RESEARCH ARTICLE

Diabetes Management

Guidelines to improve perioperative management of diabetes mellitus: an example of a successful quality initiative

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Practice points

- The perioperative phase of surgery is characterized by many transitions in care.
- Appropriate treatment of hyperglycemia and hypoglycemia during the perioperative phase of surgery could improve the likelihood of successfully transitioning a patient within a desired glucose target range to the inpatient healthcare team.
- Lack of attention to perioperative glucose monitoring could result in a missed severe hypoglycemic or hyperglycemic event.
- Careful monitoring of glucose levels should occur at all phases of perioperative care to monitor for extremes in glucose levels.
- Institutions should examine how their diabetes patients are being managed throughout the perioperative period, identify aspects of care in need of improvement, and develop local standards of care.
- Implementing standards of care for patients with diabetes undergoing elective surgery can improve key quality measures during the perioperative period.

SUMMARY **Aim:** Assess impact of perioperative care guidelines for patients with diabetes mellitus undergoing elective surgical procedures. **Methods:** Perioperative guidelines were developed, with key measures compared with a historical cohort. **Results:** The postguidelines implementation cohort (n = 303) had 326 surgeries compared with 254 in the historical cohort (n = 241). Hemoglobin A_{1c} was measured in 80 versus 47% historically ($p < 0.01$); preoperative glucose monitoring was 95 versus 88% ($p < 0.01$); intraoperative glucose monitoring was 67 versus 29% ($p < 0.01$); and postanesthesia care unit data were unchanged ($p = 0.11$). Insulin use increased throughout perioperative care ($p \leq 0.04$). Mean preoperative glucose was 130 versus 141 mg/dl ($p < 0.01$); and, for postanesthesia care, 152 versus 162 mg/dl ($p = 0.01$). **Conclusion:** Standards of care improve perioperative glucose monitoring, insulin use and possibly glucose control.

KEYWORDS
• diabetes mellitus • glucose monitoring • glycemic control • guidelines • perioperative • standards of care • surgery

Preoperative, intraoperative, and postoperative hyperglycemia are all associated with poorer patient outcomes [1–18]. Limited data indicate that lower preoperative hemoglobin A_{1c} (HbA_{1c}) is associated with fewer infectious complications in surgical patients [1,2]. One study demonstrated

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that intraoperative glucose management decreased complications in surgical patients [12], whereas another study did not show any benefit [19]. Additionally, hyperglycemia during the hospitalized postoperative phase of surgical care has been associated with increased complications, most notably surgical site infections, longer lengths of hospital stay, greater mortality, and a higher frequency of preoperative interventions [20–27]. Effective management of hyperglycemia can reduce complications in hospitalized postoperative patients who are not critically ill, and treating inpatient hyperglycemia is therefore now generally recommended [20,28–32].

Given the interest of clinicians and researchers in the topic, the management of patients with diabetes mellitus during each phase of the continuum of surgical care (as outlined in the proposed model in **Figure 1**) deserves special attention from the healthcare team. Although data on the benefits of glycemic control during these periods may still be uncertain, at least two arguments support a focus on a quality improvement initiative during the preperioperative and perioperative phase of surgical care. First, appropriate management of hyperglycemia during these phases of surgery can improve the chances of a successfully transitioning a patient within a desired glucose range to either the healthcare team caring for the individual in the hospital (if the patient is admitted), or to the patient and family (for same-day procedures when the patient is discharged home). The second reason relates to patient safety. Lack of attention to perioperative glucose monitoring, for instance, could result in a missed severe hypoglycemic or hyperglycemic event. Glucose monitoring is particularly relevant given the number of care transitions that occur as patients move through the different segments of perioperative management. Yet, there has been little attention paid to the details of the care provided to patients with diabetes particularly during the perioperative phase of surgery, nor do any consensus recommendations exist in currently available guidelines [30–32].

In 2011, we set out to evaluate institutional processes of diabetes management throughout the continuum of surgical care. As part of this initiative, data on diabetes management during the perioperative setting for patients were collected, and among the identified deficiencies included suboptimal intraoperative glucose monitoring in patients with prolonged periods under anesthesia [34]. The identification of these deficiencies led to a multidisciplinary effort to develop guidelines and a unified framework for the care of patients with diabetes as they transitioned through the various segments of perioperative care. This report details an initial assessment of perioperative care after the implementation of these practice guidelines at our tertiary care academic hospital in Phoenix (AZ, USA). The goal of the analysis was to determine whether previously identified gaps in care had been corrected as a result of the intervention.

