This article discusses the glucose monitoring and treatment practices of a small community hospital and aims to determine how these practices relate to postoperative complications in patients undergoing vascular surgery. Previous studies in patients undergoing cardiovascular surgery have demonstrated that glucose control directly affects outcomes, including length of stay and incidence of infection, stroke, renal failure, myocardial infarction, and readmissions within 30 days of the initial surgery. A retrospective analysis of 101 patients who underwent vascular surgery was performed. After informed consent was obtained, patient charts were reviewed. Perioperative blood glucose levels, frequency of monitoring, treatment practices, and postoperative complications were collected by review of both electronic and paper medical records. Twenty-seven of the 101 patients had a blood glucose level greater than 140 mg/dL preoperatively. Intraoperative blood glucose levels were monitored for 8 patients. Nine patients had blood glucose levels treated during the perioperative period. The threshold for treatment of preoperative hyperglycemia was a blood glucose level of 236 mg/dL. Increased vigilance of perioperative blood glucose levels is needed so that appropriate interventions can be instituted and outcomes improved. Glucometers must be readily available to anesthesia providers so that intraoperative monitoring of blood glucose levels can occur.

Keywords: Hyperglycemia, outcomes, perioperative, vascular.

Intraoperative glycemic control has an important role in improving surgical outcomes. Patient outcomes, including length of stay, stroke, renal insufficiency, and mortality, have been shown to improve with greater glycemic control.1,3 As healthcare continues to endure cuts to reimbursement, methods to reduce expenditures and improve outcomes must be identified. Studies of improved glucose control have demonstrated a net annualized savings of $1,339,500.3 Intraoperative glycemic control continues to be an area of opportunity for reducing costs and improving mortality and morbidity.

The incidence of diabetes has continued to rise from 12 million in 2000 to 20.9 million in 2010.4 Clement et al1 estimated that between 15% and 20% of surgical patients in the United States have diabetes. Even though intraoperative management of diabetic patients is a daily occurrence, the intraoperative management of blood glucose continues to be inconsistent. Accessibility to glucometers in the operating room continues to be a barrier to change. The current analysis was initiated so that a dedicated glucometer for our anesthesia department could be justified. It has been well documented that glycemic control in patients undergoing coronary artery bypass surgery and in critically ill adult patients significantly improves mortality and morbidity and reduces length of hospital stay, translating into decreased costs.1,3,5-7 There continues to be an ongoing debate regarding acceptable levels for blood glucose control during surgery.

Furnary et al2 has documented that maintaining blood glucose levels at a target below 150 mg/dL with continuous insulin infusions reduces the incidence of sternal wound infections by 1.2% and decreases length of stay by 2.4 days in cardiothoracic surgical patients. There is a need for evidence-based data on intraoperative glycemic control and use of continuous insulin infusion protocols in all surgical populations.

For provision of appropriate intraoperative care to diabetic patients, criteria for monitoring and standards for treatment should be established. This study was performed to document the frequency of intraoperative blood glucose monitoring at our institution and to establish the need for a dedicated glucometer for the anesthesia department.

Methods
The institutional review board approved this retrospective chart review with the requirement of obtaining informed consent from all patients before accessing their
medical records. The review was conducted at a 186-bed community hospital in southwestern Pennsylvania. The anesthesia department was staffed by 8 anesthesiologists and 20 nurse anesthetists. After informed consent was obtained, medical records from patients who had undergone open vascular surgery were reviewed.

The medical records of 101 patients who met the inclusion criteria were analyzed. Data collection included preoperative glucose levels; frequency of glucose monitoring; any treatment of blood glucose levels; and a history of hypertension, high cholesterol, diabetes, morbid obesity, smoking, coronary artery disease, peripheral vascular disease, renal failure, and previous vascular surgery. Patients whose vascular surgery was more than 5 years earlier were excluded. Criteria for inclusion were a documented open vascular procedure and 1 or more blood glucose measurements during the perioperative period.

