Diabetes & Metabolic Syndrome: Clinical Research & Reviews 13 (2019) 2647–2652

Contents lists available at ScienceDirect

Diabetes & Metabolic Syndrome: Clinical Research & Reviews

journal homepage: www.elsevier.com/locate/dsx

Original Article

Improving inpatient glycemic control by diabetes education program in internal medicine residents

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ARTICLE INFO

Article history:
Received 21 June 2019
Accepted 10 July 2019

Keywords:
Feedback
Internal medicine
Postgraduate
Small group

ABSTRACT

Aims: The purpose of this study was to investigate the effectiveness of an inpatient diabetes care education during the first year of internal medicine residency training on inpatient glycemic control.
Methods: The program was comprised of 1-hr small group teaching per 4-week rotation and twice-a-week morning insulin round by an endocrinologist. Inpatient insulin management guideline leaflet was provided to all internal medicine residents. We retrospectively collected the point-of-care testing for glucose (POCT-glu) data in patients admitted to the general medicine wards and compared the mean of blood glucose (BG) before and after the education program. A total of 134438 POCT-glu values from 7055 patients were analyzed.
Results: After the initiation of the education program, mean BG levels significantly decreased during the first year and were lowest during the second year after education (Mean BG at baseline was 161.38 ± 64.10 mg/dL; 1st year, 159.48 ± 62.53 mg/dL and 2nd year, 155.60 ± 64.94 mg/dL, p-value < 0.0001). The reduction of BG levels was more pronounced in the patients with previously undiagnosed diabetes mellitus than patients with underlying diabetes mellitus. The rates of severe hypoglycemia (defined by BG < 40 mg/dL or 2.2 mmol/L) were not significantly different before and after education (baseline 0.12%, 1st year 0.14%, and 2nd year 0.14%, p-value = 0.632).
Conclusions: Lack of confidence and inadequate knowledge of insulin treatment in physicians were important barriers to glycemic management. Consistent education in internal medicine residents led to a significant improvement in inpatient glycemic control.

1. Introduction

Hyperglycemia in the hospital setting occurs not only in patients with established diabetes mellitus but also in those with formerly undiagnosed diabetes mellitus and others with stress hyperglycemia that may occur during an acute illness. The poorly controlled hyperglycemia during hospitalization, irrespective of its cause, is associated with poor clinical outcomes, e.g. infection, prolonged hospital stay, and increased risk for morbidity and mortality, across medical and surgical patients [1–6]. Correction of hyperglycemia has been shown to reduce hospital complications [7–9].

For the majority of non-critically ill patients treated with insulin, the Endocrine Society Clinical Practice Guideline recommended a premeal blood glucose (BG) target of less than 140 mg/dL (7.8 mmol/L) in conjunction with a random BG level of less than 180 mg/dL (10.0 mmol/L) [10]. The preferred insulin regimen includes scheduled subcutaneous administration of insulin as basal-bolus insulin therapy, in combination with a correction insulin scale [10]. However, a retrospective study conducted in the teaching hospital showed that 20% of patients' BG values remained >200 mg/dL throughout the hospital stay [11]. Despite persistent hyperglycemia, one-third of patients had insulin treatment decreased rather than increased [11]. Lack of intensified insulin treatment in response to hyperglycemia or clinical inertia is common among hospitalized patients [12–14]. Several physician barriers in optimizing inpatient glycemic control include lack of experience, hesitance to initiate insulin, unfamiliarity with adjustment of insulin therapy and fear of hypoglycemia. Despite

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https://doi.org/10.1016/j.dsx.2019.07.029
1871-4021/

Abbreviations

BG	blood glucose
POCT-glu	point-of-care testing for glucose
PGY-1	postgraduate year 1

well-outlined guidelines, basal-bolus insulin therapy is perceived to be complex and therefore poorly adopted for hyperglycemia management.

