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Perioperative Hyperglycemia and Risk of Adverse Events Among Patients With and Without Diabetes

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Abstract

Objective—To study the association between diabetes status, perioperative hyperglycemia, and adverse events in a statewide surgical cohort.

Background—Perioperative hyperglycemia may increase the risk of adverse events more significantly in patients without diabetes (NDM) than in those with diabetes (DM).

Methods—Using data from the Surgical Care and Outcomes Assessment Program, a cohort study (2010–2012) evaluated diabetes status, perioperative hyperglycemia, and composite adverse events in abdominal, vascular, and spine surgery at 53 hospitals in Washington State.

Results—Among 40,836 patients (mean age, 54 years; 53.6% women), 19% had diabetes; 47% underwent a perioperative blood glucose (BG) test, and of those, 18% had BG \geq 180 mg/dL. DM

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patients had a higher rate of adverse events (12% vs 9%, $P < 0.001$) than NDM patients. After adjustment, among NDM patients, those with hyperglycemia had an increased risk of adverse events compared with those with normal BG. Among NDM patients, there was a dose-response relationship between the level of BG and composite adverse events [odds ratio (OR), 1.3 for BG 125–180 (95% confidence interval (CI), 1.1–1.5); OR, 1.6 for BG ≥ 180 (95% CI, 1.3–2.1)]. Conversely, hyperglycemic DM patients did not have an increased risk of adverse events, including those with a BG ≥ 180 (OR, 0.8; 95% CI, 0.6–1.0). NDM patients were less likely to receive insulin at each BG level.

Conclusions—For NDM patients, but not DM patients, the risk of adverse events was linked to hyperglycemia. Underlying this paradoxical effect may be the underuse of insulin, but also that hyperglycemia indicates higher levels of stress in NDM patients than in DM patients.

Keywords

adverse events; diabetes; hyperglycemia; insulin; perioperative care

Hyperglycemia in patients with diabetes (DM) who undergo surgery is associated with increased rates of surgical site infection (SSI), myocardial infarction, stroke, and death.^{1–15} Hyperglycemia also occurs in up to two thirds of surgical patients who are not known to have diabetes, and its impact has not been well characterized in surgical patients without diabetes (NDM).¹⁶ Recent observational studies have demonstrated an increased risk of complications associated with hyperglycemia in NDM patients when compared with DM patients. Kwon et al¹⁷ found that NDM patients who had perioperative hyperglycemia had nearly twice the risk of infections, reoperative interventions, and in-hospital deaths as DM patients and hyperglycemia. Frisch et al¹⁸ found an increased risk of 30-day mortality associated with hyperglycemia for NDM patients when compared with those with diabetes.

These recent studies suggest a paradox: that a disease known for complications related to hyperglycemia may have a lower risk of postsurgical complications in the setting of hyperglycemia than in people without diabetes. There are several possible mechanisms to explain this observation. The higher rate of complications among NDM patients may reflect a more extreme inflammatory and stress response that causes a NDM patient to have the same level of hyperglycemia as a DM patient. This increased stress level may be the reason for the increased rate of complications in NDM patients, with hyperglycemia serving as a marker rather than a cause of the problem. Second, the increased risk of complications in NDM patients may be the result of underdiagnosis of diabetes that is revealed in the surgical setting. Third, it may reflect undertreatment of perioperative hyperglycemia with insulin in NDM patients. It is also possible that the lower risk of adverse events among DM patients who have postoperative diabetes is indicative of insulin being poorly tolerated in patients who have not previously been exposed to it. Finally, the lower risk may reflect a form of adaptation associated with more chronic exposure to hyperglycemia.

Understanding the mechanism by which NDM patients have an increased risk of complications has important implications for quality improvement activities related to preoperative assessment of diabetes status and management of postoperative hyperglycemia. To evaluate this paradox and explore possible mechanisms, we undertook an observational

study of the association between perioperative hyperglycemia, insulin use, and adverse events in a statewide surgical cohort.

METHODS

Study Population and Setting

The Surgical Care and Outcomes Assessment Program (SCOAP) is a physician-led quality improvement collaborative that began in 2006 and now includes 55 hospitals in Washington State. Data are collected from medical records by trained abstractors. This study was a retrospective review of patients undergoing general surgery, bariatric surgery, vascular surgery, and spine operations between 2010 and 2012. These dates were selected as the same covariates were collected in each of the SCOAP modules (general, vascular, and spine) during this time period. Patients were excluded from the analysis if they did not undergo blood glucose (BG) testing in the perioperative period. Data from 53 of 55 Washington State hospitals currently participating in SCOAP were available at the time of this analysis. Research projects using deidentified SCOAP data are exempted from review by the University of Washington institutional review board.

