PAPER

# Postoperative Hyperglycemia and Surgical Site Infection in General Surgery Patients

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**Hypothesis:** Postoperative hyperglycemia is an independent risk factor for postoperative surgical site infection (SSI).

**Design:** Retrospective medical record review.

**Setting:** Academic tertiary referral center.

**Patients:** A total of 2090 general and vascular surgery patients in an institutional quality improvement database between November 1, 2006, and April 30, 2009.

**Main Outcome Measure:** Postoperative SSI.

**Results:** Postoperative glucose levels were available for 1561 patients (74.7.0%), of which 803 (51.4%) were obtained within 12 hours of surgery. The significant univariate predictors of SSI in general surgery patients were increasing age, emergency status, American Society of Anesthesiologists physical status classes P3 to P5, operative time, more than 2 U of red blood cells transfused, preoperative glucose level higher than 180 mg/dL (to convert to millimoles per liter, multiply by 0.0555), diabetes mellitus, and postoperative hyperglycemia. On multivariate adjustment, increasing age, emergency status, American Society of Anesthesiologists classes P3 to P5, operative time, and diabetes remained significant predictors of SSI for general surgery patients. After adjustment for postoperative glucose level, all these variables ceased to be significant predictors of SSI; only incremental postoperative glucose level remained significant. Subanalysis revealed that a serum glucose level higher than 140 mg/dL was the only significant predictor of SSI (odds ratio, 3.2; 95% confidence interval [CI], 1.4-7.2) for colorectal surgery patients. Vascular surgery patients were 1.8 times (95% CI, 1.3-2.5 times) more likely to develop SSI than were general surgery patients. Operative time and diabetes mellitus were the only significant univariate predictors of SSI among vascular surgery patients, and postoperative hyperglycemia was not associated with SSI.

**Conclusions:** Postoperative hyperglycemia may be the most important risk factor for SSI. Aggressive early postoperative glycemic control should reduce the incidence of SSI.

*Arch Surg. 2010;145(9):858-864*

POSTOPERATIVE SURGICAL SITE infection (SSI) is a well-known cause of morbidity in the United States.[1,2] It is the third most common nosocomial infection, and it accounts for 14% to 17% of all hospital-acquired infections.[1,3] In surgery patients, SSI is the most common nosocomial infection (38%).[2,4,5] Studies[4,6-8] have shown that these infections prolong the hospital length of stay after surgery, increase rehospitalization rates, and dramatically increase the use of emergency services and health care costs.

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*See Invited Critique at end of article*

It has been well established that patients with diabetes mellitus are more prone to surgical and other nosocomial infections.[9-11] Although the mechanism by which diabetes predisposes to SSI is not well understood, hyperglycemia has been proposed as a causative factor for the higher infection rates in diabetic patients.[11] Hyperglycemia has also been shown to be associated with increased morbidity and mortality rates in nondiabetic patients.[12,13]

Intensive insulin therapy is common in cardiac and surgical intensive care units (ICUs), often with the goal of maintaining capillary glucose levels between 80 and 110 mg/dL (to convert to millimoles per liter, multiply by 0.0555). This improved glycemic control during the first 48 hours after surgery has been shown to reduce SSIs in cardiovascular surgery and surgical ICU patients.[14-16] This reduction in SSIs seems to be independent of preoperative glycemic control. The benefit of glycemic control has been shown to be stronger and more consistent in diabetic patients.[11]

We recently analyzed data from 129 909 general surgery and colorectal surgery patients in the nationwide American College of Surgeons' National Surgical Quality Improvement Program (ACS-NSQIP) database and found that patients with diabetes had increased rates of SSI.[17] The present study was undertaken to determine whether the presence of perioperative hyperglycemia, independent of the presence of preexisting diabetes, is associated with an increased incidence of SSI.