As in many hospitals, inpatient glycemic management was not exclusively managed by endocrinologists. Residents learned from their internal medicine attending, endocrinology consultants when consults were placed and when they rotated to the endocrinology service. With this model, not 100% of the patients were covered by the endocrine service, and residents might have gotten varying degree of knowledge regarding the glycemic management, depending upon patients under their care and if they rotated through endocrinology. This project attempted to reach out in a more systematic way and evaluated the results. A pilot educational training program for medical residents has been shown to improve glycemic management [15].

In this study, we explored the effects of diabetes education program provided to internal medicine residents on inpatient glycemic control. The goals of the education program were both to improve resident knowledge and performance in treating hospitalized patients with hyperglycemia. We thus hypothesized that successful learning through the education program would lead to achieving the target glycemic range without hypoglycemia.

2. Material and methods

All first-year internal medicine residents (postgraduate year 1 or PGY-1) at our hospital were asked to join the education program during the rotation of general medicine ward. The academic year is divided into 13 four-week block rotations. The education program was comprised 1-hr small group teaching at the beginning of a 4-week rotation on one of the internal medicine wards, along with twice-a-week morning insulin round by an endocrinology staff (Chutintorn Sriphrapradang) and clinical endocrine fellows. A teaching endocrinologist rounded every Tuesday and Thursday at 7.00–7.15 a.m. with medical residents. The medical students also participated in the insulin round. It was designed to be integrated with ongoing clinical care while not burdening residents who had many responsibilities. On rounds, the endocrinology staff provided direct feedback and suggested improvement in treatment plan for patients under the care of residents.

Inpatient insulin guideline leaflet detailing the management of subcutaneous basal-bolus insulin regimen was also provided for all residents. The inpatient guideline was revised from Rush University Medical Center Inpatient Glycemic Management Guidelines, with permission [16]. The guideline provided comprehensive suggestions in inpatient glycemic management taken into account multiple patients' factors such as prior diabetes status and treatment, body weight, kidney function, nutrition status and steroid use. Based on these guidelines, residents were instructed to follow the recommendations. All patients had capillary BG monitored pre-meals and at bedtime for patients who were eating. For patients who were nil per os (NPO), BG was measured every 4–6 h. The patients who had BG > 140 mg/dL (7.8 mmol/L) needed monitoring of BG for at least 24–48 h with appropriate glycemic management. Oral hypoglycemic agents were discontinued and switched to basal-bolus insulin regimen. Patients usually received NPH and rapid-acting or regular insulin twice daily. Premixed insulin such as 70/30 was not recommended. Sole use of sliding scale insulin was not permitted. Doses were modified twice daily based on 4 daily BG values. The BG targets were as follows: fasting BG 100–140 mg/dL (5.5–7.8 mmol/L) and prelunch, predinner, and bedtime BG 140–180 mg/dL (7.8–10.0 mmol/L).

To decrease the risk of hypoglycemia, we suggested that insulin therapy be reassessed when BG values fell below 100 mg/dL (5.5 mmol/L). Modifications of treatment regimen were usually necessary when BG values were below 70 mg/dL (3.9 mmol/L). However, the cut-off value at 70 mg/dL has been debated. Recent joint position statement from the American Diabetes Association and the European Association for the Study of Diabetes recommended a BG level of <54 mg/dL (3.0 mmol/L) be defined as clinically important hypoglycemia [17]. This cut-off was associated with the risk of severe hypoglycemia [18] and mortality [19]. According to American Diabetes Association and the Endocrine Society Workgroups, severe hypoglycemia is an event requiring assistance of another person to actively administer carbohydrates, glucagon, or take other corrective actions [20]. However, we cannot retrospectively collect this information. The BG level at 40 mg/dL was used as the cut-off value of severe hypoglycemia as most of the studies have defined severe hypoglycemia arbitrarily as BG less than 40 mg/dL (2.2 mmol/L) [7,20–23].

