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Isaac R Whitman
Hospital of the University of Pennsylvania, Office of Internal Medicine

Maura Murphy
Thomas Jefferson University Hospital, Maura.Murphy@jefferson.edu

Marta M Gilson
Johns Hopkins University

Amy Campfield
Johns Hopkins University

Michel Haddad
Thomas Jefferson University Hospital, Michel.Haddad@jefferson.edu

See next page for additional authors

Authors
Isaac R Whitman, Maura Murphy, Marta M Gilson, Amy Campfield, Michel Haddad, Elizabeth Moxey, and Glenn J R Whitman

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Compliance with Surgical Care Improvement Project Blood Glucose—A Marker for Euglycemia, but Does It Put our Patients at Risk?

Isaac R. Whitman, MD,[1] Maura Murphy, BA,[2] Marta M. Gilson, PhD,[3] Amy Campfield, MD,[4] Michel Haddad, MD,[2] Elizabeth Moxey, MPH,[2] and Glenn J.R. Whitman, MD[3]

Abstract

To improve outcomes in open heart surgery (OHS) patients, the Surgical Care Improvement Project (SCIP) requires 6 AM postoperative day (POD) 1 and 2 blood glucose (BG) to be ≤200mg/dL. This study examined risk factors for SCIP noncompliance when using an insulin infusion protocol (IIP) and evaluated this SCIP metric as a surrogate for glycemic control. The authors divided 99 consecutive OHS patients, all subjected to 1 uniform IIP, into 2 groups: Group 1–SCIP compliant ($n=79$) and Group 2–SCIP noncompliant ($n=20$). They determined mean BG for the first 48 postoperative hours, percent of total time with hyperglycemia (% time BG >200mg/dL) for each group, and assessed risk of SCIP noncompliance as relates to multiple risk factors including intensity of IIP application, and switching to subcutaneous (SQ) insulin prior to 6 AM on POD 2. Group 1 had lower mean BG than Group 2 and percent of total time with hyperglycemia, $P<0.0001$. Multivariate analysis showed diabetes, obesity in nondiabetics, and switching to SQ insulin prior to 6 AM on POD 2 to be risk factors for SCIP noncompliance. The 6 AM BG values on POD 1 or POD 2 each correlated with average postoperative BG, and compliance with the SCIP BG metric was associated with virtually uniform BG ≤200mg/dL. IIP application was not significantly different between groups ($P=0.2$). Only patients who had been switched to SQ insulin prior to 6 AM POD 2 were noncompliant at 6 AM on POD 2. There were hypoglycemic events (BG <70mg/dL) in 15 of 99 patients (15%), 12 of whom (80%) were in Group 1. Noncompliance with this SCIP measure occurred more frequently in patients with diabetes or, if nondiabetic, in those patients with obesity. A trend toward increased insulin assessments in the SCIP noncompliant group suggests that 1 uniform IIP for all patients may not be effective. By not requiring the reporting of hypoglycemia, SCIP may inadvertently be exposing patients to harm. (*Population Health Management* 2012;15:309–314)

Introduction

Hyperglycemia has been shown to be deleterious to critically ill patients.[1] Various studies have shown a direct relationship between hyperglycemia and infection, need for renal replacement therapy, ventilatory support, blood transfusion, and mortality in both the short and long term.[2–4] More specifically, in postoperative cardiac surgery patients, elevated blood glucose (BG) has been linked to increased incidence of deep sternal wound infections, all-cause infection and sepsis, and mortality.[5–9]

As a result of the convincing data on the benefits of glycemic control in postoperative cardiac surgery patients and in an effort to improve adherence to evidence-based guidelines, the Surgical Care Improvement Project (SCIP) established reporting of 6 AM BG levels on postoperative days (POD) 1 and 2 for all cardiac surgery patients, requiring values of ≤200 mg/dL for compliance.[10–12] In an effort to meet SCIP standards and provide better care for patients by more reliably controlling postoperative BG, many hospitals have adopted intravenous (IV) insulin infusion protocols (IIP) rather than relying on subcutaneous

[1]Hospital of the University of Pennsylvania, Philadelphia, PA.
[2]Thomas Jefferson University Hospital, Philadelphia, PA.
[3]Johns Hopkins University, Baltimore, MD.
[4]University of Colorado.
This research was performed at Thomas Jefferson University Hospital, Philadelphia, PA.

