

BMJ Open Quality Effectiveness of standardised preoperative assessment and patient instructions on admission blood glucose for patients with diabetes undergoing orthopaedic surgery at a tertiary referral hospital

Thérèse Franco,¹ Stephen Rupp,² Barbara Williams,³ Craig Blackmore³

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ABSTRACT

Diabetes and hyperglycaemia affect a significant number of people and are associated with a variety of untoward effects, especially under physiological stress such as surgery. Due, in large part to limited evidence, clinical practice in monitoring blood glucose and treating hyperglycaemic conditions in the perioperative period is variable. We used Lean methodologies to implement a standardised approach to preoperative management of patients undergoing elective surgery in an effort to improve glycaemic control. Overall, we saw an appropriate increase in monitoring and a decrease in the rate of hyperglycaemia on presentation to the operating room. This approach may be useful in other care settings or patient populations, potentially contributing to improved glycaemic control and subsequent decrease in associated complications.

PROBLEM

Diabetes and hyperglycaemia are common conditions that are associated with significant morbidity and mortality, particularly for patients undergoing surgery.^{1 2} Given these implications, the US Center for Medicare and Medicaid Services included a measure of glycaemic control in its Surgical Care Improvement Program (SCIP) as part of the Hospital Value-Based Purchasing movement, effective in 2010. Our data for the SCIP-4 metric was below the national benchmark.³ An examination of preoperative processes for the care of a patient with diabetes undergoing surgical procedures revealed great variability in practice with a lack of shared guiding principles. We identified an opportunity to improve glycaemic control for patients with diabetes who were scheduled to have an elective surgery. This quality improvement effort deployed Lean management principles to standardise care and decrease the first blood glucose value for patients with diabetes who had elective surgery at our single institution.

Our goal was to eliminate hyperglycaemia in patients undergoing elective surgery. This project occurred at a single urban tertiary referral acute care hospital in the US Pacific Northwest licensed for 336 beds with approximately 500 physicians and approximately 17 000 surgeries (4300 inpatient cases) per year. This investigation was performed as part of a quality assurance project and a waiver was granted from the Institutional Review Board.

BACKGROUND

In 2015, 30.3 million Americans (9.4% of the general population) carried a diagnosis of diabetes. The estimated cost of diabetes in the USA in 2012 was \$245 billion for direct and indirect expenditures.⁴ Observational studies show that patients with diabetes who undergo surgery have greater healthcare utilisation, longer hospital stays, more infectious complications and higher perioperative mortality than patients without diabetes.^{2 5 6} Improved glycaemic control has been associated with a decrease in morbidity and mortality, particularly for cardiac surgery and critically ill patients.^{2 7 8}

Despite these observations, a clear consensus on postoperative, intraoperative and preoperative glucose targets and management of hyperglycaemia has been elusive. Treatment goals and recommendations vary significantly between professional societies and apply to varying patient populations in different care settings.^{1 9} The strongest evidence showing the benefit of glycaemic control in the postoperative setting is Van Den Berghe's single-centre study of mechanically ventilated patients.^{7 9} Recommendations for intraoperative glucose targets



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¹Section of Hospital Medicine, Virginia Mason Medical Center, Seattle, Washington, USA

²Department of Anesthesiology, Virginia Mason Medical Center, Seattle, Washington, USA

³The Center for Healthcare Improvement Science, Virginia Mason Medical Center, Seattle, Washington, USA

Correspondence to

Thérèse Franco MD and SFHM, Section of Hospital Medicine Virginia Mason Medical Center Seattle Washington USA ; Therese.Franco@virginiamason.org

Table 1 Descriptive characteristics for n=6466 orthopaedic surgical procedures

	Jan 2011– Dec 2012	Jan 2013– Feb 2013	Mar 2013– Dec 2017	Sig. P value (before vs after)
	Before	During	After	
# Surgeries	402	150	5914	
# Glucose labs	402	150	5914	
Mean LOS (SD)	3.5 (1.3)	2.9 (1.1)	2.6 (1.5)	<0.001
LOS >2 days (%)	389 (97)	130 (87)	4528 (77)	<0.001
Mean age (SD)	65.6 (10.1)	67.3 (11.0)	65.5 (10.9)	0.92
Male (%)	155 (39)	56 (37)	2620 (44)	0.025
Diabetes diagnosis (%)	357 (89)	37 (25)	978 (17)	<0.001
Discharge to home (%)	279 (69)	102 (68)	5348 (90)	<0.001

