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REVIEW

Preoperative considerations for patients with diabetes

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ABSTRACT

Introduction: Patients undergoing surgery require a thorough assessment preoperatively. Hyperglycemia is associated with poor outcomes, and stability of glucose levels is an important factor in preoperative management. Diabetes presents a particular challenge since patients are often on multiple medications encompassing glycemic management and cardiovascular therapies.

Areas Covered: A PubMed search of published data and reviews on preoperative approaches in diabetes was conducted. Consensus opinion drives most of the guidelines and recommendations for management of diabetes in surgical patients. Pathophysiology is often complex with varying levels of glucose and surgical stress. Establishing well-controlled diabetes prior to surgical intervention should be standard practice in non-emergent procedures. We review the best practices for implementing preoperative assessment, with diabetes with a focus on diabetes medications.

Expert opinion: The management of a patient preoperatively varies by region and country. Institutions differ in approaches to preoperative evaluation and the establishment of consistent approaches would provide a platform for monitoring patient outcomes. Multidisciplinary teams and pre-assessment clinics for preoperative evaluation can enhance patient care for those undergoing surgery.

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1. Introduction

Diabetes is a worldwide chronic disease with about 537 million affected including 30 million in the United States [1]. For patients undergoing surgery, an estimated 20% has diabetes, and there is an associated increased risk of morbidity and mortality of up to 50% higher compared to patients without diabetes [2,3]. Among general surgery patients (noncardiac), perioperative hyperglycemia was associated with an increased length of stay and higher mortality and hospital complications [3]. Early evaluation of the surgical patient is necessary to ensure optimal glucose control. High glucose levels are associated with impaired neutrophil function, increased free fatty acid formation, reactive oxygen species, and inflammatory mediator production [4]. Of concern is the risk of poor surgery outcomes, especially for individuals with comorbidities and uncontrolled diabetes [5,6]. Along with higher associated morbidity and mortality, diabetes and hyperglycemia are also associated with increased postoperative sepsis, surgical site infection, and delayed discharge [7–10]. The reasons for these outcomes are complex, but the lack of identification of patients with hyperglycemia, comorbidities, and complex medication regimens is a factor [8]. Randomized, controlled trials do not inform the mainstay of guidelines and consensus primarily comes from expert opinion. Overall, there are many guidelines with varying opinions on best practices [2,5,8,9,11,12].

Preoperative assessment (time-period before surgery) to ensure that patients with diabetes are in the best position to tolerate surgery is essential for positive outcomes. Many patients are overweight, posing a challenge to the anesthesia provider, if an airway must be established [13]. Furthermore, prediabetes or undiagnosed diabetes is often uncovered with patients unaware of their glucose intolerance [13,14]. Patients' understanding of how to navigate their diabetes medications preoperatively is an important component for preparation for surgery. The management of a patient's diabetes medicines preoperatively is imperative to assure optimization of glucose control. We review the literature and summarize approaches to preoperative management of patients and diabetes medications. We also offer an overview of frequently prescribed diabetes medications.

2. Pathophysiology

Diabetes is an endocrine and metabolic disorder encompassing dysfunction of insulin with expressions of insulin resistance and deficiency [15]. The inefficiency of the body to respond to insulin needs is a progressive process that leads to hyperglycemia and an elevated hemoglobin A1c (A1C). There is also increased hepatic glucose production coupled with low insulin concentrations and insulin resistance [16]. Genetic and environmental factors contribute to diabetes and the effectiveness of how the pancreatic beta cell responds over time to insulin demands [17]. Inflammation, autoimmunity, and metabolic stress are involved in the pathophysiology of beta cell mass and dysfunction [18]. The type of diabetes is important to determine as patients with Type 1 diabetes have absolute insulin deficiency and will require

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Article highlights

- Early evaluation of the surgical patient is necessary to ensure optimal glucose control as metabolic decompensation is a risk for patients with diabetes undergoing surgery.
- Some diabetes medications require adjustment prior to and the day of surgery
- Preoperative care coordination is necessary to assure optimal patient care and outcomes that is best facilitated by preoperative preparation in a collaborative process
- The use of algorithms for assessing patient risk and dosing medications preoperatively is being studied
- Current and future trends on glycemic control and preoperative anesthesia management will likely include continuous glucose monitoring

special attention to manage insulin therapy before surgery. Over 90% of patients with diabetes have Type 2 diabetes, which involves insulin resistance and deficiency over time with the use of both oral and injectable therapies [15,19].

The neuroendocrine response to surgery and anesthesia results in the physiological release of counterregulatory hormones (catecholamines, cortisol, glucagon, and growth hormone) triggering insulin resistance [10,20,21]. The cascade of increased hepatic glucose production and impaired insulin secretion, along with fat and protein breakdown, lead to elevated glucose [22]. Metabolic decompensation is a risk for patients with diabetes undergoing surgery. The pathophysiology of diabetes predisposes patients to the cardiovascular and renal comorbidities [18]. Additionally, patients with diabetes can pose a challenge during intubation as glycated collagen couples with stiff joint syndrome, making laryngoscopy extremely difficult [11]. Autonomic neuropathic complications of diabetes including gastroparesis factor into impaired gastric motility warranting consideration [11].

3. Preoperative assessment and glycemia goals

Since the management of diabetes can entail many types of therapies, a preoperative assessment is necessary, especially for patients who are at risk for ischemic heart disease, autonomic neuropathy, or renal compromise [2]. The pre-surgical workup includes a full evaluation of medications the patient is taking to maintain glucose control. The assessment of cardiac and renal disease along with evaluation of infection risk is necessary [20]. Additionally, some surgical procedures will require a patient to achieve a certain weight if they are obese or morbidly obese due to the risk of difficult airway management and ventilation [11]. Anesthesia work-up for patients with diabetes should also include electrophysiological and radiological studies.