Data Characteristics

Clinical Risk Factors—Demographic information, clinical comorbidities, and operative details were abstracted from the clinical record using standardized definitions. Patient diabetes status, weight, smoking status, history of coronary artery disease, history of hypertension, cancer as indication for surgery, and American Society of Anesthesiologists' (ASA) class were available. Patients are classified as having diabetes if they have a medical history of diabetes, as identified in the medical record at the time of admission for the index operation, including review of documentation from emergency department visits, previous primary care visits, surgical clinic visits, and anesthesia documentation. DM patients are subsequently divided into 2 categories, based on whether or not they use insulin at home.

Type/Method of Operation

General surgery, bariatric surgery, vascular surgery, and spine procedures were included in the cohort. General surgery procedures included appendectomies, colon operations, and bariatric operations. Colon operations included right, transverse, and left hemicolectomy, low anterior resection, abdominoperineal resection, total abdominal colectomy, stoma takedown, perineal proctectomy, and abdominal proctectomy. Bariatric operations included laparoscopic and open Rouxen-Y gastric bypass, laparoscopic gastric band placement, sleeve gastrectomy, biliopancreatic bypass with and without duodenal switch, vertical banded gastroplasty, and revision of gastric bypass. Vascular surgery procedures included carotid, aortic, and infrainguinal vascular procedures. Spine operations included cervical and lumbar fusion, corpectomy, discectomy, laminectomy, dural repair, and laminoplasty. Method of operation was identified as laparoscopic or open and as elective or nonelective. The number of hours in the operating room was also recorded.

Hyperglycemia and Insulin Use

SCOAP collects information on the highest BG level at 2 different time periods: perioperatively (including intraoperative time period, and first 24 hours postoperatively), and between 24 and 48 hours postoperatively. Abstractors identify the highest BG within the immediate perioperative period, and between 24 and 48 hours postoperatively, from both finger checks and laboratory tests. In addition, any episodes of hypoglycemia are recorded. On the basis of the highest BG perioperatively, patients were categorized into 3 groups: normal BG (< 125 mg/dL), mildly elevated BG (125–180 mg/dL), and high BG (> 180 mg/dL). In addition, patients with perioperative hyperglycemia are classified on the basis of whether they have persistent hyperglycemia (> 180 mg/dL) on repeat BG check between 24 and 48 hours postoperatively (based on the recommendation of American Diabetes Association that random BG levels be managed to below 180 mg/dL). With regard to insulin use, a binary classification is used to identify individuals as receiving perioperative insulin or not receiving perioperative insulin. Patients are considered to have received insulin if they are given insulin at any time point during the postoperative period.

Outcome Measures

A composite adverse event metric was used as the primary outcome. This overall composite metric was divided into cardiac adverse events, noncardiac adverse events, and death. This framework has previously been used for evaluation of adverse events in a surgical cohort.¹⁹ Adverse events were based on in-hospital postoperative events. The cardiac adverse event metric included myocardial infarction, stroke or transient ischemic attack, and atrial arrhythmia requiring treatment. The noncardiac adverse event metric included readmission to the intensive care unit or unplanned intensive care unit stay, fall with injury requiring surgery, infectious complications (*Clostridium difficile* infection, SSI requiring treatment, pneumonia requiring treatment, urinary tract infection requiring treatment, wound reopening, or debridement), renal insufficiency or initiation of dialysis, reintubation, percutaneous drainage of an abscess, and any reoperative intervention.

Analytic Methods

Demographic and clinical characteristics were compared among patients with and without diabetes both in the entire patient cohort and in the cohort of patients who underwent BG test who make up the study cohort. Characteristics were summarized using frequency distributions for categorical variables and means and standard deviations for continuous variables. Categorical variable comparisons were evaluated for significance using the Pearson χ^2 test. Continuous variable comparisons were evaluated for significance using *t* tests.