LOS, length of stay.

are also variable, extrapolated from a number of trials, most focused on cardiac surgery. The largest study is the Portland Diabetes Project, a non-randomised trial that targeted an intraoperative blood glucose of <200 mg/dL for patients with diabetes undergoing coronary artery bypass grafting (n=4864), which showed a reduction in mortality. Using the best evidence available, the Endocrine Society and the Society for Ambulatory Anesthesia has issued consensus guidelines recommending a target of <180 mg/dL intraoperatively.^{1 10 11} Data to support any specific preoperative blood glucose target have also been scarce. In one large (n=61 536) observational study, Abdelmalak *et al* found that patients with preoperative blood glucose values of 60–100 mg/dL had a significantly lower 1-year mortality rate than those presenting with a blood glucose >216 mg/dL.^{1 12} Thus, there is no singular, definitive glucose target range in the preoperative setting. Likewise, recommendations for management are variable and generally based on pharmacological principles and small studies.¹⁹

The clear association of poor outcomes with elevated blood glucose drives providers to act, but the dearth of clear and concise clinical decision support is problematic, resulting in variation of practice. Taichii Ohno, Japanese engineer and father of the Toyota Production System is credited with saying, 'Without standards, there can be no improvement'.¹³ In the healthcare setting, this principle has translated into clinical pathways and

order sets as effective means to simplify and standardise care consistent with best current evidence. This practice is supported by the medical literature.¹⁴ Our institution has previously leveraged order sets to improve care for patients with diabetes and for patients undergoing surgical procedures.^{15 16} Attention to blood glucose control during preoperative care offers an opportunity to screen for diabetes, improve glycaemic control throughout the perioperative period and is an area ripe for standardisation.

MEASUREMENT

Our first indication that we had opportunities for improvement with respect to perioperative glycaemic control was our performance on the SCIP-4 metric. We began to track our glycaemic control outcomes across the hospital and recognised that many patients in the pre-op area and subsequently in the operating room were hyperglycaemic or not being monitored at all.

For identification of hyperglycaemia, our primary outcome was the per cent of blood glucose values in the operating room (OR) that were ≥ 180 mg/dL extracted from the electronic health record (EHR). The first point of care (POC) blood draw on the day of surgery with location 'OR' was analysed for each patient. Most patients (64%) had only one OR blood draw, if there was more than one POC blood draw on the day of surgery, then the first draw was selected for analysis. Patients were considered 'diabetic' if they had an International Classification of Disease diabetes diagnosis (250.*, 357.2, 362.01, 366.41, E10.*, E11.*) at discharge during the study period. Preintervention and postintervention blood glucose values were assessed with T-tests for continuous variables, χ^2 for dichotomous variables and statistical process control charts over time, using Stata MP 12.1.

In the baseline period January 2011 to December 2012, there were 357 patients with diabetes undergoing surgery. The average age was 65.6, and 39% (155/357) were men (table 1). The proportion of patients with diabetes undergoing surgery with baseline blood glucose ≥ 180 mg/dL was 15.1% (54/357) (table 2).

DESIGN

Our institution deploys Lean management principles adapted to the healthcare setting. This management method is a very deliberate and systematic approach to

Table 2 Glucose values in patient undergoing orthopaedic surgical procedures before, during and after the intervention

	Patients without diabetes			Patients with diabetes		
	Jan 2011– Dec 2012	Mar 2013– Dec 2017	χ^2 sig P value	Jan 2011– Dec 2012	Mar 2013– Dec 2017	χ^2 sig P value
# Glucose labs	45	4936		357	978	
# Glucose ≥ 180	1	1		54	92	
% Glucose >180	2.2	0.1	<0.001	15.1	9.4	0.003

eliminate waste in order to increase the quality and efficiency of healthcare delivery. It is based on the manufacturing method that was pioneered by Toyota Motor Company.¹⁰ This was the operational framework for our quality improvement initiative.^{17 18}

At baseline, glycaemic control had been identified as a top priority for the organisation, which was an indication of executive buy-in and support in pursuit of this work. We had done substantial targeted work toward addressing glycaemic control through 2012, but the effect on outcomes was limited. However, this work was foundational to supporting the success of the intervention.

The intervention was designed around a 5-day rapid process improvement workshop (RPIW) quality improvement event. Initial work consisted of goal setting and root cause analysis. During the event, we designed and tested the various interventions through small-scale plan-do-study-act (PDSA) cycles. Postevent, the work centred on implementation throughout the institution.