Data collection included the following: demographics (eg, age, gender), comorbidities, procedure date, admitting diagnosis, type of surgery, type of anesthesia, length of surgery in minutes, length of time in the postanesthesia care unit (PACU) in minutes, any blood glucose measurements in the perioperative period, frequency of blood glucose monitoring, any treatments of hyperglycemia or hypoglycemia, medical history, history of previous vascular surgery, length of stay, preoperative serum urea nitrogen and creatinine levels, incidence of surgical site infection, postoperative renal failure, any ischemic events, readmission within 30 days, return to the operating room, graft occlusion, and 30-day mortality.

SPSS software was used for statistical analysis (SPSS for Windows version 20, IBM SPSS). Descriptive variables were summarized by minimum, mean, and maximum values. Abnormal blood glucose levels were separated into 3 categories: (1) less than 70 mg/dL, (2) 70 to 139 mg/dL, and (3) greater than 140 mg/dL during the perioperative period. A subset of blood glucose levels greater than 180 mg/dL was also calculated from the greater than 140 mg/dL category.

Results

One hundred one patients were included in this analysis. All 101 patients had a blood glucose level documented preoperatively. Two patients had preoperative blood glucose levels less than 70 mg/dL. Seventy-two patients had a preoperative blood glucose level greater than 180 mg/dL. Twenty-one (72%) of 29 patients who had abnormal blood glucose levels preoperatively. Thirteen of the 27 patients with a blood glucose level greater than 140 mg/dL preoperatively was 236 mg/dL. Their hypoglycemia was not a result of treatment of hyperglycemia. Both patients had preoperative blood glucose levels greater than 180 mg/dL. Their true threshold for treatment was calculated to be 222 mg/dL. This measurement was recorded in the PACU.

Discussion

For this analysis, blood glucose levels between 70 and 139 mg/dL were considered normal. Abnormal blood glucose levels were divided into 2 categories: (1) values less than 70 mg/dL and (2) values 140 mg/dL or greater with 1 subcategory (> 180 mg/dL). Twenty-nine patients had blood glucose levels that were outside the normal range. Eight of the 29 patients who had abnormal blood glucose levels preoperatively had blood glucose levels monitored during surgery. For this reason, the data represented in the Table for intraoperative monitoring are not a valid assessment of intraoperative blood glucose levels. Even though the threshold for treatment was calculated to be 222 mg/dL, this measurement was recorded postoperatively. The true threshold for treatment of hyperglycemia preoperatively was 236 mg/dL.

The 2 patients who had blood glucose levels less than 70 mg/dL were outpatients who presented with hypoglycemia preoperatively. Their hypoglycemia was not a result of treatment of hyperglycemia. Both patients had fasted since midnight for their scheduled surgery. Once
hypoglycemia was identified, intravenous dextrose solution was titrated until a blood glucose level of 70 mg/dL or greater was achieved. The 2 patients with blood glucose levels less than 70 mg/dL had a mean length of stay of 7 days, which is 4.4 days more than for patients with a blood glucose level of 70 to 139 mg/dL. This finding is consistent with several studies that have demonstrated that patients who experience hypoglycemia have an increased length of stay and increased incidence of complications.6,9-11

In a comparison of the length of stay in patients with blood glucose levels 70 to 139 mg/dL with that of patients in the 2 categories of hyperglycemia (blood glucose levels 140 mg/dL or greater and 180 mg/dL or greater), the patients with a blood glucose 180 mg/dL or greater experienced an increased length of stay of 0.4 days.11,12 It is worth noting that 1 patient had a preoperative blood glucose level of 253 mg/dL, which was not treated. In the PACU his blood glucose level was 271 mg/dL. Treatment was initiated on the floor at 9 PM the day of surgery with sliding-scale insulin therapy. The patient experienced a surgical site infection and required additional surgery. The patient had a length of stay of 5 days, which was 2 days longer than the mean of 3 days. These findings are consistent with the results of the NICE-SUGAR trial11 and the study by van den Berghe et al,12 which established that patients with hyperglycemia experienced a higher morbidity and mortality. It is the authors’ opinion that if the blood glucose level of 253 mg/dL had been treated more aggressively, the patient may have had a different clinical course, avoiding infection and additional surgery.

