Perioperative Hypoglycemia in Patients With Diabetes: Incidence After Low Normal Fasting Preoperative Blood Glucose Versus After Hyperglycemia Treated With Insulin

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Perioperatively, insulin to treat hyperglycemia is administered judiciously to minimize the risk of hypoglycemia. In patients with diabetes in whom preoperative blood glucose levels are on the low end of normal, hypoglycemia risk may be underestimated. This retrospective study enrolled subjects with presenting preoperative blood glucose values in these ranges: 70 to 89 mg/dL (low normal group) and above 249 mg/dL (hyperglycemia-treated group). These groups were compared for subsequent perioperative hypoglycemia development.

Subjects in the low normal group (n = 308) were older (P < .001), had increased incidence of renal disease (P = .02), and more prevalent β-blocker use (P = .02) than the hyperglycemia-treated subjects (n = 279). Accounting for differences between groups, the incidence of perioperative blood glucose levels below 70 mg/dL was greater in the low normal group than the hyperglycemia-treated group (17.2% vs 3.6%, P < .001). Of subjects whose blood glucose levels fell below 70 mg/dL, blood glucose levels dropped below 50 mg/dL in 40% of hyperglycemia-treated subjects and 4% of low normal subjects.

Perioperative hypoglycemia was likelier to develop in patients with diabetes who presented preoperatively with low normal blood glucose values than in patients treated with insulin for presenting hyperglycemia.

Keywords: Diabetes, glycemic, hypoglycemia, perioperative.

The perioperative management of glycemic control in patients with diabetes is challenging. Signs and symptoms alerting hypoglycemia are obscured in anesthetized patients. To avoid hypoglycemia during pre-procedural fasting, a downward adjustment in dose or omission of usual glucose-lowering medications is often advocated. 1,2 Surgical stress, however, has been associated with increased glucagon and decreased insulin response. 3 Although the mechanisms are unclear, isoflurane and sevoflurane for anesthesia have been associated with suppressed endogenous insulin secretion and prolonged plasma glucose disappearance. 4 Insulin sensitivity varies among individuals. 3 For these reasons, the glucose-lowering effect of exogenous insulin is difficult to predict.

There is substantial evidence linking inpatient hyperglycemia with greater morbidity and mortality. 5-9 Low glucose values have also been associated with increased hospital costs, higher likelihood of discharge to a skilled nursing facility, increased length of stay, and greater mortality. 10,11 Severe hypoglycemia may contribute to, increase vulnerability to, or be a marker of poor outcomes. 12,13 During continuous glucose monitoring, cardiac ischemia has been detected more frequently during hypoglycemia than either normoglycemia or hyperglycemia. 14 Development of spontaneous, but not iatrogenic, hypoglycemia in patients experiencing acute myocardial infarction has been linked to increased mortality. 15 In out-of-hospital settings, profound hypoglycemia has been associated with adverse neurologic sequelae, including lower IQ scores, 16 cognitive dysfunction, 17 dementia, 18 and death. 19,20 Integrated physiology studies have specified potentially harmful autonomic and immune responses to hypoglycemia. These pathologic responses include elevation of proinflammatory cytokines, 21,22 platelet activation, 22 alteration in cardiac repolarization, 23 and impairment of baroreflex sensitivity and the sympathetic response to hypotension. 24
Hypoglycemia in hospitalized patients has been attributed to decreased food intake without change in glucose-lowering medications, divergence from the usual course of care as during radiologic or surgical procedures, use of sliding-scale insulin, use of basal insulin, and severe diabetes. Unpublished data from William Beaumont Hospital, Royal Oak, Michigan (written data, 2003-2008), identified 478 patients who experienced 1 or more blood glucose values below 70 mg/dL during the perioperative period. Glucose-lowering medications were used by 91.8% of these patients. Renal disease was present in 34.5% of the cases. Of the 316 patients with recorded blood glucose values preceding the hypoglycemic value, 64.5% of the most recent preceding blood glucose values were below 100 mg/dL. Administration of rapid-acting or short-acting insulin within 6 hours before the hypoglycemic value was documented in only 7.7% of patients.