The RPIW was held in December 2012 and resulted in a standard evidence-based care protocol for patients with diabetes undergoing surgery, to be deployed by a small number of trained providers, as well as a standardised set of preoperative patient instructions. The simplified algorithmic approach significantly reduced ambiguity for providers and allowed for real-time clinical decision support within the work flow of the primary operator. Implementation was supported by small-scale PDSA cycles.

STRATEGY

Preintervention glycaemic control work

Effective January 2012, the institution had identified glycaemic control as an organisational priority, and as a result, many providers had a good sense of urgency around this issue. In April of 2012, there was a grand rounds conference held to provide a general awareness of basal-bolus insulin prescribing, proven to be safe and effective for hospitalised patients outside the critical care unit.^{19 20} This approach to prescribing insulin was adopted across the organisation and was an important part of establishing a shared mental model of care.²¹ The grand rounds educational session also identified an institution-wide blood glucose target range of 100–180 mg/dL across all patient populations and clinical settings, which was new. Prior to this, it was left up to the individual to determine the goal and what interventions should be used to get there. More focal educational outreach to the perioperative team was an effort to further and more specifically, ‘prepare the people’, a process referred to in Lean as *Nemiwashi*. The multidisciplinary perioperative team developed several cognitive aids to assist in identification of patients with diabetes early in their surgical planning so that their needs could be appropriately addressed for the entire episode of care from the first symptom through effective treatment. Our orthopaedic surgery line was fertile ground for this work because the

department had recently been engaged in developing their service line with horizontal integration, which allows communication and planning across an entire episode of care. The ‘Insulin Dictionary’ is an example of one such cognitive aid. The insulin dictionary elaborated the pharmacokinetics of various forms of insulin and allowed the practitioner to immediately have a reference to understand the patients home insulin regimen. This instrument was important because the perioperative value stream stretches from the initial preparation in the surgeon’s office through the postanesthesia care unit, and it is critically important to have a shared language to communicate effectively throughout the continuum. The team also developed a mutually agreed on Surgery Prep Admission Blood Glucose Management Action Grid that provided clinical decision support with the best available evidence to support thresholds for action and targets for blood glucose values. Ongoing care of the patient with diabetes requires good handoffs. In the third quarter of 2012, initial improvement work was directed at improving the handoff after surgery between the operating room and postanesthesia care unit. This involved coaching providers to use the insulin dictionary to report in a situation, background, assessment, recommendation, or SBAR, format to each other. Incremental improvements in that process involved determining the best location for the handoff, most appropriate operators to give and receive the handoff and keeping language complete, but succinct. This experience allowed providers to understand best practices for a successful handoff, which required specialised knowledge and training with respect to diabetes and the insulin dictionary. Then, in November 2012, a glycaemic control summary page, available in every patient’s chart, launched in our EHR. This highly visual summary page provided a thorough yet concise view of all the relevant clinical data necessary to develop a plan of care for a patient with diabetes within the workflow, thus significantly reducing provider time spent information gathering.¹⁵ This preparation served as a primer for the successful RPIW, where the insulin dictionary and summary page were embedded upstream, in the preanaesthesia assessment team’s workflow.

RPIW preparation

In preparation for the December 2012 RPIW, we identified causes of hyperglycaemia in patients undergoing surgery through direct observation of the care process sometimes referred to as ‘walking the genba’. We identified several opportunities for improvement. For example, of those surgery patients with plans for admission postoperatively, only 23% of patients had a baseline blood glucose checked. (The American Diabetes Association recommends all hospitalised adults have at least one blood glucose checked during admission.) Additionally, of those patients who required glycaemic management, one third were not identified appropriately. Furthermore, of those patients appropriately identified as needing glycaemic management, none had an up-to-date haemoglobin A1c

(HbA1c) value in the system. As follow-up to these observations, we interviewed various providers and deployed the 'Five Whys' methodology to determine root causes. Many providers recognised a need for a more aggressive approach to insulin dosing prior to surgery but voiced concern about the potential for hypoglycaemia even though a mutually agreed on dosing regimen had already been established. Taking these concerns under advisement, we then used the Lean technique of Value Stream Mapping to further delineate more granular opportunities for improvement. We prioritised work in the area of preoperative care, thinking that this would set the trajectory of care in the right direction for the duration of the perioperative period.