(SQ) insulin, as IIPs appear to more reliably control blood sugars.[13,14]

Justification for maintenance of euglycemia by SCIP centers on the relationship of hyperglycemia to morbidity and mortality.[15, 16] Interestingly, as solid as the evidence is for the benefit of postoperative euglycemia in open heart surgery patients, there appears no evidence that 2 randomly chosen morning blood sugars reflect this degree of glycemic control. To this point, the specific SCIP metric reported herein is based on a theoretical relationship not addressed by the literature.

Our university hospital cardiac surgical program found itself able to uniformly meet all SCIP reported metrics at the top 10% of hospitals in the country except for BG control, for which it was inexplicably at the 50th percentile. Confounded by this, the authors hypothesized that the mediocre performance resulted from a failure to strictly implement our IIP; specifically, that its utilization was inconsistent and BG assessments were not performed at the required frequency. Secondly, given that the reporting of 6 AM BG as a marker of overall glycemic control had no justification in the literature, the authors recognized that while testing that hypothesis, they had the opportunity to address the question of whether the SCIP metric of 6 AM BG was, in fact, reflective of overall glycemic control during the early postoperative period. They specifically hoped that this single-center study might generate further hypotheses and research on this subject and the subject of reported metrics in general.

Methods

Study design

The authors conducted a retrospective chart review of 140 consecutive postoperative heart surgery patients admitted to the surgical cardiac care unit in our academic, quaternary care hospital between September 1, 2007 and October 1, 2008. Patients qualifying for the study had postoperative orders for our hospital's IIP. Patients were excluded if they were not receiving insulin IV on POD 1 at 6 AM, as the primary purpose of the study was to examine the reasons patients on an IIP might fail to meet the SCIP metric. Furthermore, patients who died prior to POD 2 or who had missing descriptive data were excluded. This resulted in 99 eligible patients upon whom this study was based. The change in the insulin infusion rate determined by the IIP algorithm involved both real-time BG level and the change in BG from the previous hour. We used the capillary blood glucose sample reported in the medical record for all data analysis as (*a*) SCIP utilizes this manner of glucose measurement for its report, and (*b*) as stated above, our protocolized insulin adjustments are based on this measurement. BG was targeted at 80—140 mg/dL. The decision to transition to insulin SQ on POD 1 was determined by the attending. The insulin SQ regimen for each patient was based on the quantity of insulin that the patient received over the immediately previous euglycemic period, and followed the guidelines of the American Diabetes Association.[17]

Evaluation of SCIP 6 AM BG POD 1 and 2 as a surrogate of euglycemia

To evaluate the appropriateness of using "6 AM BG on POD 1 and 2" as a surrogate for glycemic control, the authors compared the SCIP compliant group (Group 1, defined as those patients with BG ≤ 200 mg/dL at 6 AM on both POD 1 and 2) to the SCIP noncompliant group (Group 2, defined as those patients with BG >200 mg/dL at 6 AM on either POD 1 or 2). They examined each group's average BG over the measured 48-hour period, the number of episodes of BG >200 mg/dL, the percent time with BG >200 mg/dL, and performed a linear regression analysis to relate each patient's 6 AM BG with his or her average BG over the course of the study period. The BG measurement taken closest to 6 AM was used as the 6 AM BG, per the SCIP definition.

Total time of BG monitoring was defined as the first 48 postoperative hours, beginning with the time of the first BG check on POD 0. Time with BG >200 mg/dL (hyperglycemic) was determined such that if 1 BG measure was >200 mg/dL and the next measure was BG ≤ 200 mg/dL, the entire time between measurements was viewed as hyperglycemic; when a BG was not hyperglycemic followed by one that was, that interim period was viewed as not hyperglycemic. Hyperglycemic time was expressed as a percent of the total time of BG monitoring. The authors additionally counted both the number of hypoglycemic and hyperglycemic episodes, defined as any BG <70 mg/dL and BG >200 mg/dL, respectively. However, if a patient met the requirements for a hypoglycemic or hyperglycemic episode, adjacent noneuglycemic values did not count as separate episodes (ie, multiple adjacent BG >200 mg/dL values did not count as separate episodes).

Factors associated with SCIP compliance

Baseline patient and postoperative characteristics were compared for Groups 1 and 2. The Fisher exact test was used to compare categorical variables; continuous variables were compared using the Kruskal-Wallis test.