Methods

• Overview

The quality improvement project consisted of four stages. The first was a baseline data collection period (designated the historical cohort) conducted from 1 January to 30 April 2011, and previously published [34]. This analysis provided the impetus for the initiative. The next step was guidelines development from April 2012 to December 2012. Third was dissemination of guidelines and staff education from 1 January to 30 March 2013. The last step was the postguidelines implementation data collection period from 1 April to 30 June 2013. While the emphasis of quality improvement was on perioperative care, we also wished to close gaps identified during the preperioperative phase of management [34].

• Development of guidelines

After the baseline data collection period, a multidisciplinary team comprising representatives from endocrinology, surgery, anesthesiology and nursing met regularly from April to December 2012 to discuss the elements of preperioperative and perioperative diabetes care in need of improvement. The primary goal of the team was to establish a framework for the development of processes and protocols to measure and maintain a random blood glucose level of <180 mg/dl without increasing rates of hypoglycemia in patients with known diabetes. In order to meet the goal of keeping glucose below 180 mg/dl, the threshold to treat hyperglycemia was set at 140 mg/dl.

Guidelines were drafted and finalized after repeated cycles of review and revision. The guidelines were intended only for adult patients with diabetes who were undergoing elective surgery requiring general anesthesia. Management guidelines for postoperative inpatient diabetes

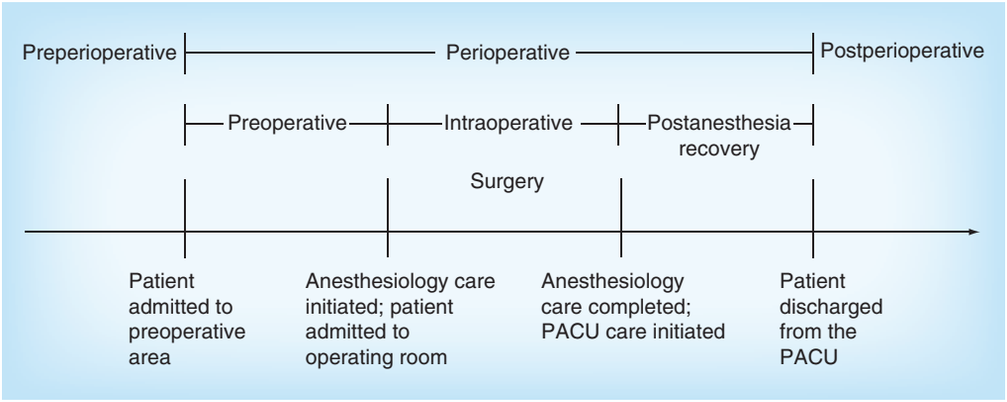

Figure 1. Model for the analysis of diabetes management during the continuum of surgical care, divided into preperioperative, perioperative and postperioperative phases. The preperioperative phase reflects the patient's history of diabetes and its management (e.g., mode of therapy, presence of diabetes complications and metabolic control) that could have an impact on perioperative and/or postperioperative glycemic control and patient outcomes. The perioperative phase is divided into preoperative, intraoperative and postanesthesia recovery segments that are defined by discrete start and end times identified in the medical record. The postperioperative phase represents glycemic control and management after discharge from the PACU, which would take place during a hospital stay or when the patient is discharged home. Each phase (and each perioperative segment) represents a transition in care that should prompt appropriate glucose monitoring and therapy to maintain desired glucose targets. Although diabetes surgical care is a continuum, this model allowed that care to be compartmentalized for quality analysis and improvement purposes.
PACU: Postanesthesia care unit.
Adapted with permission from the American Association of Clinical Endocrinologists [33].

care were addressed through a separate quality improvement initiative [35,36]. Consequently, this analysis focused only on those areas targeted for improvement during the preperioperative and perioperative phases of care **(Box 1)**. Thus, we were looking for improvements in the frequency of performance of a preoperative medical evaluation, increased measurement of HbA_{1c} and perioperative glucose monitoring, and changes in the frequency of insulin administration in patients with glucose above the 140 mg/dl threshold. With the institutionally established insulin correction scales, subcutaneous rather than short-acting intravenous bolus insulin was emphasized for correcting hyperglycemia.