We retrospectively collected the bedside capillary point-of-care testing for glucose (POCT-glu) data in patients admitted to all of the five general medicine wards (the specific ward where the teaching took place and four others), and compared the mean of POCT-glu before (July 2013–June 2014) and after the education program (July 2014–June 2016). BG data for the same timeframes in 2013–2016 provided year-over-year comparison. The analysis of POCT-glu data was also conducted in a subgroup of patients with cancer and previously diagnosis with diabetes mellitus. We identified patients with cancer and diabetes mellitus in the databases using ICD-10 codes E10.x-E14.x and C00.x-C97.x, respectively.

Accu-Chek Inform II POCT-glu monitoring system (Roche Diagnostics, Indianapolis, IN) was used for measurement of glucose in fresh capillary whole blood samples drawn from the fingertips. The enzyme on the test strip, modified glucose dehydrogenase, converts the glucose in the blood sample and creates an electrical current that the meter interprets for the BG result (electrochemical detection technique). This device is a wireless hospital glucose meter that enables an immediate transfer of BG results to the hospital medical record. The reportable range for the system is 10–600 mg/dL (0.55–33.3 mmol/L). If the report is <10 or >600 mg/dL, it will count as 10 or 600 mg/dL, respectively.

A group of residents who participated during the first six months of the program also answered questionnaires evaluating their satisfaction with the program.

Statistical analysis was performed in Microsoft Excel 2011 (Microsoft, Seattle, WA) and STATA 14 (STATACorp, College Station, TX). Comparisons between two groups and three groups on continuous variables were calculated using student *t*-test and one-way ANOVA, respectively. Differences in categorical variables were analyzed using Chi-square test. Results were considered statistically significant when two-tailed p-value < 0.05.

3. Results

3.1. Characteristics of residents and patients participating in this study

For the consecutive 3 academic years, 111 PGY-1 internal medicine residents participated in the study. Fifty four percent of the residents were female.

A total of 134438 POCT-glu values from 7055 patients were analyzed. The number of POCT-glu data was 42513, 42312 and 49613 values at baseline and after the education at year 1 and year 2, respectively. Patient characteristics were shown in Table 1. The mean age was 65.3 ± 16.0 years and 46.5% of the patients were male. The mean hospital length of stay was 12.6 ± 20.0 days. There were no significant difference in age, sex and length of stay among the patients at baseline, after the education program year 1 and 2.

3.2. Glycemic outcomes

1. Average BG (Fig. 1)

Mean BG (mean ± SD) at baseline was 161.38 ± 64.10 mg/dL. Mean BG levels at 1st and 2nd year after the education program significantly decreased to 159.48 ± 62.53 and 155.60 ± 64.94 mg/dL compared with baseline (p-value < 0.0001).

After the education program, the reduction of BG was more obvious in the group of patients with no previous diagnosis of diabetes mellitus (Table 2).

2. Hyperglycemia

Percentage of high BG levels >180 mg/dL (10.0 mmol/L) were significantly decreased from 30.91% at baseline to 29.79% and 27.53% at 1st and 2nd year after education (p-value < 0.0001). The percentage of high BG levels >200 and >300 mg/dL (>11.1 and >16.6 mmol/L) were also significantly decreased after education (p-value < 0.0001).

3. Hypoglycemia

Rates of BG < 70 mg/dL were increased after the education (baseline 1.25%, 1st year 1.47%, and 2nd year 1.67%, p-value < 0.0001). The rates of clinically important hypoglycemia (defined by BG < 54 mg/dL or 3 mmol/L) were 0.28% at baseline, 0.42% at 1st year and 0.42% at 2nd year (p-value = 0.06). The rates of severe hypoglycemia (defined by BG < 40 mg/dL or 2.2 mmol/L) were not significantly different before and after the education (baseline 0.12%, 1st year 0.14%, and 2nd year 0.14%, p-value = 0.632).

4. Resident satisfaction

After the end of the rotation, the residents (n = 24) were asked to complete the 8-item survey and rated their satisfaction on a 5-point scale, ranging from 1 (no satisfaction at all) to 5 (extreme satisfaction). The mean satisfaction was reported as followings: (1) understanding the importance of inpatient glycemic control, 4.4 ± 0.5; (2) increased knowledge about insulin, 4.3 ± 0.5; (3) confidence in prescribing and adjusting insulin, 4.3 ± 0.5; (4) confidence in prescribing home diabetes medications, 4.1 ± 0.4; (5) improvement in patients' glycemic control compared to before joining the program, 4.4 ± 0.5; (6) frequency of rounding, 4.1 ± 0.5; (7) timing of rounding, 4.1 ± 0.5; (8) this program should be continued, 4.5 ± 0.5.