Potential risk factors of SCIP noncompliance included age, obesity, sex, epinephrine infusion, history of diabetes mellitus (DM), intensity of implementation of the IIP, defined as number of assessments of the insulin infusion rate per hour, and switching to insulin SQ prior to 6 AM on POD 2. Logistic regression was used to evaluate the relationship between SCIP noncompliance and these potential risk factors. Additionally, we compared those patients who transitioned to insulin SQ prior to 6 AM on POD 2 versus those who remained on the IIP through 6 AM on POD 2.

As a point of clarification, the number of BG assessments per hour while on the IIP was used as a marker for intensity of IIP implementation. If a patient had 10 assessments over 20 hours, the intensity of IIP implementation would be 0.5; the intensity of IIP implementation for a patient with 20 assessments in 20 hours would be 1.0.

Significance was determined by a P value < 0.05 by univariate and multivariate analyses. Statistical analyses were performed using SAS software, version 9.1 (SAS Institute Inc, Cary, NC).

This study was approved by each organization's Institutional Review Board.

Results

Group 1 comprised 79 patients. There were 20 patients in Group 2: 10 had BG >200 mg/dL on POD 1 only, 9 had BG >200 mg/dL on POD 2 only, and 1 patient was hyperglycemic both mornings. Among the approximately

Table 1. Blood Glucose Characteristics of Study Groups

	*Group 1: SCIP compliant**	*Group 2: SCIP noncompliant**	P *value*
Average BG over 48 hours	146 (15.7)	186 (42.6)	< 0.0001
Percent time with BG > 200 mg/dL	7 (10.0)	36 (13.9)	< 0.0001
Number of episodes of BG > 200 mg/dL	0.9 (1.0)	2.4 (1.2)	< 0.0001

*mean (Std Dev).
BG, blood glucose; SCIP, Surgical Care Improvement Project.

5000 BG checks measured in this study, there were 18 episodes of hypoglycemia (BG < 70 mg/dL) in 15 patients, although no patient was symptomatic of hypoglycemia.

Blood glucose characteristics of study groups

Group 1 had a lower overall mean BG compared to group 2, a lower mean BG on the IIP (147 mg/dL vs. 193 mg/dL), a lower percent time in a hyperglycemic state, and fewer episodes of hyperglycemia over the measured 48-hour period ($P \leq 0.0001$ for all) (Table 1).

Furthermore, POD 1 and 2 BG were reliable metrics reflective of overall BG in that a patient's mean BG over the 48-hour study period was related to his POD 1 or 2 BG by linear regression (BG mean = 0.94 [6 AM BG POD 1], BG mean = 0.96 [6 AM BG POD 2]; $P < 0.0001$).

Factors associated with SCIP noncompliance

Both the univariate and multivariate analyses show that Groups 1 and 2 were similar regarding age, sex, and receipt of epinephrine infusion (Table 2). By univariate analysis, switching to insulin SQ was a risk factor for noncompliance. Group 2 switched to insulin SQ prior to 6 AM on POD 2 more frequently (85%) compared to group 1 (61%) ($P = 0.05$). Even more striking, no patient maintained on insulin IV through 6 AM on POD 2 had a BG > 200 mg/dL that morning. Specifically, 34 of 34 patients on the IIP were SCIP compliant on POD 2, whereas only 55 of 65 patients who had switched to insulin SQ were compliant on POD 2 ($P = 0.01$). Also by univariate analysis, DM and obesity were significant risk factors for SCIP noncompliance ($P = 0.003$ and $P = 0.04$, respectively). Of the patients with diabetes in the study, only 63% were SCIP compliant compared to 89% of nondiabetics. Finally, in that the intensity of IIP implementation was not different between groups, SCIP noncompliance was not the result of provider inattention. In fact, the trend was for more assessments in the noncompliant group. (Group 1: 0.62 assessments/hour; Group 2: 0.72 assessments/hour; $P = 0.25$).

By multivariate analysis, obesity ceased to be a predictor of SCIP noncompliance, but DM and switching to insulin SQ continued to be. Of note, by stepwise multivariate analysis, if DM was not present, obesity then became a significant risk factor. As with the univariate analysis, switching to insulin SQ prior to 6 AM on POD 2 continued to be a risk factor for SCIP noncompliance. As already indicated, every patient maintained on insulin IV was compliant on POD 2.