The purpose of this study was to compare the incidence of subsequent perioperative hypoglycemia between patients who had "low normal" preoperative blood glucose values and patients who received insulin for treatment of perioperative hyperglycemia. Because hypoglycemia is defined by the American Diabetes Association as blood glucose values below 70 mg/dL, we designated 70 to 89 mg/dL as the low normal range. Typically, patients with blood glucose values above 249 mg/dL, the threshold for ketoacidosis, received insulin to treat hyperglycemia at our institution. Therefore, blood glucose values above 249 mg/dL were defined as hyperglycemia in this study.

Methods
The Human Investigations Committee of Beaumont Hospitals in the Detroit, Michigan, area and the institutional review board of Oakland University, Rochester, Michigan, approved this retrospective study. The study was conducted at a 1,070-bed suburban hospital, where a team of approximately 100 anesthesiologists and Certified Registered Nurse Anesthetists staff the operating suite on a daily basis. The Remote Automated Laboratory System (RALS) was queried for blood glucose results in the range of 70 to 89 mg/dL and above 249 mg/dL from the preoperative units between 2005 and 2009. The RALS data management system connects point-of-care blood glucose results with software features, enabling institutional analyses of glycemic control.

A total of 1,569 point-of-care glucometric values were found within these 2 targeted ranges. Multiplicity in preoperative glucose testing on individual patients and improper electronic patient identification entries excluded 131 values. Twenty-four patients were also excluded because 1 of 2 preoperative blood glucose values, which had both been drawn within a 5-minute period, was not in either of the selected ranges (70-89 mg/dL or >249 mg/dL). The remaining 1,414 patient records were screened. Inclusion criteria were as follows: (1) documented diabetes diagnosis; (2) performance of 1 or more blood glucose tests during the perioperative period subsequent to the RALS result; and (3) documentation of administration of insulin during the perioperative period if RALS values exceeded 249 mg/dL.

Groups. Eligibility criteria were met by 587 subjects. Subjects were divided into 2 groups determined by their presenting preoperative blood glucose values: the low normal group and the hyperglycemia-treated group. The low normal group (n = 308) included subjects who presented with preoperative blood glucose values of 70 to 89 mg/dL. The hyperglycemia-treated group (n = 279) included subjects who presented with preoperative blood glucose values above 249 mg/dL and were subsequently treated with insulin. The perioperative period extended from arrival in the preoperative area through discharge from the postanesthesia care unit.

The low normal group and the hyperglycemia-treated group were compared for frequency of perioperative hypoglycemia, defined as blood glucose below 70 mg/dL. Hypoglycemic incidences were subsequently stratified by severity, based on blood glucose values (60-69 mg/dL, 50-59 mg/dL, and <50 mg/dL). The low normal group and the hyperglycemia-treated group were then compared for differences in severity.

Glycemic Management. Patients who arrived from home on the morning of surgery (n = 433) had been routinely instructed by the anesthesia department to (1) begin fasting after midnight and (2) on the day of surgery withhold all oral antihyperglycemic medications and injectable exenatide and pramlintide, as well as rapid-acting or short-acting insulin, insulin isophane suspension (NPH), and premixed insulin, such as 70% insulin isophane suspension/30% regular human insulin injection (Novolin 70/30) and 75% insulin lispro/25% insulin lispro suspension (Humalog Mix 75/25). Usual insulin glargine (Lantus) and insulin detemir (Levemir) doses were adjusted by the patients’ own diabetes care physicians (individualized) or the anesthesia department guidelines (80% of the patient’s usual evening dose the night before surgery and/or 50% of the usual morning dose on the day of surgery). From 2008, patients who self-reported usual fasting blood glucose values above 149 mg/dL were advised by the anesthesia department to take the usual basal insulin dose the evening before surgery. Attending physicians directed insulin administration, as needed, in hospitalized patients (n = 154) before their arrival in the preoperative area.