The overall adverse event rate and death, cardiac, and noncardiac adverse event rates were compared between patients with and without diabetes. Perioperative insulin administration was compared between patients with and without diabetes, stratified by perioperative BG level. The association between perioperative hyperglycemia and composite adverse events was then evaluated in patients with and without diabetes, adjusting for potential confounders using multivariate logistic regression. Potential confounders included age, sex, race, insurance status, type and method of surgery, operative time, ASA class, comorbidities,

smoking status, home medications, and elective or emergent operation classification. Type of surgery was included in regression model in a discrete fashion. Sensitivity analyses were conducted for cardiac adverse events, noncardiac adverse events, and death.

RESULTS

There were 40,836 patients who underwent general, bariatric, vascular, and spine operations between 2010 and 2012. Within this cohort, 19% had a diagnosis of diabetes mellitus, 47% had a perioperative BG test, and of those, 18% had perioperative hyperglycemia (40% of DM patients, 6% of NDM patients; Fig. 1). A total of 6595 DM patients and 12,663 NDM patients underwent BG testing in the perioperative period, and these patients make up the study cohort. Clinical and demographic characteristics of the cohort are described in Table 1.

Perioperative Insulin Use

Perioperative insulin administration was compared between patients with and without diabetes, stratified by level of perioperative hyperglycemia (Fig. 2). At each level of BG, DM patients were significantly more likely to receive insulin than NDM patients ($P < 0.001$). We evaluated the effectiveness of correction of hyperglycemia (to < 180 mg/dL) after initial hyperglycemia among patients with and without diabetes. Among all patients who had perioperative hyperglycemia and received insulin, those who had persistent hyperglycemia had significantly higher adverse event rates than those whose BG was corrected (40.3% vs 25.6% for NDM patients; 17.5% vs 8.3% for DM patients).

Overall Rate of Adverse Events

In our complete patient cohort of more than 40,000 patients, DM patients had a higher composite adverse event rate than NDM patients (12.0% vs 8.9%, $P < 0.001$). In our study cohort of patients with BG testing, we found no significant difference in the rate of adverse events between DM patients with diabetes and NDM patients (12.6% vs 12.1%, $P = 0.26$) in an adjusted analysis. This difference between the overall cohort and the study cohort suggests that NDM patients are selected for perioperative BG testing in a nonrandom way. Differences in risk characteristics are addressed in the multivariate analysis.

Risk Adverse Events Associated With Hyperglycemia

The rate of adverse events was compared by level of hyperglycemia among patients with and without diabetes (Fig. 3). Among DM patients, those with hyperglycemia did not have increased odds of adverse events {odds ratio [OR] = 0.76 [95% confidence interval (CI), 0.57–1.0, $P = 0.06$], for BG 125–180 mg/dL; and OR = 0.94 (95% CI 0.72–1.2; $P = 0.65$) for BG > 180 mg/dL} in an unadjusted analysis. After controlling for confounders, DM patients with a BG level between 125 and 180 mg/dL were found to have decreased odds of an adverse event [OR = 0.66 (95% CI = 0.49–0.91)] when compared with the reference group (BG < 125 mg/dL; Table 2). Patients with a BG level more than 180 mg/dL, however, had no significant difference in odds of an adverse event [OR = 0.78 (95% CI = 0.58–1.04)] when compared with the reference group.

In contrast, among NDM patients, those with hyperglycemia had significantly higher odds of a composite adverse event [OR = 2.4 (95% CI, 1.9–3.0) for BG 125–180 mg/dL; and OR = 5.1 (95% CI, 3.8–6.9) for BG > 180 mg/dL; $P < 0.001$ for both] in an unadjusted analysis. After controlling for confounders, this increased risk of complications associated with hyperglycemia for NDM patients persisted, with a dose-response relationship between the level of hyperglycemia and the odds of a composite adverse event [OR = 1.26 (95% CI, 1.08–1.47) for BG 125–180 mg/dL; OR = 1.63 (95% CI, 1.27–2.10) for BG > 180 mg/dL; Table 2]. When patients with and without diabetes were compared, the overall rates of adverse events increased in a dose-response fashion for each increasing level of hyperglycemia among NDM patients, but not for DM patients.

For both those with diabetes and those without diabetes, advanced age, patients undergoing open operations, patients with colorectal disease and patients with cancer, and patients with an increased operative time had higher odds of an adverse event. In both cohorts, patients undergoing elective operations had decreased odds of an adverse event. Patients with Medicaid had increased odds of an adverse event among DM patients but not among those without. Patients who were considered to be ASA class III, IV, and V had increased odds of an adverse event among NDM patients but not among those with diabetes. Patients with private insurance and patients undergoing carotid operations had decreased odds of an adverse event among NDM patients but not among those with diabetes.