Discussion

The evidence of the benefit of glycemic control in postoperative cardiac surgery patients has been consistent.[5,7–9,18,19] In these studies, glycemic control has led to improved outcomes when BG has been kept in the 150–170 mg/dL range as compared to >200 mg/dL. Coincident with these findings regarding BG and postoperative wound infections, it has become apparent that protocols and checklists that "force" physician behavior reduce medical errors and improve quality of care,[20–23] and many hospitals have instituted insulin-glucose algorithms to good effect.[24–33] However, our experience in instituting an IIP was less successful; in particular, as evidenced by our inability to consistently meet the SCIP metric of BG ≤ 200 mg/dL on POD 1 and 2 at 6 AM. We initially hypothesized that erratic implementation of our IIP, which aimed for a BG of < 140 mg/dL, was responsible for our inability to dependably prevent hyperglycemia. To the contrary, our findings showed that poor BG control in the SCIP noncompliant group occurred in the face of a trend toward an increased number of BG assessments. A variety of published studies appear to mirror our experience; specifically, one uniform IIP is not effective for all patients,[34–36] and when it fails, it fails in patients with diabetes.[37]

The data also showed that all instances of noncompliance on POD 2 were in patients on insulin SQ, while every patient on insulin IV on POD 2 was compliant, regardless of risk

Table 2. Predictors of SCIP Noncompliance, Univariate and Multivariate Models

Measurement	*Univariate Odds Ratio (95% CI)* P *value*	*Multivariate Odds Ratio (95% CI)* P *value*
Age, continuous	1.003 (0.95–1.06) 0.9	1.035(0.97–1.10) 0.29
Male	1.74 (0.53–5.77) 0.36	2.304 (0.53–9.94) 0.21
Obese	2.88 (1.03–8.00) 0.04	3.025 (0.84–10.90) 0.07*
DM	4.81 (1.70–13.64) 0.003	4.926 (1.32–18.42) 0.003
Epi	1.03 (0.38–2.74) 0.96	0.706 (0.17–2.89) 0.58
Switched to Ins SQ prior to 6 AM POD 2	3.66 (0.99–13.53) 0.05	17.140 (2.77–105.96) 0.03
IIP intensity (checks/hour)	0.44 (0.1–71.10) 0.09	0.132 (0.02–0.78) 0.56

*By stepwise multivariate analysis, in the absence of DM, obesity is a significant risk factor for SCIP noncompliance with an odds ratio 3.27, 95% confidence interval (CI) 1.05 – 10.18, $P = 0.04$.
DM, diabetes mellitus; Epi, epinephrine infusion; IIP, insulin infusion protocol; Ins, insulin, SCIP, Surgical Care Improvement Project; SQ, subcutaneous.

factors. Interestingly, 9 of the 10 noncompliant patients on POD 2 had diabetes and the nondiabetic patient was obese. It seems clear from this study that transitioning patients with DM or obesity to insulin SQ prior to POD 2 is ill advised if hyperglycemia is to be avoided.

Although picking a moment in time to report BG measurement makes perfect sense as a metric hospitals could be expected to report, the SCIP utilization of 6 AM POD 1 and 2 BG as a surrogate for overall glycemic control is without supporting evidence.[15,16] Our paper is the first of which we are aware to document the association between this SCIP metric and overall glycemic control. It also is interesting to remark that while individual 6 AM BGs were highly correlated with an individual patient's mean BG, the 6 AM value is consistently *higher than* the mean BG (BG mean = 0.94 [6 AM BG POD 1], BG mean = 0.96 [6 AM BG POD 2]; $P < 0.0001$). In that the 6 AM time point represents a BG that is higher than the patient's mean, it becomes a more sensitive measure for glycemic control. Further support of this SCIP metric as reflective of hyperglycemia is illustrated by the fact that during the first 2 postoperative days, almost 40% of the time Group 2 patients were hyperglycemic. Prior studies have not looked at this metric,[2, 5] but we found it striking that the duration of hyperglycemia was so different between the 2 groups.