## METHODS

Data for this study were abstracted from the ACS-NSQIP database.[18] Albany Medical Center, Albany, New York, is a 630-bed tertiary care hospital that participates in the ACS-NSQIP. The program provides participating hospitals with data for the purposes of quality improvement. The study sample included data from patients who underwent general or vascular surgery at Albany Medical Center between November 1, 2006, and April 30, 2009. The details of the ACS-NSQIP sampling methods, data abstraction process, and variables collected have been described elsewhere.[18,19] Briefly, the program collects data on preoperative risk factors, intraoperative variables, and 30-day postoperative mortality and morbidity outcomes for patients undergoing major surgical procedures. Data are collected and uploaded electronically to the ACS-NSQIP database by each site's surgical clinical reviewer using a variety of methods, including medical record abstraction. The sampling strategy requires hospitals to report their first 40 consecutive eligible cases on an 8-day cycle. Each subsequent cycle starts on a different day of the week to capture a variety of cases and surgeons and to minimize bias in case selection. General and vascular surgery patients were identified using the surgical subspecialty variable. In general surgery, colorectal surgery patients were identified using the following *Current Procedural Terminology* codes: 44140, 44141, 44143 to 44147, 44150 to 44153, 44155, 44156, 44160, 44204 to 44208, 44210 to 44212, 44239, 45110 to 45116, 45119 to 45121, 45123, 45395, 45397, 45499, and 45550. Colorectal procedures were open or laparoscopic and included partial or complete removal of the colon or rectum. This study was limited to patients 16 years or older at the time of admission. The ACS-NSQIP does not require collection of information on the preoperative, intraoperative, or postoperative blood glucose level or its management. Therefore, information on preoperative and postoperative blood glucose levels was abstracted via medical record review by a medical student (J.L.) and a research nurse (S.L.B.). After data were abstracted from the ACS-NSQIP database, they were supplemented with information on postoperative serum glucose levels and the time of blood sample collection in the 48 hours after surgery.

The study sample was a randomized selection of noncolorectal general surgery and vascular surgery patients from all available patients (n=3129) during the previously mentioned period. Colorectal surgery patients were oversampled for statistical precision. Data from 2090 randomly selected patients were abstracted and were supplemented with postoperative glucose information from medical records. The study sample included all colorectal surgery patients from the specified period. Postoperative serum glucose information was available for 1561 patients (74.7%), of which 803 (51.4%) were obtained within 12 hours of the end of surgery. Postoperative glucose values were determined for 776 noncolorectal general surgery patients, 559 vascular surgery patients, and 226 colorectal surgery patients.

Postoperative infection was the primary outcome of interest and was defined as a postoperative occurrence of a superficial, deep incisional or organ space SSI. Dependent variables were selected based on a previous analysis of data from 129 000 patients in the 2005-2006 ACS-NSQIP participant user data file. The risk factors and potential confounders assessed for this study included age at hospital admission (16-40, 41-60, or >60 years), sex, race/ethnicity (white, black, Hispanic, other, or unknown), diabetes mellitus, emergency vs elective surgery, the most recent preoperative serum glucose level within 3 months of surgery, the patient's preoperative status as indicated by the American Society of Anesthesiologists (ASA) physical status classification (P1 through P5 indicating none to mild systemic disease through life-threatening to moribund systemic disease) and the number of red blood cell (RBC) units given intraoperatively (≤2 or >2 U), operative time, and first postoperative serum glucose level. Preoperative serum glucose levels were available within 7 days of the operation date for 90% of the study population.

Risk factors were determined separately for general and vascular surgery patients. A subanalysis of general surgery patients to determine risk factors for colorectal surgery patients was also conducted. For bivariate analysis, *t* tests and simple logistic regression were used to estimate and compare the unadjusted risk of infection across exposure categories. Variables significant at the .20 level were fitted into the multiple logistic regression model. Variables significant at the .05 level were retained in the final models. For risk of SSI associated with operative time, intraoperative time risk was estimated using odds ratios for every 10-minute increase in operative time. If postoperative glucose level was found to be significant during bivariate analysis, a multivariate model that excluded adjustment for postoperative serum glucose level was determined first. Postoperative glucose level was then added to the model to assess whether the variables exerted their effect on SSI via postoperative serum glucose level. Separate analyses were conducted for general (n=1002) and vascular (n=559) surgery patients. A subanalysis of 226 colorectal surgery patients in the general surgery group was also conducted. The effects of the significant risk factors on postoperative serum glucose levels were also determined separately via bivariate analysis of risk factors and postoperative serum glucose levels, with the latter as the dependent variable dichotomized at a cutoff value of 140 mg/dL.