Our institution did not have a standardized protocol for perioperative glycemic management. Anesthesia providers administered care according to usual practice. For the hyperglycemia-treated group, insulin therapy had been initiated in the preoperative area or shortly after arrival in the operating room. Further treatment was rendered perioperatively, as judged necessary by the anesthesia provider.
Data Collection. Data were collected on demographics, anesthesia start time, presence of renal disease, and use of β-blocker medications. Diabetes type, preoperative glucose-lowering medication regimen, subsequent lowest perioperative blood glucose values, and perioperative glucose monitoring data were documented. The administration of rapid-acting or short-acting insulin, which occurred within 6 hours before the patient’s arrival in the preoperative unit, was noted. Intraoperative dextrose bolus or boluses, preexisting dextrose infusion, and initiation of dextrose infusion were recorded. The number of subcutaneous and intravenous bolus insulin doses and the total units of insulin administered were tallied for the hyperglycemia-treated group. The trend-based perioperative intravenous insulin infusion algorithm had a target blood glucose range of 100 to 150 mg/dL. When intravenous insulin infusions were administered, the total insulin dose was not ascertainable.

Blood glucose values were measured (Accu-Chek Inform gluometers, Roche, Basel, Switzerland), and quality control was checked daily on the gluometers. Using control samples, laboratory technicians had conducted semiannual correlative testing of these gluometers with hospital laboratory equipment. The gluometer used had consistently demonstrated an acceptable variance of less than 15%.

Statistical Analysis. Continuous variables were summarized using mean ± standard deviation, minimum, median, and maximum. Categorical variables were summarized using frequencies and percentages. Based on this preliminary assessment, continuous variables were analyzed using the Wilcoxon 2-sample test based on the t approximation. Similarly, categorical variables were compared between the low normal and hyperglycemia-treated groups using the Pearson $\chi^2$ test, Mantel-Haenszel $\chi^2$ test, or Fisher exact test with the unadjusted odds ratios and 95% confidence intervals, computed wherever appropriate. Multiple logistic regression analysis was used to determine the most parsimonious subset of predictors that best explained the rate of hypoglycemia in low normal and hyperglycemia-treated patients after adjusting for presence of renal disease, age, and use of β-blockers.

Adjusted odds ratios and their corresponding 95% Wald confidence intervals were also computed. P values less than an α of .05 (probability of type I error) were considered statistically significant. Statistical analysis was performed using SAS software (SAS for Windows version 9.2, SAS Institute Inc, Cary, North Carolina).

Results. Table 1 illustrates the diversity in preoperative glucose-lowering medication regimens both within and between groups. Analyses of baseline characteristics revealed that the subjects in the low normal group were older, had an increased incidence of renal disease, and had an increased use of β-blocker medications compared with the hyperglycemia-treated subjects (Table 2). In the low normal group (n = 308), 7 subjects had received subcutaneous rapid-acting or short-acting insulin within 6 hours of their arrival in the preoperative unit, and 7 subjects presented to the preoperative area with an existing intravenous insulin infusion. In the hyperglycemia-treated group (n = 279), the mean (± standard deviation) preoperative presenting blood glucose value was 324.0 ± 58.9 mg/dL (median, 317 mg/dL; range, 250-567 mg/dL). For hyperglycemia-treated subjects who were administered subcutaneous and/or intravenous insulin boluses by anesthesia providers (n = 230), the mean total insulin administered was 10.8 ± 7.7 U (median, 6 U; range, 2-40 U) and the mean number of doses was 1.6 ± 0.8 (range, 1-3 doses). Of the remaining hyperglycemia-treated subjects, 44 subjects were
managed by intravenous insulin infusions, and 5 subjects were given long-acting basal or premixed insulin to treat the preoperative blood glucose value above 249 mg/dL.

• **Primary Findings.** After statistically adjusting for age, β-blockers, renal disease, and anesthesia start time, subjects who were in the low normal group (n = 308) were more likely to develop blood glucose values below 70 mg/dL than subjects who were in the hyperglycemia-treated group (n = 279) (OR, 5.44; 95% CI, 2.68-10.99; P < .001; Table 3). Of the 53 subjects in the low normal group who experienced blood glucose values below 70 mg/dL, 3 subjects had documented receipt of 6, 7, or 14 U of rapid-acting or short-acting insulin boluses within 6 hours before their arrival in the preoperative unit, in response to blood glucose values of 318 mg/dL, 425 mg/dL, and 244 mg/dL, respectively. A separate subject in the low normal group arrived in the preoperative area from the intensive care unit with an insulin infusion titrated to 1.5 U/h.