Finally, we would like to highlight an issue of significant importance that is ignored by the SCIP guidelines. By targeting a lower blood sugar, SCIP may inadvertently be increasing the incidence of hypoglycemia. In this study, 15 patients experienced BG <70 mg/dL, the vast majority (80%) of whom were in the SCIP compliant group. In the recent NICE-SUGAR Study, which targeted a tightly controlled BG of 80-110 mg/dL, investigators reported a hypoglycemia rate of 6.8% (BG <40 mg/dL),[38] with an increased mortality in that group related solely to the deaths in the hypoglycemic subpopulation. Thus, while it is true that hyperglycemia in postoperative cardiac surgery patients increases morbidity and mortality, it is also clear that tight BG control puts patients at risk for hypoglycemia, with its own associated morbidity and mortality.[39–41] We contend that SCIP should require concurrent reporting of hypoglycemia, an unintended consequence of BG control, as it is at least of equal if not more importance to patient outcomes than hyperglycemia. Although none of our patients experienced hypoglycemia to the degree seen in the NICE-SUGAR Study, virtually all of the patients who experienced BG <70 mg/dL fell in the SCIP compliant group. Aiming for SCIP compliance may inadvertently make hypoglycemia an issue for this population, and safeguarding against that by requiring its report is advisable.

We would be remiss if we did not acknowledge that SCIP metrics have become an indicator of hospital performance for all of us who care for surgical patients.[42] Adherence to SCIP metrics is now viewed as synonymous with quality of care.[16, 43] Publicly reporting compliance with SCIP guidelines on Web sites such as Hospital Compare.org[43] is designed to help consumers make choices regarding hospitals. Viewed in this manner, compliance with SCIP metrics has become much more than simply an attempt to diminish postoperative wound infections or other complications, but a way for our hospitals to assure the public that they are being well served. The choice of metrics required by SCIP for public reporting is arguably even more important, when viewed in this manner, as they no longer simply reflect perioperative care but are much more far-reaching.

The authors recognize that a weakness of this study is its size and retrospective design. Furthermore, recent data show the capillary blood glucose sample may not perfectly correlate with serum glucose levels.[44,45] Yet, the findings are significant and striking, and we feel accurately reflect the problems hospitals face in carrying out glucose control for cardiac surgery patients in the early postoperative period. Furthermore, during the analysis of this study, we recognized that by emphasizing only control of hyperglycemia, SCIP may be fostering unwanted, unmeasured morbidity in this population. Future investigation should continue to examine improved tools to prevent hyperglycemia in postoperative patients, but with the caveat that we must simultaneously determine to what degree hypoglycemia occurs as a result.

Conclusion

This study shows that a single uniform IIP may not be effective to treat all intensive care unit patients, particularly postoperative cardiac surgery patients with DM and obesity. Furthermore, transition to insulin SQ should not occur prior to POD 2, especially in those 2 classes of patients, as they represent the highest risk for SCIP noncompliance. Finally, whether by luck or by design, 6 AM BG on POD 1 and 2 significantly correlates with postoperative hyperglycemia (BG >200 mg/dL) as measured by mean BG, percent time >200 mg/dL, and number of episodes >200 mg, supporting its use as a marker for glycemic control. Nevertheless, it is apparent that the SCIP focus on hyperglycemia, while ignoring the incidence of hypoglycemic events, may have unintended, deleterious consequences. In this respect, our study points out the need for continued assessment of publicly reported metrics, to critically evaluate them as adequate surrogates for quality of care, assuring that adherence to them is without unintended, adverse consequences.

Author Disclosure Statement

Drs. Whitman, Gilson, Campfield, Haddad, and Whitman, and Ms. Murphy and Ms. Moxey disclosed no conflicts of interest.

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References

1. Inzucchi SE. Clinical practice. Management of hyperglycemia in the hospital setting. N Engl J Med. 2006;355:1903–1911.
2. van den Berghe G, Wouters P, Weekers F, et al. Intensive insulin therapy in the critically ill patients. N Engl J Med. 2001;345:1359–1367.
3. Krinsley JS. Association between hyperglycemia and increased hospital mortality in a heterogeneous population of critically ill patients. Mayo Clin Proc. 2003;78:1471–1478.
4. Malmberg K. Prospective randomised study of intensive insulin treatment on long term survival after acute myocardial infarction in patients with diabetes mellitus. DIGAMI (diabetes mellitus, insulin glucose infusion in acute myocardial infarction) study group. BMJ. 1997;314:1512–1515.