## RESULTS

The overall SSI rate in the study sample was 7.42%. Infection rates were significantly higher for colorectal (14.11%) and vascular (10.32%) surgery patients than for noncolorectal general surgery patients (4.36%) ($P<.001$ for both). Colorectal surgery patients were 3.6 times (95% confidence interval [CI], 2.3-5.7 times) and vascular surgery patients were 2.5 times (1.7-3.7 times) more likely to develop an SSI than were noncolorectal general surgery patients.

### GENERAL SURGERY

Bivariate analysis revealed that compared with patients with a first postoperative glucose level of 110 mg/dL or less, the likelihood of getting an SSI increased progressively for patients with higher serum glucose levels (**Table 1**). The incidence of SSI ranged from 1.8% in the 110 mg/dL or less category to 17.7% in the greater than 220 mg/dL category (Table 1). The likelihood increased from 3.61 times (95% CI, 1.22-10.67 times) in patients with a first postoperative serum glucose level in the 111 to 140 mg/dL range to 12.13 times (3.71-39.64

**Table 1. Effect of Various Risk Factors on the Odds of Postsurgical Infection in General Surgery Patients**

| Variable | SSI, % | OR (95% CI) | | |
|---|---|---|---|---|
| | | Unadjusted | Adjusted | |
| | | | Without Serum Glucose Level | With Serum Glucose Level |
| Postoperative serum glucose, mg/dL | | | | |
| ≤110 | 1.8 | 1 [Reference] | NM | 1 [Reference] |
| 111-140 | 6.1 | 3.61 (1.22-10.67) | NM | 3.61 (1.22-10.67) |
| 141-180 | 10.0 | 6.26 (2.17-18.17) | NM | 6.26 (2.17-18.17) |
| 181-220 | 9.5 | 5.92 (1.73-20.22) | NM | 5.92 (1.73-20.22) |
| >220 | 17.7 | 12.13 (3.71-39.64) | NM | 12.13 (3.71-39.64) |
| Age, y | | | | |
| 16-40 | 3.1 | 1 [Reference] | 1 [Reference] | NM |
| 41-60 | 5.8 | 1.91 (1.09-3.33) | 1.60 (0.89-2.88) | NM |
| ≥61 | 8.7 | 2.95 (1.69-2.12) | 2.12 (1.15-3.90) | NM |
| ASA physical status class | | | | |
| None to mild (P1/P2) | 3.8 | 1 [Reference] | 1 [Reference] | NM |
| Severe (P3) | 6.7 | 1.80 (1.18-2.74) | 1.07 (0.67-1.73) | NM |
| Life-threatening to moribund (P4/P5) | 14.6 | 4.29 (2.39-7.71) | 2.08 (1.07-4.03) | NM |
| Emergency | | | | |
| No | 5.3 | 1 [Reference] | 1 [Reference] | NM |
| Yes | 9.3 | 1.84 (1.22-2.80) | 2.09 (1.30-3.36) | NM |
| Operative time[a] | | 1.05 (1.04-1.07) | 1.05 (1.04-1.07) | NM |
| Diabetes mellitus | | | | |
| No | 5.3 | 1 [Reference] | 1 [Reference] | NM |
| Yes | 11.2 | 2.26 (1.44-3.55) | 1.80 (1.12-2.90) | NM |
| Preoperative serum glucose, mg/dL | | | | |
| ≤110 | 5.0 | 1 [Reference] | | |
| 111-140 | 6.1 | 1.24 (0.1-2.53) | NM | NM |
| 141-180 | 5.3 | 1.08 (0.38-3.12) | NM | NM |
| 181-220 | 23.3 | 5.87 (2.38-14.44) | NM | NM |
| >220 | 15.4 | 3.51 (1.16-10.63) | NM | NM |
| Intraoperative RBC transfusion, U | | | | |
| ≤2 | 5.7 | 1 [Reference] | NM | NM |
| >2 | 23.5 | 5.11 (2.26-11.54) | NM | NM |