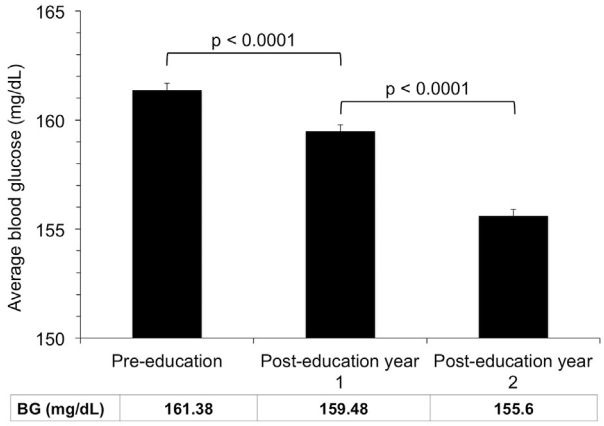

Fig. 1. Comparison of average blood glucose (expressed as mean ± standard error) before and after the residency diabetes education.

4. Discussion

Significant improvement of glycemic control was achieved in the present study. The intervening education program resulted in lower the mean BG levels and a fewer percentage of BG levels >180 mg/dL (10.0 mmol/L). This accomplishment came at the expense of an increase in hypoglycemic events. Fortunately, the rate of clinically important hypoglycemia (BG < 54 mg/dL or 3 mmol/L) and severe hypoglycemia (BG < 40 mg/dL or 2.2 mmol/L) did not significantly increase after the diabetes education program. The effects of resident education have been observed in the group of patients with no previous diagnosis of diabetes mellitus.

Management of inpatient hyperglycemia is quite distinct from management of outpatient diabetes in the following ways: (1) BG goals are different, (2) patients are not in their usual state, (3) nutritional intake may be unpredictable, (4) patients may be given intravenous fluids or medications that can alter BG levels, and (5) many diabetes medications commonly used in the outpatient setting are not recommended for use in the inpatient setting. Even for endocrinologists, inpatient management may present significant challenges and require additional knowledge and skills. In academic teaching institutions, residents are most often responsible for managing the complex spectrum of conditions for which the patients have been admitted. However, surveys show that medical residents have substantial deficits in basic diabetes knowledge and inpatient diabetes management skills [24–27]. Residents often fail to intensify therapy when BG levels are high, a

Table 1
Patient characteristics.

	Pre-education	Post-education year 1	Post-education year 2
Number of patients	2356	2293	2406
Age, years*	64.6 ± 16.1	66.1 ± 15.8	65.2 ± 16.2
Male (%)	46.25	45.77	47.58
Underlying disease Cancer (%)	44.25	38.88	45.67
DM (%)	65.74	68.66	62.61
Number of POCT-glu	42513	42312	49613
Length of stay, days*	13.1 ± 23.7	12.0 ± 16.6	12.8 ± 18.6

*Data were presented as mean ± standard deviation.
DM, diabetes mellitus; POCT-glu, point-of-care testing for glucose.

Table 2
Blood glucose levels according to underlying disease of cancer and diabetes mellitus (Data were presented as mean ± standard deviation).

Blood glucose levels (mg/dL)	Pre-education	Post-education year 1	Post-education year 2
Non-cancer, non-DM	140.15 ± 50.38	136.04 ± 47.15	129.08 ± 46.41*
Non-cancer, DM	170.79 ± 67.55	168.35 ± 64.36	171.17 ± 70.33
Cancer, non-DM	141.42 ± 47.81	136.63 ± 44.95	132.11 ± 45.81*
Cancer, DM	173.79 ± 68.72	173.16 ± 68.99	169.78 ± 69.02

*p-value < 0.0001 compared with pre-education and post-education year 1.
DM, diabetes mellitus.

problem known as clinical inertia [28].