RPIW

The RPIW team was tasked with eliminating defects in missed or delayed blood glucose monitoring and insulin prescribing outside the new paradigm. Interventions were generally focused on early, consistent signalling, simplifying and standardising care and then training the involved operators. First, rather than having preoperative diabetic medication management recommendations come from any of the over 150 surgical providers, we routed all patients through the Pre-Anaesthesia Assessment Clinic for standardised diabetic medication management. This required early coordination between anaesthesia and surgical providers. By routing all patients with diabetes undergoing surgery through the Pre-Anaesthesia Assessment Clinic, the number of operators who might offer instruction to the patient was significantly decreased. There was an algorithm that directed providers how to adjust medications in the days leading up to surgery. This algorithm was associated with standard work for the eight preanaesthesia assessment clinic nurses to assist in delivering diabetic instructions to the patient, ensuring a fundamentally consistent approach to preoperative care. Second, in order to identify patients in need of blood glucose monitoring or a HbA1c check, the team developed a report, delivered daily to surgery prep. Third, on arrival on the day of surgery, the Surgery Prep nurse, nursing assistant and charge nurse were the key operators in point of care testing for blood glucose. There was standard work for signalling the anaesthesia technician and anaesthesia provider to pull point of care blood glucose testing every 2 hours from Surgery Prep to PostAnaesthesia Care Unit. Fourth, the team produced an algorithm for action in response to abnormal fasting glucose in patients with and without diabetes. Standard work was developed for all the involved team members. Subsequently, a lean '5S' exercise was done to clean out and simplify the anaesthesia computer workspace, in order to remove outdated documents and make the new standard work as well as related documents easily accessible. Finally, a skills map was developed, and customised training for the relevant standard work was delivered to all team members. Visual cues embedded in the workflow

were a prominent feature of this training and included the insulin dictionary as well as a quick reference regarding which patients should be tested. The workshop leader visited the area on a daily basis to perform a contemporaneous review of which patients had been tested, to determine the test result and to help solidify the subsequent actions. Steady, constructive and supportive feedback was given to the team by the workshop leader.

Postintervention implementation

Post-RPIW, the team was coached on their new standard work, the workshop leader collected feedback, and through several cycles of PDSA, made incremental changes to truly capture best practices for the standard work. The team developed a tool called the Standardised Picture of the Diabetic to assist in documentation of diabetes history for the EHR. This template included the type of diabetes, daily antidiabetic medications including insulin, total body weight and HbA1c if available. This solidified the standard work. Over the next month, in another cycle of PDSA, a 'Pre-Anaesthesia Assessment Clinic Instructions for Diabetic Patients' table was developed by the frontline providers. The table was a visual aid that could be used by the nurse during the interview to quickly ensure that the patient was receiving the right instructions. Over the next several months, the nurses in the Pre-Anaesthesia Assessment Clinic developed a documentation template for the instructions given to the patient that could be quickly inserted into the EHR during the interview. Blank spaces in the template served as prompts for discussion and entry in the record. The template and the table both became valuable tools for training of new nurses to the clinic. These also became invaluable tools to quickly help determine the cause of why a patient might not have followed the expected protocol.

Retrospective aggregate rates of hyperglycaemia and hypoglycaemia were shared with the team as data became available, and they received positive feedback as their rates of hyperglycaemia decreased. We continue our educational support with an annual diabetes CME course and weekly insulin safety rounds to present day. In addition, shortly after the RPIW, in January of 2013, we launched an interface within the EHR called the Diabetes Tracking Board that made highly visible to the entire ward unit information on the glycaemic control status of each patient. This board created situational awareness of which patients are diabetic, thus warranting close attention to blood glucose monitoring and management. This visual cue allowed for routine surveillance and ongoing coaching in real time, a so-called 'measure-vention,' and served as a trigger to activate the RPIW derived care roadmap for abnormal blood glucose results.

RESULTS

In order to evaluate the effectiveness of the intervention, we performed a single institution time series quality improvement study. Our study population was those

patients undergoing orthopaedic surgery, most commonly elective hip and knee replacement. This population was selected because a major component of the intervention was the provision of standardised preoperative instructions, which would affect only those patients undergoing elective surgery. The study period was from 1 January 2011 to 31 December 2017. Baseline metrics were measured from 1 January 2011 through 31 December 2012. The intervention was implemented between 1 January 2013 and 28 February 2013.