Abbreviations: ASA, American Society of Anesthesiologists; CI, confidence interval; NM, not in the model; OR, odds ratio; RBC, red blood cell; SSI, surgical site infection.

SI conversion factor: To convert glucose to millimoles per liter, multiply by 0.0555.

[a] Odds ratios presented are for every 10-minute increase in operative time.

times) in patients with serum a glucose level higher than 220 mg/dL (Table 1).

Increasing age, higher ASA class, emergency surgery, diabetes, more than 2 U of intraoperative RBCs transfused, preoperative serum glucose level higher than 180 mg/dL, and increasing operative time were the other significant unadjusted risk factors for SSI (Table 1). The risk did not vary significantly by race or sex.

A multivariate model that included all the significant variables except postoperative serum glucose level revealed that intraoperative RBC transfusion and preoperative serum glucose level were not independent predictors of SSI. Patients with ASA classes P4 and P5 (life-threatening to moribund systemic disease) but not class P3 (severe systemic disease) were significantly more likely than were those with ASA classes P1 and P2 (none to mild systemic disease) to acquire a postoperative SSI (Table 1). The adjusted odds ratios for all the significant risk factors were similar to but slightly lower than the unadjusted odds ratios.

After adjustment for postoperative serum glucose level in the previous multivariate model, all the risk factors ceased to be significant predictors of SSI. Postoperative glucose level was, therefore, the single most important risk factor for SSI in general surgery patients. The effect of postoperative glucose level on SSI in general surgery patients was, therefore, the same as the unadjusted effect (Table 1).

## COLORECTAL SURGERY

Subanalysis of colorectal surgery patients in the general surgery group revealed that a postoperative serum glucose level higher than 140 mg/dL was the only significant predictor of SSI for colorectal surgery patients. The incidence of infection in colorectal surgery patients with postoperative serum glucose levels higher than 140 mg/dL (20.6%) was 3.2 times (95% CI, 1.4-7.2 times) that of those with serum glucose levels of 140 mg/dL or less (7.6%).

## VASCULAR SURGERY

Bivariate analysis revealed that postoperative serum glucose level was not significantly associated with the likelihood of postoperative SSI in vascular surgery patients