• Dissemination of guidelines

The institutional guidelines were presented to all applicable departments: anesthesiology, the POME clinic, surgical departments and divisions, and preoperative, intraoperative and postanesthesia care unit (PACU) nursing staff from January to March 2013. Each department was educated by one or more lectures regarding the goals and objectives of this initiative, the process of implementation, and the use of the guidelines in each phase of the perioperative setting. Prior to implementation of the guidelines, preoperative and postoperative order sets were established within the framework of the electronic health record to synchronize the ordering of appropriate glucose-monitoring, insulin therapy, and hypoglycemia treatment in accordance with the guidelines. The number of glucometers in the operating suites was increased in response to the expected increase in intraoperative monitoring. Progress was followed by a dedicated nurse practitioner who monitored care and reviewed any questions or problems that arose.

• Case selection & data extraction

To assess the preliminary impact of the guidelines, we selected for analysis from a surgical database all ambulatory adult patients with diabetes who underwent an elective surgical procedure under general anesthesia between 1 April 2013 and 30 June 2013. Data for these patients were compared with data for the historical cohort [34]. Patients managing their diabetes via insulin pump therapy were included under a separate care process model [37,38]. Additionally, patients with diabetes who were undergoing

Box 1. Guidelines for preperioperative and perioperative assessment, and management of the adult patient with diabetes undergoing elective surgery under general anesthesia.

- Preperioperative period
- Conduct preoperative medical examination
- Obtain HbA_{1c} level if not performed within 3 months
- Perioperative period
- Preoperative
- Measure glucose level on arrival, then hourly
- Treat glucose ≥140 mg/dl with insulin
- Intraoperative
- Measure glucose hourly
- Treat glucose to ≥140 mg/dl with insulin
- PACU
- Measure glucose level on arrival, then hourly
- Treat glucose to ≥140 mg/dl with insulin

HbA_{1c}: Hemoglobin A_{1c}; PACU: Postanesthesia care unit.

cardiothoracic surgery were excluded as they were also being tracked via a separate quality improvement program. The study was approved by the institutional review board.

Demographic information was collected. Additional information that was obtained included self-reported duration of diabetes, whether patients received a POME either from a primary care physician or from the staff of the specialty POME clinic, outpatient medications used for treatment of diabetes and preoperative HbA_{1c}. The perioperative period was divided into preoperative, intraoperative, and PACU segments, as previously described **(Figure 1)** [34]. The frequency of blood glucose monitoring during each of the perioperative care segments was documented. Glucose monitoring was analyzed according to whether it was performed with a point-of-care blood glucose (POC-BG) device (ACCU-CHEK Inform II System; Roche Diagnostics North America) or by some other method (venous or arterial). Insulin treatment administered to correct hyperglycemia was also noted.

• Data analysis

Data from the postguidelines implementation group were compared with data from the historical group. The primary measures of interest were whether patients received a POME, whether a preoperative HbA_{1c} measurement was obtained, the frequency of perioperative glucose monitoring and perioperative insulin use. Additionally, preoperative and PACU glucose control between the two groups was compared; comparisons could not be made for intraoperative glucose control because of the low frequency of monitoring in the historical cohort and the variable nature of the methods used to determine glucose levels [34].

Data are reported as mean (standard deviation [SD]) or percentage, as appropriate. Differences between categorical variables were assessed using the χ^2 test. Differences between continuous variables were evaluated with both parametric and nonparametric means, and because statistical conclusions were identical, results of t-tests are reported.

Results

• Patient characteristics

The postguidelines implementation group was composed of 303 patients who underwent 326 elective surgical procedures, whereas the historical group was composed of 241 patients who underwent 254 surgeries. The two cohorts were comparable in age, sex, and race. The duration of diabetes, when documented, was comparable. The two groups were also similar in the outpatient pharmacologic management of their diabetes **(Table 1)**.

There were differences in the distribution of surgical services caring for the postguidelines implementation and historical groups **(Table 1)**. For instance, the postguidelines implementation cohort was characterized by more patients who underwent a general surgical procedure and fewer patients who underwent vascular surgical procedures. This variation in the classes of surgical procedures may explain the differences in intraoperative times detected in the postguidelines implementation group,

Table 1. Characteristics of patients with diabetes undergoing elective surgical procedures: historical and postguidelines implementation cohorts[†].