Sensitivity Analyses

Sensitivity analyses were conducted for cardiac adverse events, noncardiac adverse events, and death. The findings from these analyses mirrored the main analysis of composite adverse events, with the exception that for cardiac adverse events and death, NDM patients did not have increased odds of adverse events for BG 125 to 180 mg/dL when compared with the reference group (< 125 mg/dL).

DISCUSSION

The results from this statewide evaluation of surgical patients demonstrate that although DM patients have a higher rate of adverse events than NDM patients overall, among those with any given level of hyperglycemia, NDM patients have higher rates of adverse events than those with diabetes. In addition, among NDM patients, there is a dose-response relationship between the level of hyperglycemia and the risk of adverse events, with higher rates at higher glucose levels. For patients—with and without diabetes alike—who have perioperative hyperglycemia, receive insulin, and still have persistent hyperglycemia, there is an even higher rate of adverse events.

The findings from this study prompt exploration of a number of theories regarding the mechanism for this diabetes paradox—that hyperglycemic NDM patients have higher odds of adverse events than those with diabetes. The first theory is that hyperglycemia in NDM patients is really a marker for increased surgical stress or severity of illness. Although we endeavored to correct for this in our multivariate model, including operation type, method (open vs minimally invasive), duration, ASA class, and other proxies for surgical stress, it is possible that some residual confounding exists. Studies have demonstrated that surgical

stress results in decreased insulin sensitivity and subsequent hyperglycemia and that this relationship is relative to the magnitude of the surgical procedure.²⁰ Given that DM patients have a baseline level of insulin resistance and hyperglycemia, it is possible that it requires lower levels of surgical stress for such patients to reach each level of hyperglycemia, or, conversely, that it requires higher levels of surgical stress for NDM patients to reach a given level of BG. In this way, hyperglycemia in those without diabetes may be an indicator of patients with greater surgical stress or severity of illness—patients who are known to be at higher risk for complications.

A second theory is that, in the perioperative setting in association with surgical stress, previously undiagnosed diabetes is revealed. Studies indicate that nearly 40% of surgical patients with perioperative hyperglycemia more than 200 mg/dL have no previous diagnosis of diabetes²¹ and that up to 60% of NDM patients with postoperative hyperglycemia and a myocardial infarction were ultimately diagnosed with diabetes.²² Preoperative HbA_{1c} or fasting BG is not currently the standard for patients without a known diagnosis of diabetes, and as such, it is not clear how many of the patients in this study had previously undiagnosed diabetes. However, if undiagnosed diabetes were the major driver of increased risk for NDM patients, it would not explain why their observed risk was higher than that of patients with a known diagnosis of diabetes.

Third, insulin treatment in the setting of perioperative hyperglycemia may be better delivered in patients with a diagnosis of diabetes. Our findings indicate that this may be true, as only 40% of NDM patients with a BG level of 180 to 250 mg/dL and 55% of those with a BG level of 250 mg/dL or more received insulin therapy in the postoperative period. This rate of insulin use by level of hyperglycemia was statistically different than rates of insulin use in DM patients (60% for BG 180–250 mg/dL and 80% for BG ≥ 250 mg/dL; $P < 0.001$). In DM patients, providers may be more likely to suspect and test for hyperglycemia and system protocols may enhance that detection as well.

A fourth theory is that insulin treatment in patients previously unexposed to insulin—NDM patients and DM patients not on home insulin—may not be well tolerated. Insulin administration, especially in the setting of acute hyperglycemia, may increase inflammation and oxidative stress through a pathway involving the potentiation of NF κ B²¹ and through an increase in IL-6 and TNF- α ,²² may worsen atherosclerosis by inducing smooth muscle cell proliferation and sterol synthesis^{23–26} and create a hypercoagulable state by increasing procoagulant factors (plasma activator inhibitor-1, tPA antigen, von Willenbrand factor, factor VII, and fibrinogen).²⁷ However, in a post hoc analysis among DM patients, we did not find that those starting new insulin during the hospitalization had increased odds of an adverse event. In addition, we observed hypoglycemia in less than 1% of the patients in our cohort.