**Table 2. Effect of Various Risk Factors on the Odds of Postsurgical Infection in Vascular Surgery Patients**

| Variable | SSI, % | OR (95% CI) Unadjusted | OR (95% CI) Adjusted |
|---|---|---|---|
| Postoperative serum glucose, mg/dL | | | |
| ≤110 | 13.2 | 1 [Reference] | NM |
| 111-140 | 8.3 | 0.60 (0.30-1.23) | NM |
| 141-180 | 11.2 | 0.83 (0.40-1.74) | NM |
| 181-220 | 11.1 | 0.83 (0.31-2.22) | NM |
| >220 | 20.0 | 1.65 (0.70-3.89) | NM |
| Age, y | | | |
| 16-40 | 6.45 | 1 [Reference] | NM |
| 41-60 | 11.06 | 1.80 (0.40-8.04) | NM |
| ≥61 | 9.61 | 1.54 (0.36-6.58) | NM |
| ASA physical status class | | | |
| None to mild (P1/P2) | 9.00 | 1 [Reference] | NM |
| Severe (P3) | 9.79 | 1.10 (0.53-2.27) | NM |
| Life-threatening to moribund (P4/P5) | 10.27 | 1.16 (0.51-2.60) | NM |
| Emergency | | | |
| No | 9.61 | 1 [Reference] | NM |
| Yes | 11.28 | 1.20 (0.67-2.14) | NM |
| Intraoperative RBC transfusion, U | | | |
| ≤2 | 9.83 | 1 [Reference] | NM |
| >2 | 9.72 | 0.99 (0.44-2.21) | NM |
| Preoperative serum glucose, mg/dL | | | |
| ≤110 | 11.1 | 1 [Reference] | NM |
| 111-140 | 8.3 | 0.72 (0.34-1.55) | NM |
| 141-180 | 10.9 | 0.99 (0.42-2.32) | NM |
| 181-220 | 10.7 | 0.97 (0.28-3.35) | NM |
| >220 | 16.2 | 1.56 (0.62-3.97) | NM |
| Operative time[a] | | 1.07 (1.05-1.09) | 1.06 (1.04-1.08) |
| Diabetes mellitus | | | |
| No | 7.72 | 1 [Reference] | 1 [Reference] |
| Yes | 15.36 | 2.17 (1.44-3.28) | 1.84 (1.20-2.82) |

Abbreviations: ASA, American Society of Anesthesiologists; CI, confidence interval; NM, not in the model; OR, odds ratio; RBC, red blood cell; SSI, surgical site infection.

SI conversion factor: To convert glucose to millimoles per liter, multiply by 0.0555.

[a] Odds ratios presented are for every 10-minute increase in operative time.

(**Table 2**). The rates of SSI were relatively high across all categories of serum glucose level, ranging from 13.2% in the lowest category (≤110 mg/dL) to 20.0% in patients with serum glucose levels higher than 220 mg/dL (Table 2). None of the predictors of SSI in general surgery patients except operative time and diabetes were associated with SSI in vascular surgery patients (Table 2). After adjustment for significant variables, the likelihood of SSI in vascular surgery patients increased by 6% (95% CI, 4%-8%) for every 10-minute increase in operative time (Table 2). Compared with nondiabetic patients, diabetic patients were 1.84 times (95% CI, 1.20-2.82 times) more likely to develop SSI in vascular surgery patients.

## COMMENT

The rates of SSI for various surgical subspecialties in this study are similar to those reported in other studies.[1,20,21]

**Table 3. Bivariate Effect of Risk Factors[a] on the Likelihood of Postoperative Hyperglycemia[b] in General Surgery Patients**

| Variable | OR (95% CI) | *P* Value |
|---|---|---|
| Age, y | | |
| 16-40 | 1 [Reference] | |
| 41-60 | 1.39 (0.99-1.95) | .06 |
| ≥61 | 1.84 (1.29-2.61) | .001 |
| ASA physical status class | | |
| None to mild (P1/P2) | 1 [Reference] | |
| Severe (P3) | 2.05 (1.55-2.70) | <.001 |
| Life-threatening to moribund (P4/P5) | 2.00 (1.21-3.31) | .007 |
| Emergency | | |
| No | 1 [Reference] | |
| Yes | 1.56 (1.13-2.15) | .007 |
| Intraoperative RBC transfusion, U | | |
| ≤2 | 1 [Reference] | |
| >2 | 3.19 (1.30-7.81) | .01 |
| Operative time, 10 min/U | 1.05 (1.03-1.07) | <.001 |
| Diabetes mellitus | | |
| No | 1 [Reference] | |
| Yes | 4.28 (2.83-6.46) | <.001 |

Abbreviations: ASA, American Society of Anesthesiologists; CI, confidence interval; OR, odds ratio; RBC, red blood cell.

[a] Significant risk factors for surgical site infection in the multivariate model without adjusting for postoperative serum glucose level.

[b] Defined as a serum glucose level greater than 140 mg/dL (to convert to millimoles per liter, multiply by 0.0555).