Of subjects who became hypoglycemic (n = 63), those who were in the hyperglycemia-treated group had a higher incidence (40%) of blood glucose values below 50 mg/dL compared with the low normal group (4%) (P = .02, Mantel-Haenszel χ² test, Table 4). Both subjects with low normal blood glucose values below 50 mg/dL, however, had received insulin within 6 hours of preoperative unit arrival (Table 5). Thus, all 6 subjects experiencing blood glucose values below 50 mg/dL (range, 38-47 mg/dL) had received insulin after hyperglycemic values either before arrival in the preoperative area or perioperatively. Renal failure was present in 4 of the 6 subjects who experienced severe hypoglycemia. Table 5 illustrates additional characteristics of the subjects.

• **Secondary Findings.** In the low normal group, the development of blood glucose below 70 mg/dL was more frequent when anesthesia start times were 12 PM or later (22.6% incidence) compared with before 12 PM (12.9% incidence) (P = .02). Subjects in the low normal group who received insulin therapy preoperatively were not found to have significantly increased development of blood glucose values below 70 mg/dL compared with subjects not receiving preoperative insulin therapy (P = .33). Of this low normal group, 30.5% received a parenteral dextrose bolus or infusion for treatment of their preoperative glucose levels from 70 to 89 mg/dL. There was no significant difference with the initiation of parenteral 5% dextrose or a nondextrose intravenous fluid in the subsequent development of blood glucose below 70 mg/dL (P = .85).

Only 10 subjects (3.6% of the hyperglycemia-treated group) developed hypoglycemia below 70 mg/dL. Six subjects had been administered subcutaneous rapid-acting or short-acting insulin and/or intravenous insulin boluses, and the remaining 4 subjects had an intravenous insulin infusion. The mean lowest blood glucose value in the hyperglycemia-treated group (n = 279) was 216.5 ±

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<table>
<thead>
<tr>
<th>Factor</th>
<th>Low normal group (n = 308)</th>
<th>Hyperglycemia-treated group (n = 279)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>61.3 ± 14.9</td>
<td>56.3 ± 14.2</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Gender (% male)</td>
<td>166 (53.9)</td>
<td>142 (50.9)</td>
<td>.47</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>31.5 ± 8.7</td>
<td>30.4 ± 8.4</td>
<td>.07</td>
</tr>
<tr>
<td>Diabetes type (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type 1</td>
<td>37 (12.0)</td>
<td>46 (16.5)</td>
<td>.11</td>
</tr>
<tr>
<td>Type 2</td>
<td>217 (70.5)</td>
<td>175 (62.7)</td>
<td></td>
</tr>
<tr>
<td>Not documentedb</td>
<td>54 (17.5)</td>
<td>57 (20.4)</td>
<td></td>
</tr>
<tr>
<td>Insulin usec (%)</td>
<td>266 (86.4)</td>
<td>240 (86.0)</td>
<td>.90</td>
</tr>
<tr>
<td>Insulin secretagogue use</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>without insulin (%)</td>
<td>18 (5.8)</td>
<td>18 (6.5)</td>
<td>.76</td>
</tr>
<tr>
<td>β-Blocker use (%)</td>
<td>148 (48.1)</td>
<td>107 (38.4)</td>
<td>.02</td>
</tr>
<tr>
<td>Renal diseasec (%)</td>
<td>85 (27.6)</td>
<td>54 (19.4)</td>
<td>.02</td>
</tr>
<tr>
<td>Time elapsed from midnight until anesthesia start time (min)</td>
<td>691.8 ± 208.4</td>
<td>693.3 ± 198.7</td>
<td>.78</td>
</tr>
</tbody>
</table>

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Table 2. Baseline Characteristics of Subjectsa

a Data that are not indicated as percentages are presented as mean ± SD.

b Basal/bolus insulin regimen without documentation of diabetes type.

c Receiving insulin before arrival in preoperative area.

d Documented on anesthesia assessment form.
Table 3. Variables Associated With Hypoglycemia Using Multiple Logistic Regression Analysis

