blood glucose level 181 to 199 mg/dL — 2 units Regular Human Insulin SQ
- Blood glucose level 200 to 219 mg/dL — 3 units Regular Human Insulin SQ
- Blood glucose level 220 to 249 mg/dL — 4 units Regular Human Insulin SQ
- Blood glucose level 250 to 289 mg/dL — 6 units Regular Human Insulin SQ
- Blood glucose level 290 to 300 mg/dL — 8 units Regular Human Insulin SQ
- Blood glucose greater than 300 mg/dL — 10 units Regular Human Insulin SQ and call PA / HO

If blood glucose is greater than 180mg/dL times 2 checks, call PA/HO to initiate insulin infusion

☐ **REGULAR INSULIN INFUSION —** Prepare a standard insulin drip with 100 units of Regular Human Insulin in 100 mL of normal saline **(Final Conc. = 1 unit/mL) NOTIFY PHARMACY IF UNIT NEEDS INITIAL DRIP**
- Insulin infusion is preferred in patients on pressors or with significant tissue edema
- Check blood glucose levels every 1 hour after initiating or adjusting the infusion until stable, then every 4 hours

Initial infusion rate: If blood glucose is less than or equal to 180 mg/dL, do not start insulin infusion
If blood glucose is 181 to 250 mg/dL, start infusion at 2 units/hour
If blood glucose is greater than 250 mg/dL, start infusion at 4 units/hour

Adjust insulin infusion as follows:
If blood glucose level is less than 70 mg/dL, **administer 1 ampule (50 mL or 25 gm) of dextrose 50%, call PA/HO, discontinue infusion** and check blood glucose in 15 minutes. If level remains less than 70 mg/dL, check blood glucose every 30 minutes until greater than 100 mg/dL, then check every hour and restart infusion when blood glucose is greater than 180 mg/dL.

If blood glucose level is 70 to 100 mg/dL, hold infusion and check blood glucose in 1 hour. If level remains 70 to 100 mg/dL, check blood glucose every hour and restart infusion when blood glucose is greater than 180 mg/dL.

If blood glucose level is 101 to 140 mg/dL, decrease infusion by 1 unit per hour; check blood glucose every hour and follow infusion guidelines

If blood glucose level is 141 to 180 mg/dL, continue at same rate

If blood glucose level is 181 to 200 mg/dL, increase rate by 1 unit per hour

If blood glucose level is 201 to 250 mg/dL, increase rate by 2 units per hour

If blood glucose level is 251 to 350 mg/dL, increase rate by 3 units per hour

If blood glucose level is 351 to 400 mg/dL, increase rate by 4 units per hour

If blood glucose level is greater than 400 mg/dL, increase rate by 5 units per hour and call PA/HO

☒ The insulin infusion is discontinued if the patient has to leave the ICU/PCU for a diagnostic test, or if enteral or parenteral feedings are discontinued over 1 hour

Practitioner's Signature: _____ Date: _____ Time: _____

RN's Signature: _____ Date: _____ Time: _____

W.PO FORM #25837 (Rev. 7/12)

7