Finally, in keeping with the idea of a paradox, whereas diabetes is a disease characterized by complications related to chronic hyperglycemia, diabetes may be “protective” for patients with hyperglycemia, as the very result of chronic exposure to elevated BG. There is experimental evidence to suggest that patients tolerate chronic hyperglycemia better than acute hyperglycemia because of conditioning. In the setting of chronic hyperglycemia,

myocytes become resistant to hypoxia-induced apoptosis and necrosis through upregulation of Bcl-2 (anti-apoptotic) and reduction of intracellular calcium.²⁸ With acute hyperglycemia, the sensitivity of myocytes to ischemia increases and this negates the beneficial effects of ischemia preconditioning.²⁹ As a result, DM patients, in the setting of chronic hyperglycemia, may have better outcomes associated with hypoxia and lower rates of myocardial ischemia. Inflammatory or oxidative preconditioning may exist as well. This form of conditioning has yet to be described in relation to immune function or tolerance of surgical stress.

In summary, there are 5 theories we posit as to why NDM patients have higher observed odds of adverse events associated with perioperative hyperglycemia: (1) hyperglycemia is a marker for greater surgical stress or severity of illness; (2) previously undiagnosed diabetes is revealed in the setting of surgical stress; (3) insulin therapy is better delivered in patients with a known diagnosis of diabetes; (4) insulin administration is associated with potential harm and inflammation in previously insulin-naive patients; and (5) DM patients may have an adaptation to hyperglycemia. Our group is currently engaged in ongoing studies to explore the plausibility of the first, second, and fifth theories. Our current research suggests that—at the very least—the third theory is true and that administration of insulin for NDM patients is a target for quality improvement. We do not find any evidence in our results to suggest that the fourth theory—positing potential harm from insulin in insulin-naive patients—is true.

This study must be interpreted in the context of its limitations. First, the major limitation is the retrospective nature of the analysis and missing information in our data set. Given that NDM patients do not routinely undergo fasting BG, preoperative HbA_{1c}, or even post-operative BG testing, it is difficult to make clear conclusions about the mechanism of increased risk. It is possible that our findings may just reveal previously undiagnosed diabetes, although this does not explain increased odds of adverse events compared with DM patients. Only 38% of NDM patients underwent a perioperative BG test, and as a result, confounding by indication may play a role in our findings. We attempted to adjust for this as best we could in multivariate models, including both demographic and clinical factors, such as age, sex, weight, comorbidities, smoking status, and home medications in our models. However, some residual confounding may exist. In addition, among DM patients, limited information on diabetes status was available, including the duration since diagnosis and current home medication regimens. We also did not have information on the type of insulin (dose or continuous infusion vs basal bolus vs sliding scale) used in-hospital.

CONCLUSIONS

This study confirms and expands upon previously reported findings regarding the impact of perioperative hyperglycemia in NDM patients. We demonstrate a dose-response relationship between hyperglycemia and adverse events, suggesting that NDM patients may fare worse with postoperative hyperglycemia. Further prospective studies are needed to help clarify the mechanism of increased risk and to determine whether or not hyperglycemia among NDM patients is, in fact, a marker for increased surgical stress or undiagnosed diabetes. A clearer

understanding of the risk of hyperglycemia for surgical NDM patients has profound implications for future management of hyperglycemia in a perioperative setting.

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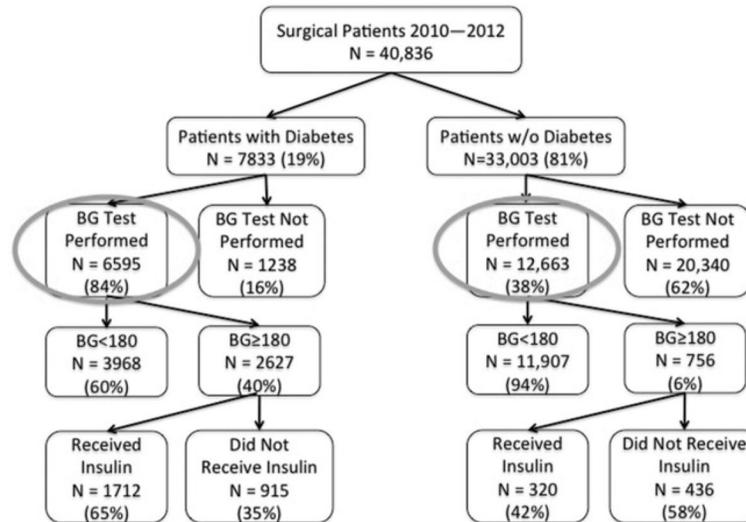


FIGURE 1. Flow diagram (ovals indicate patients who comprise the study cohort).