Variable	Historical cohort	Postguidelines implementation cohort	p-value
Patient characteristics			
Patients (n)	241	303	
Age; mean (SD), years	68 (10)	67 (12)	0.28
Male sex	149 (61.8)	192 (63.4)	0.71
White race	220 (91.3)	269 (88.8)	0.33
Diabetes duration; mean (SD), years[‡]	11 (12)	12 (10)	0.51
Outpatient diabetes treatment[§]:			0.11
– Diet only	36 (14.9)	44 (14.5)	
– Oral agent only	145 (60.2)	158 (52.1)	
– Oral agent plus insulin	16 (6.6)	34 (11.2)	
– Insulin only	43 (17.8)	59 (19.5)	
– Other	1 (0.4)	8 (2.6)	
Surgical characteristics			
Cases (n)	254	326	
Type of surgery:			<0.01
– Colorectal	9 (3.5)	0 (0)	
– General	43 (16.9)	97 (29.8)	
– Gynecology	12 (4.7)	22 (6.8)	
– Neurosurgery	13 (5.1)	15 (4.6)	
– Ophthalmology	0 (0)	1 (0.3)	
– Orthopedic	59 (23.2)	53 (16.3)	
– Otolaryngology	26 (10.2)	32 (9.8)	
– Plastic	10 (3.9)	27 (8.3)	
– Urology	62 (24.4)	79 (24.2)	
– Vascular	20 (7.9)	0 (0)	
Perioperative times; mean (SD), min:			
– Preoperative	120 (59)	117 (45)	0.40
– Intraoperative	178 (110)	152 (112)	<0.01
– PACU	179 (81)	164 (135)	0.08
– Total perioperative	478 (152)	432 (163)	<0.01

[†]Values are number (percentage) unless indicated otherwise.
[‡]Available in 142 of the historical cohort and in 208 of the postguidelines implementation cohort.
[§]Percentages total <100% due to rounding in both the historical cohort and the postguidelines implementation cohort.
PACU: Postanesthesia care unit; SD: Standard deviation.

which in turn translated into differences in perioperative times compared with the historical cohort.

• Performance of POME

In our previous study, we found that ambulatory patients with diabetes who underwent a surgical procedure with general anesthesia had an average American Society of Anesthesiologists' physical status score of 3, connoting severe, systemic disease [34]. Consequently, the guidelines development team decided that patients with diabetes should undergo a POME either with their primary care medical team or through the designated POME clinic. However, the percentage of cases undergoing a POME in the postguidelines implementation cohort (76% [249 out of 326]) was comparable to that in the historical cohort (80% [202 out of 254]; p = 0.60; data not shown).

• HbA_{1c} measurement

A significant increase in HbA_{1c} measurement occurred after implementation of the guidelines. HbA_{1c} was measured in 80% (260 out of 326) of the postguidelines implementation cases but in only 47% (120 out of 254) of the surgical cases in the historical cohort (p < 0.01). Mean (SD) HbA_{1c} was lower at 6.7% (1.1%) in the postguidelines implementation cohort versus 7.0% (1.4%) in the historical cohort (p = 0.02). The mean ± SD interval between HbA_{1c} measurement and the day of surgery was longer in the postguidelines implementation cohort at