Without accounting for postoperative glucose level, the risk factors and their respective effects were similar to those reported in earlier studies by other authors and our own analysis of a larger multihospital ACS-NSQIP data set.[17,21] However, after accounting for postoperative serum glucose level, all the risk factors ceased to be significant predictors of SSI. For general surgery patients, we assessed the association of each risk factor with postoperative glucose level in a separate crude bivariate analysis. The analysis shows that all the independent risk factors for SSI, before adjusting for postoperative serum glucose level (Table 1), were associated with an increased likelihood of postoperative serum glucose levels (**Table 3**). For colorectal surgery patients, postoperative serum glucose level was the only significant risk factor in bivariate and multivariate analyses. This might be owing to the few colorectal surgery patients in this study. Vascular surgery patients were more than 2 times more likely to develop an SSI compared with noncolorectal general surgery patients and 1.8 times (95% confidence interval, 1.3-2.5 times) more likely compared with all general surgery patients. The likelihood of SSI in vascular surgery patients was unaffected by the same risk factors as for general surgery patients, including postoperative serum glucose level. The likelihood of infection was positively associated with operative time in vascular and general surgery patients (**Figure**).

In a landmark study in 2001, van den Berghe et al[22] showed that aggressive treatment of postoperative hyperglycemia in the surgical ICU significantly reduced rates of infection, morbidity and mortality, and 1-year survival. However, their study population consisted mainly of cardiac surgery patients. Studies have largely focused on the

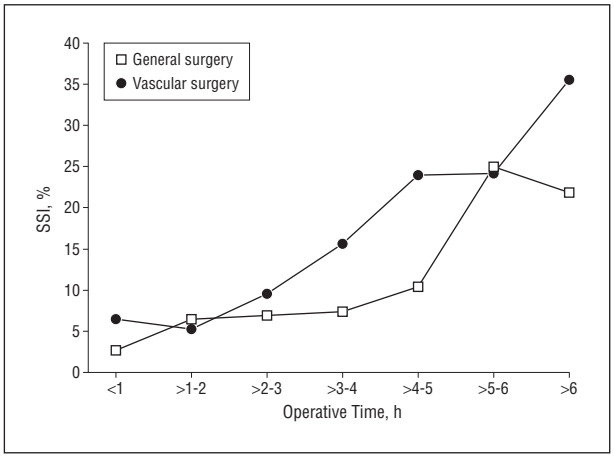


**Figure.** Effect of operative time on the likelihood of surgical site infection (SSI) in all general surgery patients (n=2059) and vascular surgery patients (n=1070).

cardiac population or post–cardiac surgery infections because up to a quarter of the patients undergoing cardiac surgery have diabetes, and postoperative infections in this subpopulation are associated with high mortality rates as well.[14-16,23] A retrospective study[24] of diabetic patients who had cardiac surgery showed that increased mean glucose levels for the first 2 days after surgery was an independent risk factor for deep sternal wound infection. The same group[25] showed in a prospective study of 2467 diabetic patients undergoing cardiac surgery that postoperative hyperglycemia was associated with deep sternal wound infection. An indirect association was demonstrated by showing that tight glycemic control via a continuous insulin infusion leads to a 66% reduction in deep sternal wound infections.[25] A prospective study[13] of nondiabetic cardiac patients undergoing coronary artery bypass graft surgery also demonstrated an increased incidence of mediastinitis in nondiabetic patients with postoperative hyperglycemia. The present study confirms the previous findings in noncardiac general surgery patients. In a subanalysis of nondiabetic patients, we found increasing postoperative glucose levels to be significantly associated with the risk of SSI, and the dose-response relationship was also similar.