Traditionally, clinical diabetes training for residents may be inconsistent and limited to informal teaching. To address this deficit, our division has tried a more formal approach to training. We offered the formal small-group lecture at the beginning of rotation and also provided inpatient insulin guideline leaflet to all residents. In addition, residents received regular feedback from endocrinologists twice a week. Quick insulin round was performed without increased time constraints for residents. From the previous studies, residents gained confidence about their knowledge and felt more at ease with inpatient glucose management, but significant improvement in glucose management outcomes generally have not occurred [29]. Many educational efforts to improve resident education have been reported such as printed materials, web-based learning and case conferences. However, the most important factor linked with glycemic outcomes was the real-time feedback on management of the real patients [30]. Moreover, we taught the residents on the certain ward and collected BG data from all general medicine wards. The improvement of glycemic control suggests that we are able to improve outcomes with resident carrying knowledge they have learned. The educational wisdom is found in this ancient Chinese proverb "give a man a fish and you feed him for a day; teach him to fish and you feed him for a lifetime". This program was well received by the residents as evident by high satisfaction. Interestingly, the glycemic outcomes improved better year by year. These results emphasized to continuing the education efforts for the residents.

In our study, the reduction of average BG concentrations was more apparent in the patients who had no history of diabetes before the admission, compared to those with established diabetes diagnosis. Umpierrez et al. reported that patients with newly diagnosed hyperglycemia or "stress hyperglycemia" had significantly increased rate of in-hospital mortality, poor clinical outcomes and prolonged length of hospital stay than patients with a previously diagnosis of diabetes mellitus [1]. The detrimental effects of hyperglycemia include immune dysfunction (impaired leukocyte function and phagocytosis), hemodynamic effects (electrolyte loss, intracellular and extracellular dehydration) and tissue effects (inflammation, oxidative stress and endothelial dysfunction) [31–33].

In the past, the strict glycemic control (BG 80–110 mg/dL or 4.4–6.1 mmol/L) was the glycemic goals in the hospital setting [23,34]. However, the large multicenter randomized study in critically ill patients, NICE-SUGAR study, showed increased mortality and severe hypoglycemic rates in tightly controlled patients [35]. This result changed the recommended glucose target to 140–180 mg/dL (7.8–10.0 mmol/L) in both critically ill and non-critical ill patients. Despite a higher glucose target recommended in terminally ill patients [10], the average BG levels in patients with cancer were not different from non-cancer group. This could possibly be partly explained from the diagnosis of cancer based on the use of ICD-10. The cancer group in the present study included not only patients with currently active disease of cancer, but with cancer remission.

Despite the significant reduction of BG, there were no differences in the length of hospital stay in the present study. Although the clinical impact of hyperglycemia among hospitalized patients has been well established [7–9], there was no difference in hospital length of stay in both general medicine and surgery wards after the optimal glycemic control [7,36]. The mean length of stay in our study was much longer than other studies. It could be implied that the study population had a greater severity of illness, and that correction of hyperglycemia could not decrease the length of stay. In addition, the absolute reduction in glucose values was small, which could partly explain the null effect on the length of stay. Nevertheless, our study did not address the question of whether better glycemic control may shorten stays in the hospital due to retrospective design. Future research is required to investigate the long-term results.

Our study has a strength by including the large accurate dataset from the computer-based system. However, there were several limitations. The study was a retrospective design. There likely existed confounders which we could not control. Some parameters such as prior diabetes types and treatments were not readily available in the dataset but these were taken into account in the insulin dosing per the guidelines. While statistically significant, the absolute reduction in glucose values was small and it was unclear whether this was clinically meaningful. We did not see significant changes in glucose levels in those with pre-existing DM, therefore this could be a focus of improvement in our further teaching. Other adverse outcomes, such as infection rates, were not collected.