<table>
<thead>
<tr>
<th>Parameter</th>
<th>df</th>
<th>Estimate</th>
<th>Standard error</th>
<th>Wald $\chi^2$</th>
<th>$P$ value (95% Wald CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1</td>
<td>-2.06</td>
<td>0.63</td>
<td>10.74</td>
<td>.001</td>
</tr>
<tr>
<td>Group: hyperglycemia-treated (≥249 mg/dL) vs low normal (70-89 mg/dL)</td>
<td>1</td>
<td>-1.69</td>
<td>0.36</td>
<td>22.05</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Age</td>
<td>1</td>
<td>0.002</td>
<td>0.01</td>
<td>0.03</td>
<td>.87</td>
</tr>
<tr>
<td>$\beta$-blocker use: + vs –</td>
<td>1</td>
<td>0.19</td>
<td>0.29</td>
<td>0.43</td>
<td>.51</td>
</tr>
<tr>
<td>Renal disease: + vs –</td>
<td>1</td>
<td>0.16</td>
<td>0.31</td>
<td>0.27</td>
<td>.60</td>
</tr>
<tr>
<td>Anesthesia start time: ≥12 PM vs &lt;12 PM</td>
<td>1</td>
<td>0.51</td>
<td>0.28</td>
<td>3.34</td>
<td>.07</td>
</tr>
</tbody>
</table>

Table 4. Frequency of Subsequent Hypoglycemia According to Severity

<table>
<thead>
<tr>
<th>Subsequent perioperative blood glucose (mg/dL)</th>
<th>Low normal group (n = 53)</th>
<th>Hyperglycemia-treated group (n = 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60-69</td>
<td>31</td>
<td>4</td>
</tr>
<tr>
<td>50-59</td>
<td>20</td>
<td>2</td>
</tr>
<tr>
<td>&lt;50</td>
<td>2b</td>
<td>4c</td>
</tr>
</tbody>
</table>

$P = .02$, Mantel-Haenszel $\chi^2$ test.

Although blood glucose values below 50 mg/dL were more frequent in the hyperglycemia-treated group, all 6 subjects experiencing severe hypoglycemia had received rapid-acting or short-acting insulin in the previous 6 hours to correct hyperglycemia. Four of the 6 subjects had recently received subcutaneous insulin, and the other 2 subjects had intravenous insulin infusions initiated at 5 and 10 U/h, respectively (Table 5). Coexisting renal failure likely contributed to severe hypoglycemia in these patients.
the severe hypoglycemia in 4 of 6 cases. Previous data from our institution indicated that more than one third of blood glucose values below 70 mg/dL occurred in patients with renal disease. Insulin clearance is prolonged in renal disease,\(^35\) leading to significantly reduced insulin requirements.

In addition to presence of renal disease, previous studies have also offered rationale for other baseline differences that we found between the low normal group and the hyperglycemia-treated group. Advancing age has been associated with decreased insulin clearance, reduced glucagon secretion, and perhaps delayed epinephrine secretion.\(^36\) Inhibition of glucose counterregulation by β-adrenergic blocking agents during hypoglycemia is controversial, and studies have supported\(^37\) or refuted\(^38\) this action.

Anesthesia start time was analyzed in our study because preoperative sedation is routinely administered and usual signs of hypoglycemia are subsequently obtunded. In the low normal group, an anesthesia start time of 12 pm or later was the only factor associated with subsequent increased incidence of perioperative hypoglycemia. This finding concurs with expert recommendation to schedule surgeries in the morning for patients with diabetes.\(^1,39,40\)

For outpatient surgery, dextrose therapy is advocated for blood glucose values below 70 mg/dL to prevent decline to values that may trigger hypoglycemia counterregulatory responses.\(^39\) Subjects in the low normal group who received intravenous 5% dextrose infusion for low normal preoperative glucose values did not demonstrate a lower incidence of subsequent hypoglycemia than did subjects with nondextrose intravenous solutions. More aggressive therapy with 10% or 50% intravenous dextrose solutions may be necessary to prevent subsequent perioperative hypoglycemia. Further investigation is merited.

DiNardo et al\(^2\) found that use of a standardized perioperative order set resulted in a greater percentage reduction in preoperative blood glucose values above 200 mg/dL, without increased hypoglycemia, compared with usual care. Although mean postoperative blood glucose measurements were lower in their standardized order set group (186 mg/dL) than in the usual care group (208 mg/dL), many subjects in both of their groups did not demonstrate a decline in perioperative blood glucose values to beneath the suggested upper limit of 180 mg/dL.\(^39,41\) Nearly three fourths of subjects in the hyperglycemia-treated group in our study did not achieve subsequent perioperative blood glucose value below 180 mg/dL. The question is raised whether insulin doses to correct preoperative hyperglycemia rendered by usual care were sufficient to be efficacious. The mean of the lowest subsequent perioperative blood glucose values (216.5 mg/dL) was more than 100 mg/dL less than the mean presenting preoperative blood glucose value (324.0 mg/dL). Rapid lowering of blood glucose may result in release of counterregulatory hormones, while wide glycemic variability has been associated with increased