Although the American Diabetes Association and the American Association of Clinical Endocrinologists recommend maintaining random serum glucose values of 180 mg/dL or less in the perioperative period for all noncardiovascular surgical procedures, there is less evidence supporting the association between hyperglycemia and SSI after noncardiac operations or in non-ICU patients.[26] A recent meta-analysis[27] of 5 randomized controlled trials found insufficient evidence to support strict glycemic control (glucose level <200 mg/dL) over conventional management for the prevention of SSI. Most studies of general surgery patients have had small sample sizes, resulting in inconclusive results, and few studies have specifically examined the relationship between the level of hyperglycemia and SSI in general surgery patients.[28-31] In a prospective randomized study, Grey and Perdrizet[32] reported a reduction in nosocomial infections in general surgery ICU patients using strict glycemic control. With the finding of relatively higher mortality in the group with a blood glucose target of 81 to 108 mg/dL in the NICE-SUGAR (Normoglycemia in Intensive Care Evaluation–Survival Using Glucose Algorithm Regulation) trial, the benefits of strict glycemic control remain controversial.[33] The study, however, focused on medical and surgical ICU patients.

In a retrospective study of patients undergoing infrainguinal vascular surgery, Vriesendorp et al[30] found that postoperative hyperglycemia was associated with increased postoperative infections. The association weakened in patients with type 2 diabetes mellitus after correcting for postoperative glucose level.[30] The same authors[29] found conflicting results in another retrospective study of 151 ASA class P1 and P2 patients undergoing esophagectomy. They found no associations among postoperative glucose level, insulin administration, and infection. A randomized trial[28] of the effect of intensive insulin therapy on the infection rate in 78 patients undergoing intracerebral aneurysm clipping after subarachnoid hemorrhage showed reduced infection rates in the intensive therapy arm. In a study of 100 diabetic patients undergoing elective abdominal or cardiac surgery, Pomposelli et al[31] demonstrated that the infection rates were more than 2 times higher in hyperglycemic patients compared with those with postoperative serum glucose values less than 220 mg/dL. A recent study[34] of diabetic colorectal surgery patients found that serum glucose levels higher than 200 mg/dL in the initial 48 hours after surgery were independently associated with increased SSI rates.

In the present study, the disappearance of the effect of all the risk factors on SSI after adjusting for postoperative glucose level suggests that the effect of other risk factors may be exerted via alteration of serum glucose levels. Although we may speculate that hyperglycemia may be the cause of the increased SSI rate, it is also possible that the accumulation of the other well established SSI risk factors lead to hyperglycemia. Treating hyperglycemia, therefore, might not necessarily reduce the risk of SSI. However, it is commonly accepted that hyperglycemia affects the immune system via impaired chemotaxis, phagocytosis, and the production of reactive oxygen species.[35] There is also evidence that insulin itself has anabolic, anti-inflammatory, anticoagulant, and antiapoptotic activities.[36-38]

The present treatment algorithm for patients with postoperatively identified hyperglycemia is to begin basal insulin glargine (Lantus; Sanofi-Aventis US, Bridgewater, New Jersey) therapy once daily or basal neutral protamine Hagedorn every 12 hours at a dose of 0.2 to 0.3 U/kg/d rounded to the nearest unit subcutaneously. Glargine is a long-acting basal insulin analogue with a longer duration of action (approximately 24 hours) than NPH (approximately 18 hours). Postoperatively, capillary blood glucose measurements are obtained every 6 hours, and the dose of basal insulin (or insulin analogue) is adjusted to achieve glucose levels that are consistently less than 180 mg/dL. The use of "sliding scale insulin" (or "rapid-acting insulin analogues") is discouraged. This study shows that the SSI rates for general surgery patients increase dramatically to 10% at postopera-

tive serum glucose levels of 140 mg/dL and higher. In colorectal surgery patients, 140 mg/dL was also the cutoff value for increased SSI rates. Based on the results of this study, a revised protocol targeted at achieving glucose levels less than 140 mg/dL will be considered for a future prospective study.

This study was limited by the fact that the patients were from a single hospital, and the results, therefore, need to be verified by larger, prospective, multiple-hospital studies. Also, the first postoperative serum glucose value was available within 12 hours for only 51.3% of the study population and within 24 hours for 96.0% of the patients. The results should, therefore, be interpreted with caution.