5. Conclusions

Inpatient glycemic control is important but can be very challenging. Insufficient knowledge among internal medicine residents is one of the factors contributing to hyperglycemia. Our study demonstrated that endocrinologist-supported education program aimed at medical resident to reduce clinical inertia could improve diabetes management in the inpatient setting.

Declarations

Ethics approval and consent to participate

Ethical approval for the study was obtained by the Committee on Human Rights Related to Research Involving Human Subjects of Faculty of Medicine Ramathibodi Hospital, Mahidol University (approval reference number ID 07-58-51). Internal medicine residents gave their verbal consent to participate in the study, as no identifiable data would be used and this was part of routine teaching program. Patients' consents were not required because neither confidential information nor blood samples were obtained from any patients for this research.

Consent for publication

Not applicable.

Data availability statement

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Conflicts of interest

All authors declare that they have no competing interests.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Authors' contributions

CS was responsible for the concept and design of the study, data collection and analysis, and for several drafts of the paper. PM and HT were contributors to data collection, analysis, and interpretation. SR contributed to the concept and design of the study and to writing the paper. All authors contributed to the critical revision of the manuscript, approved the final manuscript for publication, and have agreed to be accountable for all aspects of the work including any issues related to accuracy or integrity.

Acknowledgement

Dr. Mongkolrattanakul is currently working at Phanat Nikhom Hospital, Chon Buri, Thailand. Dr. Reutrakul is currently working at Division of Endocrinology, Diabetes and Metabolism, Department of Medicine, University of Illinois College of Medicine at Chicago, Chicago, IL. We would like to thank Dr. David Baldwin, Rush University Medical Center, for his expert input with the insulin management guideline leaflet.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.dsx.2019.07.029.