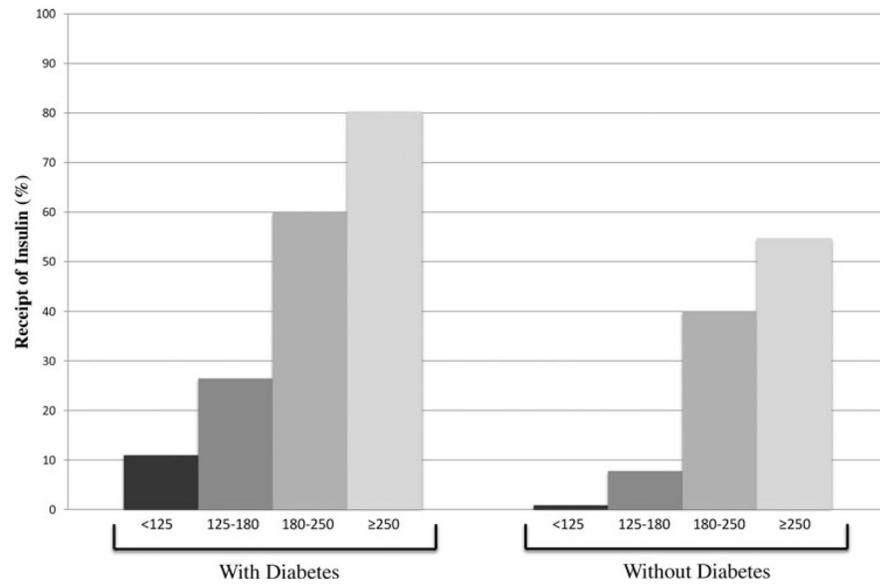


FIGURE 2. Receipt of insulin, by glucose level. Differences were statistically significant between patients at different levels of hyperglycemia for both patients with and without diabetes.

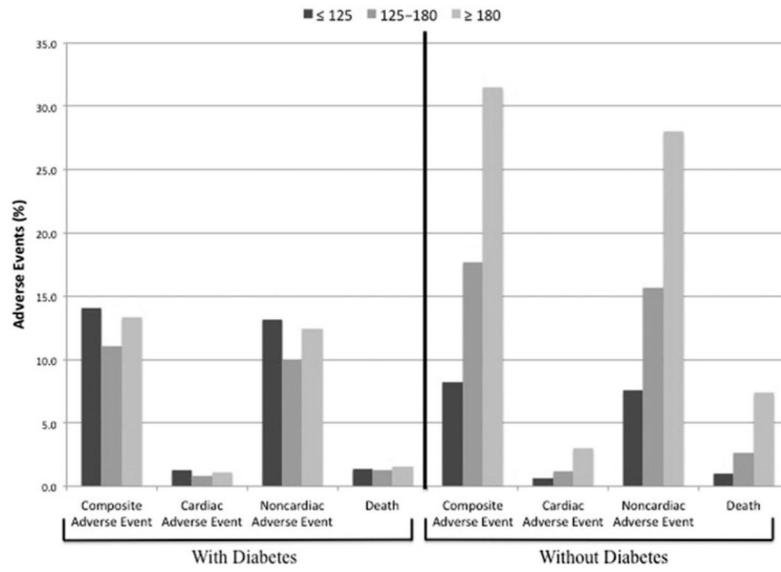


FIGURE 3.
Adverse events, by diabetes status and postoperative glucose level.