There were 6466 blood glucose values were used in the analysis of 6466 unique patients undergoing orthopaedic surgery during the study time frame. Overall, 1123/5466 (20%) of patients carried a diagnosis of diabetes. The proportion of patients with diabetes decreased after the intervention, reflecting greater blood glucose surveillance, even in subjects without diabetes. Length of stay decreased and a greater proportion of patients were discharged directly home after our intervention. Other characteristics of the population, such as age and gender, were unchanged (table 1).

We tracked the number of blood glucose tests in patients without diabetes as a measure of implementation of the standard work, which included direction to measure these values. We observed a dramatic increase in number of blood glucose tests for patients without diabetes during the intervention, from 20/193 (10%) in

all 2012 to 868/1075 (81%) in 2013. This increase was sustained throughout the study period.

Following the intervention, there was a decrease in the rate of hyperglycaemia for patients undergoing orthopaedic surgical procedures from 15.1% to 9.4% ($p=0.003$) (table 2), that corresponded temporally to the intervention (figure 1). There was no significant increase in the rate of hypoglycaemia in either patients with diabetes (1/357 prior to intervention, 6/978 after intervention, $p=0.46$) or without diabetes (1/45 prior to intervention, 47/4936 after intervention, $p=0.39$, data not shown). In comparison, blood glucose in patients with diabetes who underwent cardiothoracic and vascular surgery (who more often have non-elective procedures) was unchanged, 32/125 (26%) before the intervention and 135/542 (25%) after the intervention ($p=0.87$, data not shown).

Lessons and limitations

In this report, we describe a targeted intervention using standardisation of care to an institutionally agreed on and evidence-based practice as an effective means to improve presenting blood glucose for patients undergoing elective surgery. We changed patient diabetic medication management from the chaotic and highly variable instructions given by over 150 surgical clinics to a very structured, rigorous set of algorithm-based instructions provided by

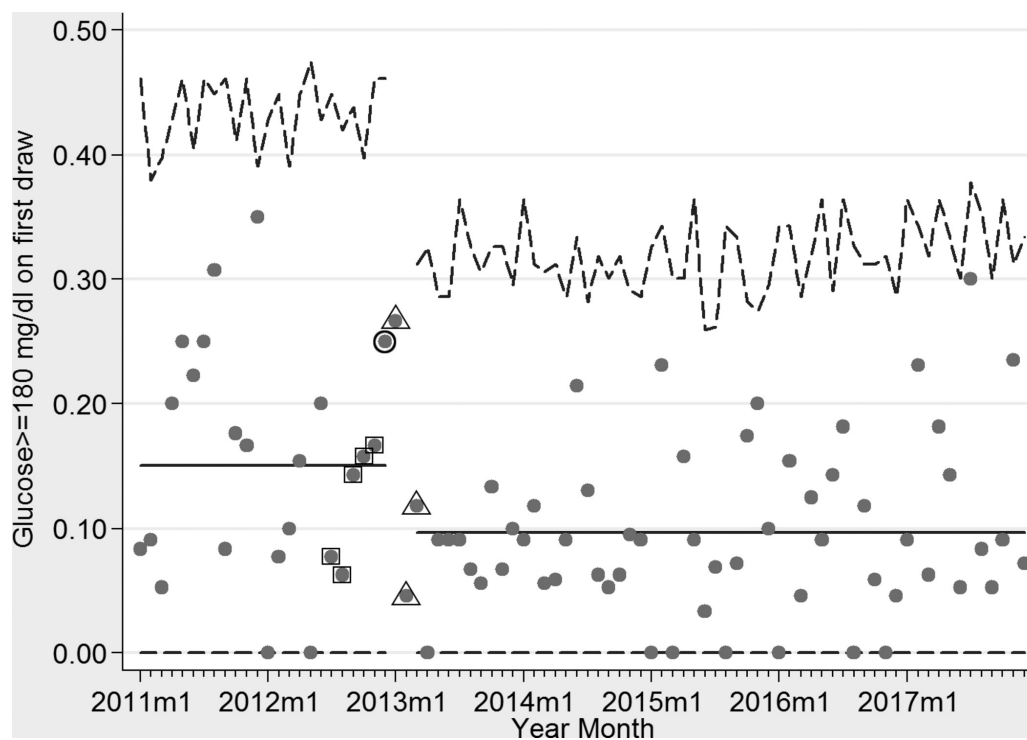


Figure 1 Run chart of initial blood glucose for patients with diabetes January 2011–December 2017. Statistical process control chart of the monthly proportion of patients with diabetes who had a blood glucose of ≥ 180 mg/dL on presentation for surgery before and after the implementation of standard work. The months marked with a square indicate the preintervention glycaemic control work that included development of the insulin dictionary and the glycaemic control summary page. The RPIW occurred in December of 2012, which is marked with a circle. The months of postintervention implementation period are marked with triangles, and included cycles of PDSA that were largely directed at visual cues and documentation in the EHR. EHR, electronic health record; PDSA, Plan-Do-Study-Act; RPIW, rapid process improvement workshop.