5. Furnary AP, Zerr KJ, Grunkemeier GL, Starr A. Continuous intravenous insulin infusion reduces the incidence of deep sternal wound infection in diabetic patients after cardiac surgical procedures. Ann Thorac Surg. 1999;67:352–360, discussion 360–362.
6. Furnary AP, Wu Y, Bookin SO. Effect of hyperglycemia and continuous intravenous insulin infusions on outcomes of cardiac surgical procedures: the Portland diabetic project. Endocr Pract. 2004;10(suppl 2):21–33.
7. Zerr KJ, Furnary AP, Grunkemeier GL, Bookin S, Kanhere V, Starr A. Glucose control lowers the risk of wound infection in diabetics after open heart operations. Ann Thorac Surg. 1997;63:356–361.
8. Hruska LA, Smith JM, Hendy MP, Fritz VL, McAdams S. Continuous insulin infusion reduces infectious complications in diabetics following coronary surgery. J Card Surg. 2005;20:403–407.
9. Golden SH, Peart-Vigilance C, Kao WH, Brancati FL. Perioperative glycemic control and the risk of infectious complications in a cohort of adults with diabetes. Diabetes Care. 1999;22:1408–1414.
10. The Joint Commission. Surgical care improvement project core measure set. Available at: http://www.jointcommission.org/assets/1/6/Surgical%20Care%20Improvement%20Project.pdf. Accessed December 12, 2011.
11. Berwick DM. A user's manual for the IOM's "quality chasm" report. Health Aff (Millwood). 2002;21:80–90.
12. Berwick DM, Calkins DR, McCannon CJ, Hackbarth AD. The 100,000 lives campaign: setting a goal and a deadline for improving health care quality. JAMA. 2006;295:324–327.
13. Kanji S, Singh A, Tierney M, Meggison H, McIntyre L, Hebert PC. Standardization of intravenous insulin therapy improves the efficiency and safety of blood glucose control in critically ill adults. Intensive Care Med. 2004;30:804–810.
14. Vogelzang M, Loef BG, Regtien JG, et al. Computer-assisted glucose control in critically ill patients. Intensive Care Med. 2008;34:1421–1427.
15. Institute for Healthcare Improvement. Glycemic control goal. Available at: http://www.ihi.org/knowledge/Pages/Measures/GlycemicControlGoal.aspx. Accessed March 1, 2011.
16. QualityNet. Benchmarks of care. Available at: http://www.qualitynet.org/dcs/ContentServer?c=Page&pagename=QnetPublic%2FPage%2FQnetTier2&cid=1228768205297. Accessed March 1, 2011.
17. American Diabetes Association. Standards of medical care in diabetes–2009. Diabetes Care. 2009;32(suppl 1):S13–S61.
18. Furnary AP, Gao G, Grunkemeier GL, et al. Continuous insulin infusion reduces mortality in patients with diabetes undergoing coronary artery bypass grafting. J Thorac Cardiovasc Surg. 2003;125:1007–1021.
19. Lazar HL, Chipkin SR, Fitzgerald CA, Bao Y, Cabral H, Apstein CS. Tight glycemic control in diabetic coronary artery bypass graft patients improves perioperative outcomes and decreases recurrent ischemic events. Circulation. 2004;109:1497–1502.
20. Whitman G, Cowell V, Parris K, et al. Prophylactic antibiotic use: hardwiring of physician behavior, not education, leads to compliance. J Am Coll Surg. 2008;207:88–94.
21. Gawande A. The checklist: if something so simple can transform intensive care, what else can it do? New Yorker. 2007 Dec 10:86–101.
22. Trussell J, Gerkin R, Coates B, et al. Impact of a patient care pathway protocol on surgical site infection rates in cardiothoracic surgery patients. Am J Surg. 2008;196:883–889, discussion 889.
23. Haynes AB, Weiser TG, Berry WR, et al. A surgical safety checklist to reduce morbidity and mortality in a global population. N Engl J Med. 2009;360:491–499.
24. Zimmerman CR, Mlynarek ME, Jordan JA, Rajda CA, Horst HM. An insulin infusion protocol in critically ill cardiothoracic surgery patients. Ann Pharmacother. 2004;38:1123–1129.