References

[1] Umpierrez GE, Isaacs SD, Bazargan N, You X, Thaler LM, Kitabchi AE. Hyperglycemia: an independent marker of in-hospital mortality in patients with undiagnosed diabetes. J Clin Endocrinol Metab 2002;87(3):978–82.
[2] Sinnaeve PR, Steg PG, Fox KA, Van de Werf F, Montalescot G, Granger CB, Knobel E, Anderson FA, Dabbous OH, Avezum A, et al. Association of elevated fasting glucose with increased short-term and 6-month mortality in ST-segment elevation and non-ST-segment elevation acute coronary syndromes: the Global Registry of Acute Coronary Events. Arch Intern Med 2009;169(4):402–9.
[3] Kosiborod M, Rathore SS, Inzucchi SE, Masoudi FA, Wang Y, Havranek EP, Krumholz HM. Admission glucose and mortality in elderly patients hospitalized with acute myocardial infarction: implications for patients with and without recognized diabetes. Circulation 2005;111(23):3078–86.
[4] Pomposelli JJ, Baxter 3rd JK, Babineau TJ, Pomfret EA, Driscoll DF, Forse RA, Bistrian BR. Early postoperative glucose control predicts nosocomial infection rate in diabetic patients. JPEN - J Parenter Enter Nutr 1998;22(2):77–81.
[5] McAlister FA, Majumdar SR, Blitz S, Rowe BH, Romney J, Marrie TJ. The relation between hyperglycemia and outcomes in 2,471 patients admitted to the hospital with community-acquired pneumonia. Diabetes Care 2005;28(4):810–5.
[6] Baker EH, Janaway CH, Philips BJ, Brennan AL, Baines DL, Wood DM, Jones PW. Hyperglycaemia is associated with poor outcomes in patients admitted to hospital with acute exacerbations of chronic obstructive pulmonary disease. Thorax 2006;61(4):284–9.
[7] Umpierrez GE, Smiley D, Jacobs S, Peng L, Temponi A, Mulligan P, Umpierrez D, Newton C, Olson D, Rizzo M. Randomized study of basal-bolus insulin therapy in the inpatient management of patients with type 2 diabetes undergoing general surgery (RABBIT 2 surgery). Diabetes Care 2011;34(2):256–61.
[8] Noordzij PG, Boersma E, Schreiner F, Kertai MD, Feringa HH, Dunkelgrun M, Bax JJ, Klein J, Poldermans D. Increased preoperative glucose levels are associated with perioperative mortality in patients undergoing noncardiac, nonvascular surgery. Eur J Endocrinol 2007;156(1):137–42.
[9] Malmberg K, Ryden L, Efendic S, Herlitz J, Nicol P, Waldenstrom A, Wedel H, Welin L. Randomized trial of insulin-glucose infusion followed by subcutaneous insulin treatment in diabetic patients with acute myocardial infarction (DIGAMI study): effects on mortality at 1 year. J Am Coll Cardiol 1995;26(1):57–65.
[10] Umpierrez GE, Hellman R, Korytkowski MT, Kosiborod M, Maynard GA, Montori VM, Seley JJ, Van den Berghe G, Endocrine S. Management of hyperglycemia in hospitalized patients in non-critical care setting: an endocrine society clinical practice guideline. J Clin Endocrinol Metab 2012;97(1):16–38.
[11] Cook CB, Castro JC, Schmidt RE, Gauthier SM, Whitaker MD, Roust LR, Argueta R, Hull BP, Zimmerman RS. Diabetes care in hospitalized noncritically ill patients: more evidence for clinical inertia and negative therapeutic momentum. J Hosp Med 2007;2(4):203–11.
[12] Matheny ME, Shubina M, Kimmel ZM, Pendergrass ML, Turchin A. Treatment intensification and blood glucose control among hospitalized diabetic patients. J Gen Intern Med 2008;23(2):184–9.
[13] Coan KE, Schlinkert AB, Beck BR, Haakinson DJ, Castro JC, Apsey HA, Schlinkert RT, Cook CB. Clinical inertia during postoperative management of diabetes mellitus: relationship between hyperglycemia and insulin therapy intensification. J Diabetes Sci Technol 2013;7(4):880–7.
[14] Neubauer KM, Schaupp L, Plank J, Augustin T, Mautner SI, Tschapeller B, Pieber TR. Failure to control hyperglycemia in noncritically ill diabetes patients despite standard glycemic management in a hospital setting. J Diabetes Sci Technol 2013;7(2):402–9.
[15] Trujillo JM, Barsky EE, Greenwood BC, Wahlstrom SA, Shaykevich S, Pendergrass ML, Schnipper JL. Improving glycemic control in medical inpatients: a pilot study. J Hosp Med 2008;3(1):55–63.
[16] Baldwin D, Villanueva G, McNutt R, Bhatnagar S. Eliminating inpatient sliding-scale insulin: a reeducation project with medical house staff. Diabetes Care 2005;28(5):1008–11.
[17] International Hypoglycaemia Study G. Glucose concentrations of less than 3.0 mmol/L (54 mg/dL) should Be reported in clinical trials: a joint position statement of the American diabetes association and the European association for the study of diabetes. Diabetes Care 2017;40(1):155–7.
[18] Cranston I, Lomas J, Maran A, Macdonald I, Amiel SA. Restoration of hypoglycaemia awareness in patients with long-duration insulin-dependent diabetes. Lancet 1994;344(8918):283–7.
[19] Investigators N-SS, Finfer S, Liu B, Chittock DR, Norton R, Myburgh JA, McArthur C, Mitchell I, Foster D, Dhingra V, et al. Hypoglycemia and risk of death in critically ill patients. N Engl J Med 2012;367(12):1108–18.
[20] Seaquist ER, Anderson J, Childs B, Cryer P, Dagogo-Jack S, Fish L, Heller SR, Rodriguez H, Rosenzweig J, Vigersky R, et al. Hypoglycemia and diabetes: a report of a workgroup of the American diabetes association and the endocrine society. J Clin Endocrinol Metab 2013;98(5):1845–59.
[21] Brunkhorst FM, Engel C, Bloos F, Meier-Hellmann A, Ragaller M, Weiler N, Moerer O, Gruendling M, Oppert M, Grond S, et al. Intensive insulin therapy and pentastarch resuscitation in severe sepsis. N Engl J Med 2008;358(2):125–39.
[22] Arabi YM, Dabbagh OC, Tamim HM, Al-Shimemeri AA, Memish ZA, Haddad SH, Syed SJ, Giridhar HR, Rishu AH, Al-Daker MO, et al. Intensive versus conventional insulin therapy: a randomized controlled trial in medical and surgical critically ill patients. Crit Care Med 2008;36(12):3190–7.
[23] Van den Berghe G, Wilmer A, Hermans G, Meersseman W, Wouters PJ, Milants I, Van Wijngaerden E, Bobbaers H, Bouillon R. Intensive insulin therapy in the medical ICU. N Engl J Med 2006;354(5):449–61.
[24] Gosmanova A, Gosmanov N. Assessing diabetes-related knowledge among internal medicine residents using multiple-choice questionnaire. Am J Med Sci 2009;338(5):348–52.
[25] Rubin DJ, Moshang J, Jabbour SA. Diabetes knowledge: are resident physicians and nurses adequately prepared to manage diabetes? Endocr Pract 2007;13(1):17–21.
[26] Latta S, Alhosaini MN, Al-Solaiman Y, Zena M, Khasawneh F, Eranki V, Khilwani A, Iroegbu N. Management of inpatient hyperglycemia: assessing knowledge and barriers to better care among residents. Am J Therapeut 2011;18(5):355–65.
[27] Ahmed A, Jabbar A, Zuberi L, Islam M, Shamim K. Diabetes related knowledge among residents and nurses: a multicenter study in Karachi, Pakistan. BMC Endocr Disord 2012;12:18.
[28] Smith WD, Winterstein AG, Johns T, Rosenberg E, Sauer BC. Causes of hyperglycemia and hypoglycemia in adult inpatients. Am J Health Syst Pharm 2005;62(7):714–9.
[29] Desimone ME, Blank GE, Virji M, Donihi A, DiNardo M, Simak DM, Buranosky R, Korytkowski MT. Effect of an educational Inpatient Diabetes Management Program on medical resident knowledge and measures of glycemic control: a randomized controlled trial. Endocr Pract 2012;18(2):238–49.
[30] Phillips LS, Ziemer DC, Doyle JP, Barnes CS, Kolm P, Branch WT, Caudle JM, Cook CB, Dunbar VG, El-Kebbi IM, et al. An endocrinologist-supported intervention aimed at providers improves diabetes management in a primary care site: improving primary care of African Americans with diabetes (IPCAAD) 7.