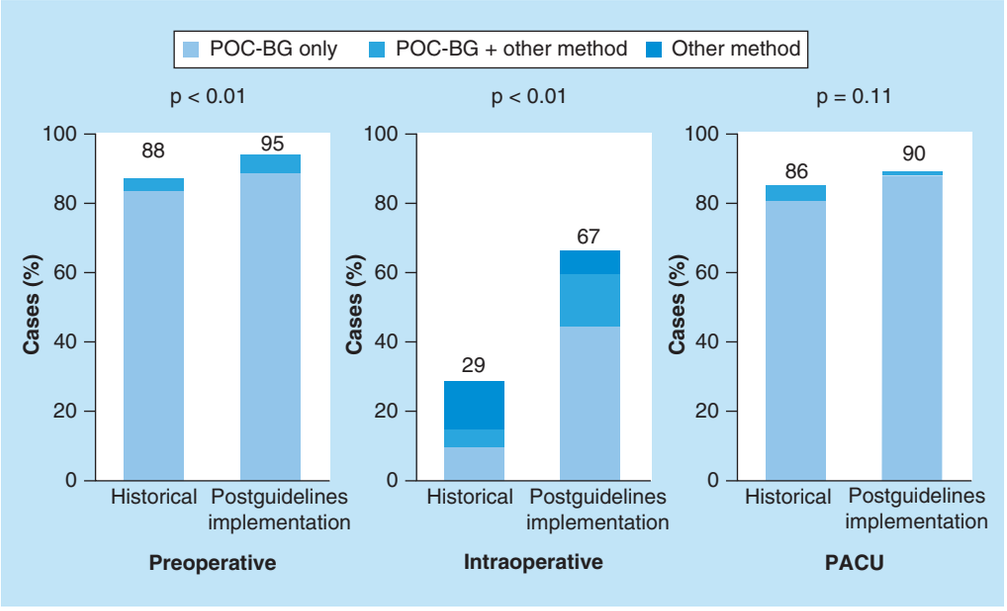

Figure 2. Percentage of cases with glucose monitoring during the perioperative phase of surgery.
Perioperative segments defined as outlined in **Figure 1**.
PACU: Postanesthesia care unit; POC-BG: Point-of-care blood glucose.

23 (26) days than in the historical group at 15 (19) days ($p < 0.01$; data not shown).

• Perioperative glucose monitoring

The total number of glucose measurements per case obtained in the preoperative area was 1.4 (0.7) in the postguidelines implementation cohort compared with 1.0 (0.8) in the historical cohort ($p < 0.01$). There was an increase in the proportion of surgical cases that had any glucose monitoring performed during the preoperative segment of care **(Figure 2)**. The number of cases for which a glucose level was obtained was 95% (311 out of 326) in the postguidelines implementation cohort compared with 88% (223 out of 254) in the historical cohort ($p < 0.01$). Of cases that had glucose monitoring performed in the preoperative area, 96% (298 out of 311) of the postguidelines implementation group and 97% (216 out of 223) of the historical group had them derived from POC-BG measurements alone.

When evaluating changes in the frequency of intraoperative glucose monitoring, we considered only those procedures lasting ≥60 min. The average number of measurements per case was 1.5 (1.8) in the postguidelines implementation cohort versus 0.8 (1.9) in the historical cohort ($p < 0.01$). There were 278 procedures in the postguidelines implementation cohort versus 247 in the historical cohort that had procedures lasting ≥60 min. The percentage of cases with a glucose level obtained was 67% (186/278) in the postguidelines implementation cohort versus 29% (71/247) in the historical cohort ($p < 0.01$) **(Figure 2)**. POC-BG devices were used with greater frequency after guidelines implementation. In cases where glucose monitoring was performed, 75% (140 out of 186) of those in the postguidelines implementation group were derived from POC-BG measurements alone compared with 31% (22 out of 71) in the historical group.

Although in the PACU the total number of glucose measurements per case increased to 1.5 (1.0) in the postguidelines implementation group from 1.1 (0.8) in the historical group ($p < 0.01$), the percentage of cases where a glucose level was measured in the PACU did not change **(Figure 2)**. The percentage of cases with glucose monitoring was 90% (295 out of 326) in the postguidelines implementation PACU group compared with 86% (219 out of 254) in the historical PACU cohort ($p = 0.11$). Use of POC-BG monitoring alone was 98 (288 out of 295) and 95% (208 out of 219), respectively.

• Glycemic control

For the historical cohort, glucose values during the perioperative period obtained by any

method ranged from 33 to 390 mg/dl, with a total of five cases with biochemical hypoglycemia. Of these, three were detected during the preoperative segment, and two in the PACU. Glucose levels ranged from 51 to 306 mg/dl during the perioperative period in the postguidelines implementation cohort, with hypoglycemia occurring in seven cases, with four occurring preoperatively, one intraoperatively and two in the PACU. Episodes would have been treated according to the institutional protocol. Mean preoperative and PACU POC-BG values were lower in the postguidelines implementation cohort than in the historical cohort. The preoperative POC-BG was 130 (37) mg/dl in the postguidelines implementation cohort versus 141 (45) mg/dl in the historical cohort ($p < 0.01$). In the PACU, these values were 152 (41) and 162 (48) mg/dl, respectively ($p = 0.01$). Intraoperative glucose levels were not compared before and after implementation of the guidelines because only a few cases in the historical cohort had POC-BG monitoring [34].