25. Avanzini F, Marelli G, Donzelli W, et al. Hyperglycemia during acute coronary syndrome: a nurse-managed insulin infusion protocol for stricter and safer control. Eur J Cardiovasc Nurs. 2009;8:182–189.
26. Barth MM, Oyen LJ, Warfield KT, et al. Comparison of a nurse initiated insulin infusion protocol for intensive insulin therapy between adult surgical trauma, medical and coronary care intensive care patients. BMC Emerg Med. 2007;7:14.
27. He W, Zhang TY, Zhou H, et al. Impact of intensive insulin therapy on surgical critically ill patients. Zhonghua Wai Ke Za Zhi. 2007;45:1052–1054.
28. Goldberg PA, Sakharova OV, Barrett PW, et al. Improving glycemic control in the cardiothoracic intensive care unit: clinical experience in two hospital settings. J Cardiothorac Vasc Anesth. 2004;18:690–697.
29. Braithwaite SS, Edkins R, Macgregor KL, et al. Performance of a dose-defining insulin infusion protocol among trauma service intensive care unit admissions. Diabetes Technol Ther. 2006;8:476–488.
30. Goldberg PA. Memoirs of a root canal salesman: the successful implementation of a hospital-wide intravenous insulin infusion protocol. Endocr Pract. 2006;12(suppl 3):79–85.
31. Osburne RC, Cook CB, Stockton L, et al. Improving hyperglycemia management in the intensive care unit: preliminary report of a nurse-driven quality improvement project using a redesigned insulin infusion algorithm. Diabetes Educ. 2006;32:394–403.
32. Taylor BE, Schallom ME, Sona CS, et al. Efficacy and safety of an insulin infusion protocol in a surgical ICU. J Am Coll Surg. 2006;202:1–9.
33. Braithwaite SS. Inpatient insulin therapy. Curr Opin Endocrinol Diabetes Obes. 2008;15:159–166.
34. Kee CA, Tomalty JA, Cline J, Novick RJ, Stitt L. Change in practice patterns in the management of diabetic cardiac surgery patients. Can J Cardiovasc Nurs. 2006;16:20–27.
35. Lecomte P, Foubert L, Nobels F, et al. Dynamic tight glycemic control during and after cardiac surgery is effective, feasible, and safe. Anesth Analg. 2008;107:51–58.
36. McMullin J, Brozek J, McDonald E, et al. Lowering of glucose in critical care: a randomized pilot trial. J Crit Care. 2007;22:112–1188, discussion 118–119.
37. Rady MY, Johnson DJ, Patel BM, Larson JS, Helmers RA. Influence of individual characteristics on outcome of glycemic control in intensive care unit patients with or without diabetes mellitus. Mayo Clin Proc. 2005;80:1558–1567.
38. NICE-SUGAR Study Investigators; Finfer S, Chittock DR, Su SY, et al. Intensive versus conventional glucose control in critically ill patients. N Engl J Med. 2009;360:1283–1297.
39. Egi M, Bellomo R, Stachowski E, et al. Hypoglycemia and outcome in critically ill patients. Mayo Clin Proc. 2010;85:217–224.
40. Gamble JM, Eurich DT, Marrie TJ, Majumdar SR. Admission hypoglycemia and increased mortality in patients

hospitalized with pneumonia. Am J Med. 2010;123: 556.e11–556.e16.
41. Umpierrez GE, Smiley D. Time-dependent glycemic variability and mortality in critically ill patients with diabetes. Crit Care Med. 2011;39:211–213.
42. Bratzler DW. The surgical infection prevention and surgical care improvement projects: promises and pitfalls. Am Surg. 2006;72:1010–1016, discussion 1021–1030, 1133–1148.
43. US Department of Health & Human Services. Hospital compare. Available at: http://www.hospitalcompare.hhs.gov. Accessed March 1, 2011.
44. Kanji S, Buffie J, Hutton B, et al. Reliability of point-of-care testing for glucose measurement in critically ill adults. Crit Care Med. 2005;33:2778–2785.
45. Scott MG, Bruns DE, Boyd JC, Sacks DB. Tight glucose control in the intensive care unit: are glucose meters up to the task? Clin Chem. 2009;55:18–20.

Address correspondence to:
Dr. Isaac R. Whitman
Hospital of the University of Pennsylvania
3400 Spruce Street
Office of Internal Medicine, 100 Centrex
Philadelphia, PA 19104

E-mail: iwhitman@gmail.com