<table>
<thead>
<tr>
<th>Periop BG value (mg/dL)</th>
<th>Age (y)</th>
<th>Diabetes type</th>
<th>Surgical procedure</th>
<th>Preop BG value (mg/dL)</th>
<th>Preop BG draw time</th>
<th>Insulin dosage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hyperglycemia-treated group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>55</td>
<td>2</td>
<td>Kidney transplant</td>
<td>General 375</td>
<td>9:07 PM</td>
<td>5 U/h insulin infusion</td>
</tr>
<tr>
<td>42</td>
<td>38</td>
<td>2</td>
<td>Arteriovenous graft revision</td>
<td>General 277</td>
<td>3:39 PM</td>
<td>Regular insulin 12 U SQ</td>
</tr>
<tr>
<td>44</td>
<td>58</td>
<td>2</td>
<td>Suboccipital craniotomy</td>
<td>General 342</td>
<td>9:07 AM</td>
<td>10 U/h insulin infusion</td>
</tr>
<tr>
<td>44</td>
<td>81</td>
<td>2</td>
<td>Total knee arthroplasty</td>
<td>Spinal 328</td>
<td>8:52 AM</td>
<td>Regular insulin 24 U SQ</td>
</tr>
<tr>
<td><strong>Low normal group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>60</td>
<td>1</td>
<td>Arteriovenous graft revision</td>
<td>General 77 (425)c</td>
<td>11:50 AM</td>
<td>Insulin aspart 7 U SQ</td>
</tr>
<tr>
<td>47</td>
<td>25</td>
<td>ND e</td>
<td>Arteriovenous graft revision</td>
<td>Local/ sedation 76 (318)c</td>
<td>7:35 AM</td>
<td>Regular insulin 6 U SQ</td>
</tr>
</tbody>
</table>

*Table 5. Characteristics of Subjects Whose Perioperative Blood Glucose Values Fell Below 50 mg/dL*

\(^a\) Total insulin administered to correct hyperglycemic value.

\(^b\) Units per hour at initiation of intravenous insulin infusion.

\(^c\) Blood glucose value in parentheses was recorded within 6 hours before arrival in the preoperative area.

\(^d\) Treatment was rendered before the patient’s arrival in the preoperative area.

\(^e\) Subject receiving a basal/bolus insulin regimen had a nondocumented (ND) diabetes type.

Abbreviations: Periop, perioperative; preop, preoperative; BG, blood glucose; SQ, subcutaneous; ND, nondocumented.
oxidative stress and increased mortality in critical care patients. Aggressive insulin treatment for patients who have poorly controlled diabetes and/or are undergoing short surgical procedures is perhaps more hazardous than perioperative hyperglycemia.

Several limitations are acknowledged. The accuracy of intermittent point-of-care testing was an inherent weakness because precise continuous blood glucose monitoring technology is not available for routine hospital use. Highly individualized diabetes regimens before preoperative area arrival confined comparative analysis of baseline characteristics to insulin use or no insulin use. Variability existed between anesthesia care providers in insulin administration for the hyperglycemia-treated group. Because of the retrospective nature of the study and multiple confounding factors, conclusions on causality of perioperative hypoglycemia cannot be made.

In summary, the overall incidence of subsequent perioperative hypoglycemia (blood glucose <70 mg/dL) was higher in patients presenting with low normal preoperative blood glucose values than in patients receiving insulin therapy to treat hyperglycemia in a single institution. Statistical adjustment was performed to account for greater renal disease incidence, β-blocker use, and age in the low normal group than the hyperglycemia-treated group. Severe hypoglycemia (blood glucose <50 mg/dL) was infrequent and followed insulin treatment for correction of hyperglycemia. Use of standardized perioperative protocols may be advantageous for prevention and treatment of glucose derangement. Prospective studies in various surgical populations are needed to determine which perioperative glycemic management strategies best achieve glycemic control while avoiding hypoglycemia.

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