• Insulin use

Our guidelines sought to maintain perioperative glucose values at <180 mg/dl, with a threshold to treat of 140 mg/dl. Therefore, we examined whether insulin use changed as a result of the implementation of the guidelines. In the preoperative area, in cases with at least one glucose value (obtained by any method) ≥140 mg/dl, the percentage of cases administered insulin was greater in the postguidelines implementation group than in the historical group **(Figure 3)**. Similar differences were seen between the two cohorts during the intraoperative and PACU segments of care.

Discussion

Poor glycemic control at any point during the continuum of surgical care can be associated with poorer patient outcomes [1–18,20–27]. For purposes of patient safety and to ensure optimal glucose control transitions, practitioners should follow a common set of practice standards relating to the diabetes patient about to undergo surgery. Historically, the preperioperative and perioperative phases of surgical care have not really been the target for quality improvement initiatives for patients with diabetes, and consensus guidelines do not exist for care. Having identified several elements of care in need of attention, we conducted a quality improvement initiative in which we developed and implemented standards of care that could be generalized, and then evaluated the impact of these guidelines on management [34].

When compared with the historical cohort, the cases evaluated in the postguidelines implementation cohort had some differences in types of surgery and in perioperative time, but otherwise were comparable. All were ambulatory

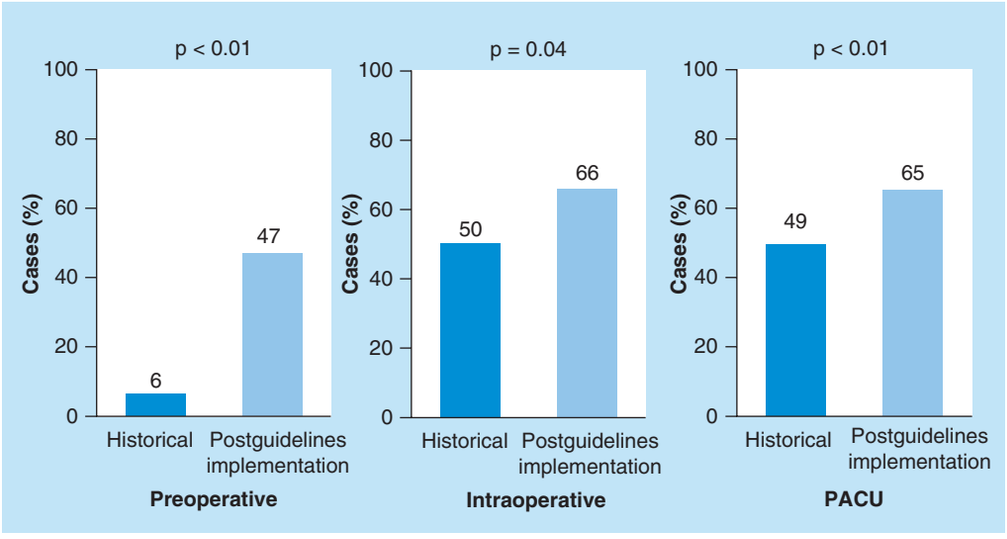

Figure 3. Insulin use during the perioperative phase of surgery. Data are the percentage of cases in each perioperative segment. Perioperative segments defined as outlined in **Figure 1**.
PACU: Postanesthesia care unit.

patients undergoing elective procedures under general anesthesia. Although the sample contained patients undergoing different surgical procedures, the principles of diabetes management in this particular type of sample should be independent of the type of patient or surgery (i.e., the same standards should apply). Our findings demonstrated that, in general, the metrics being targeted for improvement were impacted by the intervention. One exception was the POME visit, which did not change after the guidelines were introduced into the practice. One possible reason for this is that the patient had preoperative clearance outside of our healthcare system that was not documented. Another is that the procedure itself may have been perceived as low risk, resulting in deferral of the POME visit.

One goal of the intervention was to increase the assessment and monitoring of glycemic control. As a result, the number of cases for which HbA_{1c} was measured increased significantly after implementation of the guidelines. Glucose monitoring in the preoperative segment of care, which was already high, increased further. Although the absolute number of glucose measurements increased during the time patients spent in the PACU, the percentage of cases with PACU glucose monitoring did not increase, and further education of staff in this area will be required. One of the biggest deficits noted in the historical cohort was the lack of intraoperative glucose monitoring, which improved significantly as a result of the intervention, although additional work is needed to reach full compliance.