TABLE 1

Cohort Characteristics By Diabetes Status and BG Test

	All Patients (N = 40,836)		Patients With BG Test (N = 19,258)		P
	Diabetes (19.2%)	No Diabetes (80.8%)	Diabetes (34.2%)	No Diabetes (65.8%)	
Number	7833	30,003	6595	12,663	
Mean age (SD)	61.9 (18.4)	52.1 (18.8)	62.0 (13.7)	52.4 (19.5)	<0.001
Sex					0.86
Male, no. (%)	3637 (46.5)	15,286 (46.3)	3080 (46.7)	6258 (49.4)	
Female, no. (%)	4193 (53.6)	17,704 (53.7)	3512 (53.3)	6399 (50.6)	
Insurance, no. (%)					
Private	4850 (62.3)	22,151 (67.8)	4148 (63.3)	8369 (66.5)	<0.001
Medicaid	1170 (15.0)	2994 (9.2)	1009 (15.4)	1263 (10.1)	<0.001
Weight, mean (SD), kg	99.5 (27.0)	85.2 (23.9)	100.4 (27.2)	84.0 (23.6)	<0.001
Race					<0.001
White, no. (%)	6384 (81.7)	26,774 (81.3)	5358 (81.4)	9960 (78.8)	
Black or African American, no. (%)	353 (4.5)	938 (2.9)	304 (4.6)	407 (3.2)	
Asian, no. (%)	247 (3.2)	1165 (3.5)	198 (3.0)	513 (4.1)	
American Indian/Alaska Native, no. (%)	110 (1.4)	270 (0.8)	91 (1.4)	122 (1.0)	
Native Hawaiian or other Pacific Islander, no. (%)	48 (0.6)	139 (0.4)	42 (0.6)	54 (0.4)	
Unknown/NA, no. (%)	675 (8.6)	3654 (11.1)	589 (9.0)	1585 (12.5)	
SCOAP module					<0.001
General, no. (%)	4980 (63.6)	25,850 (78.3)	4221 (64.0)	10,032 (79.2)	
Spine, no. (%)	655 (8.4)	3230 (9.8)	461 (7.0)	387 (3.1)	
Vascular, no. (%)	2198 (28.0)	3923 (11.9)	1913 (29.0)	2244 (17.7)	
Type of operation					<0.001
Appendectomy, no. (%)	660 (8.4)	11,409 (34.6)	495 (7.5)	5383 (42.5)	
Bariatric, no. (%)	2272 (29.0)	3750 (11.3)	2026 (30.7)	1096 (8.6)	
Colorectal, no. (%)	1895 (24.2)	9800 (29.7)	1569 (23.8)	3405 (26.9)	
Aortic, no. (%)	180 (2.3)	722 (2.2)	157 (2.4)	472 (3.7)	
Carotid, no. (%)	568 (7.2)	1149 (3.5)	503 (7.6)	610 (4.8)	
Infringuinal, no. (%)	1450 (18.5)	2052 (6.2)	1253 (19.0)	1162 (9.2)	

	All Patients (N = 40,836)			Patients With BG Test (N = 19,258)		
	Diabetes (19.2%)	No Diabetes (80.8%)	P	Diabetes (34.2%)	No Diabetes (65.8%)	P
Spine, no. (%)	655 (8.4)	3230 (9.8)		461 (7.0)	387 (3.1)	
Cancer, no. (%)	153 (2.0)	891 (2.7)		131 (2.0)	148 (1.2)	
Open procedure, no. (%)	3053 (39.0)	12,848 (39.0)	0.928	2500 (37.9)	4446 (35.1)	<0.001
Elective operation no. (%)	5450 (69.6)	17,647 (53.5)	<0.001	4613 (70.0)	5168 (40.8)	<0.001
Admission type						
Inpatient, no. (%)	7168 (91.6)	31,663 (96.0)	<0.001	6046 (91.7)	12,161 (96.1)	<0.001
Hours in OR, mean (SD)	2.3 (1.5)	1.9 (1.6)	<0.001	2.3 (1.5)	1.8 (1.5)	<0.001
Rural, no. (%)	185 (2.4)	1557 (4.7)	<0.001	142 (2.2)	528 (4.2)	<0.001
ASA class, no. (%)			<0.001			<0.001
I	75 (1.0)	5723 (17.8)		57 (0.9)	2451 (20.8)	
II	1565 (21.1)	15,308 (47.7)		1163 (18.6)	4614 (37.8)	
III	5168 (69.8)	9920 (30.9)		4517 (72.3)	4303 (35.2)	
IV	568 (7.7)	1060 (3.3)		490 (7.8)	710 (5.8)	
V	26 (0.4)	64 (0.2)		24 (0.4)	54 (0.4)	
Risk factors						
Cigarette smoking	1479 (19.0)	7378 (22.5)	<0.001	1219 (18.6)	2970 (23.6)	<0.001
Hypertension	6407 (81.8)	12,674 (38.4)	<0.001	5461 (82.8)	4956 (39.2)	<0.001
Coronary artery disease	2098 (26.8)	3046 (9.2)	<0.001	1801 (27.3)	1459 (11.5)	<0.001
Medication use						
Statin	4779 (61.0)	7127 (21.6)	<0.001	4119 (62.5)	2910 (23.0)	<0.001
β-Blocker	3161 (40.4)	5829 (17.7)	<0.001	2727 (41.4)	2459 (19.4)	<0.001
ACE inhibitor	4722 (60.3)	6737 (20.4)	<0.001	4051 (61.5)	2673 (21.1)	<0.001
Home oxygen use, no. (%)	2083 (29.1)	3792 (12.8)	<0.001	1821 (29.7)	2205 (18.0)	<0.001
Home mobility device, no. (%)	370 (7.4)	705 (2.7)	<0.001	330 (7.8)	303 (3.0)	<0.001

NA indicates not available.