Diabetes Care 2005;28(10):2352–60.
[31] Bagdade JD, Stewart M, Walters E. Impaired granulocyte adherence. A reversible defect in host defense in patients with poorly controlled diabetes. Diabetes 1978;27(6):677–81.
[32] Umpierrez GE, Pasquel FJ. Management of inpatient hyperglycemia and diabetes in older adults. Diabetes Care 2017;40(4):509–17.
[33] Valko M, Leibfritz D, Moncol J, Cronin MT, Mazur M, Telser J. Free radicals and antioxidants in normal physiological functions and human disease. Int J Biochem Cell Biol 2007;39(1):44–84.
[34] van den Berghe G, Wouters P, Weekers F, Verwaest C, Bruyninckx F, Schetz M, Vlasselaers D, Ferdinande P, Lauwers P, Bouillon R. Intensive insulin therapy in critically ill patients. N Engl J Med 2001;345(19):1359–67.
[35] Investigators N-SS, Finfer S, Chittock DR, Su SY, Blair D, Foster D, Dhingra V, Bellomo R, Cook D, Dodek P, et al. Intensive versus conventional glucose control in critically ill patients. N Engl J Med 2009;360(13):1283–97.
[36] Umpierrez GE, Smiley D, Zisman A, Prieto LM, Palacio A, Ceron M, Puig A, Mejia R. Randomized study of basal-bolus insulin therapy in the inpatient management of patients with type 2 diabetes (RABBIT 2 trial). Diabetes Care 2007;30(9):2181–6.