Another finding was that the method of glucose monitoring was more consistent after implementation of the guidelines. The historical cohort had more variability in the methodology of how glucose was measured, particularly during the intraoperative segment of perioperative care [34]. After implementation of the guidelines, POC-BG monitoring became the most commonly employed method. In the future, consistent methods of measuring glucose will permit more accurate assessment of changes between the different segments of perioperative care. One limitation of intraoperative POC-BG monitoring, as noted in our prior analysis [34], was the unavailability of glucometers in the operating suites – a shortfall since corrected that has likely contributed to the higher frequency of intraoperative POC-BG monitoring.

Glycemic control in the postguidelines implementation cohort was better than in the historical cohort. HbA_{1c}, which reflected the care received during the outpatient, preperioperative phase of management, was lower in the postguidelines implementation cohort. Additionally, mean POC-BG levels were lower during the preoperative and PACU segments of care postguidelines intervention relative to the historical cohort. The lower glucose levels in the preoperative area may have been a reflection of the better outpatient glycemic control, and the lower PACU glucose values in the postguidelines implementation group likely reflected greater intraoperative use of insulin. It is unclear why HbA_{1c} was lower after the guidelines were introduced, especially since both cohorts were on similar outpatient therapy. Both practitioner and patient awareness of the importance of optimal perioperative and postoperative glucose control may have been higher as a result of the guidelines. This could have led to practitioner encouragement to patients for better lifestyle and/or medication compliance prior to surgery, or possibly to outpatient intensification of medication doses by the practitioners.

This analysis should be viewed within the greater context of institutional efforts to improve diabetes management throughout the continuum of surgical care. We recently reported on successful efforts to overcome clinical inertia in the use of basal–bolus insulin therapy in hospitalized postoperative patients with diabetes, demonstrating improved glucose control with no increase in hypoglycemia [36]. Future study is needed to examine whether concentrating on optimizing outpatient glycemic control prior to surgery translates into a reduction in hyperglycemia throughout the subsequent phases of surgical care and improvement in postoperative outcomes. Next steps in this quality improvement project will also include evaluating whether controlling perioperative hyperglycemia translates into better glucose control postoperatively in the hospital, or even at home for patients who are discharged directly from the PACU.

There are some limitations to our study. This was a retrospective review that utilized a surgical database to identify perioperative patients with diabetes, and as such it is subject to the biases associated with such analyses. Moreover, the analysis focused only on those patients with diabetes who underwent an elective procedure. However, the increased awareness among healthcare providers and the improved processes put in place should translate to improved care for all patients with diabetes who undergo surgery,

including emergent procedures. We conducted our first assessment of the impact of the guidelines immediately after their implementation, and it is conceivable that we would have observed even greater improvements in the metrics if more time had been allowed for practitioners to adopt these innovations. Finally, efforts described here were focused on trying to improve processes of care. Although such improvements have been made to the practice, their impact on outcomes, such as length of hospital stay, postoperative infection rates and hospital readmission rates, are unknown and will need to be addressed in future studies.

Conclusion

Despite these limitations, our analysis did demonstrate how a multidisciplinary team of surgical staff, anesthesia staff, endocrine specialists and nursing staff can collaborate to develop common standards of surgical diabetes care to close previously identified gaps in management. Adherence to a standardized set of practice guidelines resulted in improvements in practice. These interventions resulted in better preoperative HbA_{1c} monitoring, increased preoperative and intraoperative glucose monitoring, and increased use of insulin when indicated. There still are areas for further improvement (e.g., achieving 100% intraoperative glucose monitoring). Ongoing assessment will determine whether practice patterns can be improved further and sustained over time.

Future perspective

Glycemic control in the surgical patient continues to be of great interest to both researchers and clinicians. Most studies in the field have examined the relationship between hyperglycemia and postoperative outcomes among inpatients, and the majority of quality improvement initiatives have focused on quality improvement in that population. Future studies are needed to explore the impact of improving glycemic control prior to surgery on both perioperative and postoperative outcomes such as infection rates, mortality and hospital length of stay. Additionally, further work is needed to explore whether improving management during the perioperative phase of care leads to better postoperative outcomes, including the ones listed above. It would be of interest to evaluate whether the approach taken here is transferrable to other institutions. Finally, professional societies and quality improvement organizations need to come together to develop consensus guidelines for perioperative management of diabetes.

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Ethical conduct of research

The authors state that they have obtained appropriate institutional review board approval or have followed the principles outlined in the Declaration of Helsinki for all human or animal experimental investigations. In addition, for investigations involving human subjects, informed consent has been obtained from the participants involved.

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