TABLE 2

Multivariate Model for Risk of Composite Adverse Events Among Patients With and Without Diabetes

	Univariate		Multivariate	
	OR	95% CI	OR	95% CI
Patients with diabetes				
Age	1.03	1.02–1.04	1.02	1.01–1.02
Male sex	1.23	1.06–1.43	1.12	0.92–1.35
Perioperative insulin use	1.33	1.03–1.71	1.19	0.97–1.47
Perioperative BG				
BG 125	Ref		Ref	
125 < BG < 180	0.76	0.57–1.01	0.66	0.49–0.91
BG 180	0.94	0.72–1.23	0.78	0.58–1.04
Private insurance	0.62	0.50–0.76	0.84	0.63–1.12
Medicaid insurance	1.54	1.22–1.93	1.38	1.03–1.83
Open procedure	3.24	2.53–4.15	1.30	1.15–1.29
Type of operation (%)				
Appendectomy	Ref		Ref	
Bariatric	0.61	0.35–1.06	0.93	0.55–1.58
Colorectal	4.47	3.01–6.63	3.39	2.07–5.57
Aortic	1.90	1.24–2.91	1.03	0.55–1.92
Carotid	0.85	0.45–1.63	0.47	0.21–1.08
Infrainguinal	1.18	0.78–1.79	0.94	0.51–1.71
Spine	0.83	0.41–1.65	0.85	0.41–1.75
Cancer	2.48	1.28–4.80	2.50	1.51–4.43
ASA class				
I	Ref		Ref	
II	0.89	0.46–1.72	0.58	0.24–13.8
III	1.13	0.62–2.06	0.79	0.35–1.79
IV	3.79	2.06–6.94	1.48	0.67–3.23
V	14.17	3.93–51.03	3.21	0.87–11.8
Elective operation	0.48	0.38–0.62	0.46	0.36–0.59
Mean hours in operative room	1.26	1.17–1.36	1.22	1.15–1.29
Patients without diabetes				
Age	1.04	1.03–1.05	1.02	1.01–1.02
Male sex	1.02	0.87–1.19	1.07	0.91–1.27
Perioperative insulin use	3.62	2.28–5.74	1.28	0.99–1.64
Perioperative BG				
BG 125	Ref		Ref	
125 < BG < 180	2.39	1.89–3.03	1.26	1.08–1.47
BG 180	5.12	3.80–6.90	1.63	1.27–2.10
Private insurance	0.60	0.61–0.72	0.77	0.67–0.90
Medicaid insurance	1.77	1.46–2.15	1.16	0.93–1.45

	Univariate		Multivariate	
	OR	95% CI	OR	95% CI
Open procedure	5.45	4.53–6.55	1.73	1.44–2.08
Type of operation (%)				
Appendectomy	Ref		Ref	
Bariatric	2.06	0.87–4.94	1.17	0.61–2.26
Colorectal	12.39	9.36–16.40	3.34	2.35–4.76
Aortic	6.63	5.33–11.21	1.15	0.69–1.93
Carotid	2.21	1.54–3.16	0.42	0.29–0.61
Infrainguinal	3.24	2.27–4.61	0.92	0.62–1.37
Spine	2.86	1.71–4.78	0.81	0.46–1.43
Cancer	8.12	5.51–11.99	2.43	1.35–4.38
ASA class				
I	Ref		Ref	
II	3.62	2.50–5.23	1.38	0.96–2.00
III	9.45	6.42–13.90	2.76	1.85–4.12
IV	44.87	28.66–70.27	7.22	4.66–11.2
V	206.55	86.37–493.97	32.8	11.7–91.6
Elective operation	1.21	0.88–1.67	0.53	0.42–0.66
Mean hours in operative room	1.41	1.25–1.59	1.19	1.12–1.27

Bold values indicate statistical significance (odds ratios that do not include one).