The goal of this analysis was to document the need for standardized blood glucose monitoring and control during surgery. Guidelines for frequency of blood glucose monitoring as well as the threshold for treatment during surgery need to be established. Once guidelines are established, standardized monitoring and treatment can be instituted and may improve outcomes.

The strength of this analysis was randomized selection. Limitations to this project included a small sample size and the potential for sample bias because the sample was pooled from 1 surgeon’s practice.

Our analysis, which demonstrated that 73% of patients with a preoperative blood glucose level of 140 mg/dL or greater did not have intraoperative blood glucose monitoring, is similar to the 1996 analysis by Maser et al,13 which concluded that 67% of diabetic surgical patients did not have intraoperative blood glucose monitoring. Maser and colleagues13 suggested more than 17 years ago that criteria for intraoperative blood glucose monitoring be established.

### Conclusion

We continue to struggle with intraoperative monitoring of blood glucose levels as the incidence of diabetes continues to rise. It is reasonable to suggest that patients with preoperative blood glucose levels below 70 mg/dL or greater than 140 mg/dL warrant intraoperative monitoring. Anesthesia providers need to have glucose monitors readily available so that intraoperative measurements can occur. Our analysis was successful in justifying the need for a dedicated glucometer for the anesthesia department.

The next step in our project is to establish guidelines for when patients should have their blood glucose level measured intraoperatively. Future research should include prospective studies with a larger patient population with the focus on criteria for intraoperative blood glucose monitoring and the threshold for treatment. When intraoperative glucose monitoring and treatment standards are established, outcomes may improve.

### REFERENCES


### Table. Perioperative Blood Glucose Monitoring Data

<table>
<thead>
<tr>
<th>Variable</th>
<th>Preoperative (n = 101)</th>
<th>Intraoperativea (n = 8)</th>
<th>PACU (n = 36)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood glucose level, mg/dL: mean ± SD</td>
<td>130 ± 65</td>
<td>173 ± 96</td>
<td>170 ± 67</td>
</tr>
<tr>
<td>Frequency (%) of blood glucose level</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 70 mg/dL</td>
<td>2 (2)</td>
<td>2 (25)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>70-139 mg/dL</td>
<td>72 (71)</td>
<td>1 (12)</td>
<td>13 (36)</td>
</tr>
<tr>
<td>≥ 140 mg/dL</td>
<td>27 (27)</td>
<td>5 (63)</td>
<td>23 (64)</td>
</tr>
<tr>
<td>≥ 180 mg/dLb</td>
<td>13 (13)</td>
<td>4 (50)</td>
<td>13 (36)</td>
</tr>
</tbody>
</table>

Abbreviation: PACU, postanesthesia care unit.

aEight patients had intraoperative blood glucose monitoring. Twenty-nine patients had abnormal blood glucose levels preoperatively; Twenty-one (72%) of patients with abnormal blood glucose levels preoperatively did not have intraoperative blood glucose monitoring.

b≥ 180 mg/dL is a subset of the ≥ 140 mg/dL group.


AUTHORS

Suzanne Morrison, CRNA, MSN, DNP, is an assistant professor in the Department of Nurse Anesthesia at the University of Pittsburgh and a staff anesthetist, North Star Anesthesia, Sewickley, Pennsylvania. Email: sm77@pitt.edu.

John O'Donnell, CRNA, MSN, DrPh, is chairman and professor in the Department of Nurse Anesthesia at the University of Pittsburgh.

Dianxu Ren, MD, PhD, is an associate professor at the University of Pittsburgh, Pittsburgh, Pennsylvania, and a faculty statistician and methodological and analytic consultant in the university’s Center for Research and Evaluation.

Richard Henker, CRNA, PhD, FAAN, is a professor and international education coordinator at the University of Pittsburgh, Pittsburgh, Pennsylvania. He has taught the doctoral-level Research Emphasis Seminar on Critical Care Topics and has served on a number of dissertation committees.

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