approximately eight trained nurses in the Pre-Anaesthesia Assessment Clinic. This reduction in variation and clear, explicit instructions resulted in a dramatic improvement in first blood glucose on presentation day-of-surgery. The intervention occurred in the context of an institutional commitment to glycaemic control, Lean management tools and a strong leadership presence. An institutional commitment was important because diabetes and hyperglycaemia affects a large population, and therefore, multiple providers across different disciplines and in different settings. This commitment created a good situational awareness and urgency related to glycaemic control which translated to engaged providers and better access to resources such as informatics support. The application of Lean principles, such as standard work, cycles of PDSA and visual cuing, has been associated with quality improvement in a variety of clinical settings.^{16 21–24} Front-line presence of operational and executive leadership also likely enhanced implementation. In combination, these factors promoted successful implementation and subsequent improvement in glycaemic control for this select group of patients.

Despite this rather positive clinical context, there were significant challenges in developing and deploying this work. For example, developing a consensus on best practices to adopt as standardised care was difficult due to limited and equivocal evidence for appropriate glycaemic targets.^{1 12} Furthermore, recommendations regarding appropriate management were also sparse at the time of this work.¹⁹ It is somewhat validating that, subsequent to our improvement efforts, work has been published with more definitive, explicit recommendations for insulin dosing in the perioperative period very consistent with our approach.¹ In addition to the challenges around evidence for clear targets and insulin management, establishing a clear link to clinical outcomes has been even more elusive which made physician buy-in even more difficult.²⁵ In spite of these barriers, the increased number of blood glucose tests for patients without diabetes supports a high rate of implementation of the standard work. However, we cannot say whether or not the patients were able to follow the preoperative instructions as provided; we can only say that the appropriate instructions were likely provided. Future similar attempts to develop a similar intervention might include patients in the development of the instructions and an assessment of patient adherence to the recommendations. Given the presence of executive and operational leadership, it is difficult to exclude the possibility of the Hawthorne effect in our work.

Our analysis was retrospective and the intervention had several critical elements. We used the principles of quasi-experimental design to strengthen our causal inference. However, even with a strong causal inference, it is difficult to ascertain the exact effect of each element in the intervention. In addition, there were other changes and improvements in the care of patients undergoing orthopaedic surgical procedures during this period, including the wide application of the adductor canal

block rather than the femoral nerve block for total knee replacements. The adductor canal block is done lower on the thigh and allows motor function (physical therapy) rather than the bed rest needed with the femoral nerve block. This improved earlier ambulation allowed quicker recovery and earlier discharge.^{26 27} However, it is not clear that the adductor block would have any effect on blood glucose.

Certain components of the intervention may be more generalisable than others, particularly due to the extensive work in the EHR that was required. We were early adopters of the EHR and have experience in programming customised web-based user interfaces such as we used in developing our visual cue. Even with adequate support to pursue the intervention in full, generalisability may be limited by other factors. In particular, the centralised preanaesthesia assessment process using a small number of operators might be somewhat unique to our institution. At a larger institution, or at one with more than one facility, keeping the relevant skills up-to-date for staff may prove to be overly cumbersome. This is a single institution investigation in a hospital with extensive experience in Lean management methods.

Taken as a whole and in the context of institutional buy-in with adequate technological support as well as a disciplined approach to quality improvement, such as Lean, we believe the combination of standardised care with visual cues to prompt action would be equally effective in improving preoperative blood glucose at other institutions.

CONCLUSION

In summary, rates of appropriate blood glucose monitoring and rates hyperglycaemia for patients undergoing orthopaedic surgery improved via the implementation of standard work developed with the tools of Lean and in the context of institutional support. This approach may be useful in other care settings or patient populations, potentially contributing to improved glycaemic control and subsequent decrease in associated complications.

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