In conclusion, we found postoperative hyperglycemia to be the most important independent risk factor for SSI in general and colorectal surgery patients, and serum glucose levels higher than 110 mg/dL were associated with increasingly higher rates of postsurgical infection. If hyperglycemia is confirmed in future prospective studies with better postoperative glucose data to be an independent risk factor for postsurgical infection in general surgery patients, this would give surgeons a modifiable variable to reduce the incidence of postoperative infection.

**Accepted for Publication:** May 24, 2010.
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**Author Contributions:** *Study concept and design:* Ata and Stain. *Acquisition of data:* Lee, Bestle, and Stain. *Analysis and interpretation of data:* Ata, Lee, Desemone, and Stain. *Drafting of the manuscript:* Ata. *Critical revision of the manuscript for important intellectual content:* Ata, Lee, Bestle, Desemone, and Stain. *Statistical analysis:* Ata. *Obtained funding:* Stain. *Administrative, technical, and material support:* Lee, Bestle, Desemone, and Stain. *Study supervision:* Desemone and Stain.
**Financial Disclosure:** None reported.
**Previous Presentation:** This paper was presented at the 81st Annual Meeting of the Pacific Coast Surgical Association; February 14, 2010; Kapalua, Hawaii; and is published after peer review and revision.

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**INVITED CRITIQUE**

# Role of Hyperglycemia in SSIs

## *Postoperative Hyperglycemia and SSI in General Surgery Patients*

Diabetes mellitus has been thought to represent a risk factor for several types of surgical complications, as well as SSI, but is perceived to be beyond our control. The article by Ata et al dispels the notion that diabetes gives us risk we cannot manage and adds to the recent literature[1] that suggests that hyperglycemia is the issue to be controlled to reduce SSI rates.

However, various shortcomings need to be addressed as the science of understanding and controlling SSI proceeds. First, this article shows an association, not causation, between postoperative hyperglycemia and SSI. Striking is the failure to find the association in vascular surgery patients, who presumably have the highest rates of diabetes and had higher rates of SSI than did general and colorectal surgery patients. This leads one to wonder whether factors such as hemoglobin $A_{1C}$ level, nutrition, tobacco use, obesity, operative time, and tissue perfusion/oxygenation may be more powerful factors in the equation. Efforts are also under way to culture postoperative infections to understand whether current prophylaxis is inadequate for today's bacteria.

Being a retrospective study using data extracted from the ACS-NSQIP database leads to other weaknesses in the data. Only 74.7% of patients had any postoperative glucose data, and only 51.4% of those were obtained in the first 12 hours. Much of these data came from the following morning's routine laboratory tests, thus there is quite a variance as to when glucose monitoring began, how it was performed, and when, or even if, attempts at glycemic control began. Although diabetic patients were more likely than nondiabetic patients to develop an SSI in vascular patients, it may have been this lack of uniformity in postoperative care that led to the inability to correlate infection with postoperative hyperglycemia.

This work supports 3 important conclusions. First, postoperative hyperglycemia is not benign and is independently associated with SSI in general and colorectal surgery patients. With a better study design, such conclusions will likely be shown in vascular surgery patients as well. Second, this relationship is linearly related to infection such that the higher the postoperative glucose level, the higher the infection risk. Third, a glucose level less than 140 mg/dL is the threshold that should be achieved to minimize the risk of SSI. These 3 principles will form the foundation for future work in this area. This group's work also stimulates us to consider techniques with more effective glycemic control, such as the liberal use of insulin glargine.

Succeeding work will need to focus on preoperative, intraoperative, and postoperative glucose control; techniques for glucose management; and in which patients such efforts are necessary. Of course, this is one of a myriad of factors that we as surgeons can investigate to reduce SSI rates. Inspiring leaders such as Dr Stain and colleagues are to be congratulated for showing that surgeons can be the drivers for surgical quality improvement on an individual and system level.

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**Financial Disclosure:** None reported.

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