Optimized diabetes management prior to surgery helps decrease the incidence of postoperative hypoglycemia and decrease hospital stay length [23]. Avoiding electrolyte disturbances and glucose emergencies such as diabetic ketoacidosis or a hyperosmolar hyperglycemic state is paramount for a surgical patient [23,24]. Studies have conflicting results on whether the severity of diabetes affects postoperative outcomes. Worley and colleagues [25] showed that the type and severity of diabetes did not predict postoperative outcomes, while Yong et al. [26] found an increase in postoperative outcomes and increased hospital length of stay for every percentage increase in A1C. Although there is a consensus that diabetes is a predictor of poor postoperative outcomes and longer hospital length of stay, there are inconsistencies in recommendations regarding the effect of diabetes severity as measured by A1C, in guidelines.

There is concern for a lack of pre-referral optimization to prevent unwarranted variation in care for patients with diabetes undergoing surgery [26,27]. A chart review of 268 patients, in the United States undergoing elective procedures, found that only 52% had an A1C checked prior to surgery [28]. A region-wide chart audit in the United Kingdom reports a rate of 71% for A1C evaluation preoperatively among 247 patients with diabetes [29]. Perioperative hyperglycemia is estimated to occur in 20–40% of patients undergoing general surgery, and for cardiac surgery, the occurrence of hyperglycemia is up to 80% [4,30]. Assessment of glucose goals pre-surgery is necessary to optimize treatment and prevent complications. Pre-assessment of a patient with diabetes includes measurement of the average glucose by measurement of A1C to assess overall average glycemic control [12]. Depending on the surgery, consideration of postponing elective procedures if A1C indicates poor diabetes control may be necessary.

There is no clear consensus for the glycemic targets needed for safely proceeding with surgical intervention or the preoperative A1C above which delay in elective surgeries is necessary. For example, an A1C greater than 8% signifies an average glucose over 200 mg/dl (11.1 mmol/L). The ADA recommends for elective surgeries that an A1C be < 8% whenever possible and the target for blood glucose should be 100 to 180 mg/dl (5.6 to 10.0 mmol/L), 4 hours before surgery [2]. Age as a factor also needs consideration as the ADA relaxes A1C goals in patients over 65 years of age with a goal of < 8%, in patients with other illness or impairments [31]. Reviews of perioperative assessment and management goals advocate for a glycemic target of <180 mg/dl (10 mmol/L) in critical patients and a blood glucose of <140 mg/dl (7.8 mmol/L), in stable patients [10]. If hyperglycemia occurs preoperatively, many institutions administer insulin, if glucose is >180 mg/dl. Surgery may need to be postponed if glucose >250 mg/dl (13.9 mmol/L) due to concern for poor outcomes or based on institutional guidelines. Some practices have also created specific clinics that address preoperative anesthesia and surgical screening [14]. A large multicenter ($n = 50$), prospective European study involving 5000 patients is underway to assess 30-day outcomes related to preoperative anesthetic management among patients with diabetes [32].

4. Guidelines and management

There are many guidelines available on how to care for diabetes preoperatively. A recent narrative review of three major guidelines including the American Diabetes Association (ADA) and the Centre for Perioperative Care (CPOC) outlines the perioperative management of diabetes [8,21]. The National Health Service Diabetes, United Kingdom, and the Australian

Diabetes Society (ADS) have also published guidelines [33,34]. There is a lack of universal consensus for best practice of preoperative management for patients with diabetes. Table 2 shows three examples of guidelines. For elective cases and A1C goal, the ADA identifies a recommended target of < 8%; however, there is a lack of guidance on when to cancel elective cases [2]. Meanwhile, the ADS and the recommend canceling elective cases for A1C of ≥ 9% and ≥ 8.5%, respectively [33]. Guidelines, supported by evidence from research, help anesthesia providers reduce unintended perioperative outcomes; however, there is still work needed. Anesthesia providers apply a holistic approach to perioperative glycemic control. Holistic approach means that all variables affecting possible glucose control instability must be reviewed. This entails clear communication with other healthcare providers, especially when a diabetes specialist is needed to decrease undesirable postoperative outcomes.

Innovative approaches are under investigation for preoperative fluid intake. There can be variability in preoperative fasting times and the onset of surgery [12]. The American Society of Anesthesiology recommends that a clear liquid diet can be ingested 2 hours before the start of surgery, taking into consideration preoperative assessments [34,35]. Preoperative fasting has been the mainstay of practice, but there is concern for catabolism due to the stress response from surgery. Release of catabolic hormones from surgical stress contributes to insulin resistance demonstrated by an increase in ketones. Although still controversial, recommended by CPOC as one of the research areas, preoperative carbohydrate loading through ingestion or intravenous infusion may assist with minimizing insulin resistance [36–38]. Preoperative carbohydrate loading has been studied in patients with diabetes [39,40] There is a risk of hyperglycemia in the early period of surgery [41–43]. Patients who undergo more than 1 hour of surgery may benefit from preoperative carbohydrate loading. Besides the risk of hyperglycemia, if ingestion of carbohydrate on the day of surgery is selected, it may increase the risk of aspiration. Among patients with type 2 diabetes, the effect of preoperative carbohydrate loading 2 hours prior to non-cardiac surgery was evaluated regarding aspiration threat with ultrasonography without complications [39,44,45]. The risk of pulmonary aspiration is a risk for patients with diabetes because of concerns about gastroparesis. Studies show higher gastric content and slower gastric emptying [23,46–48]. A narrative review of 10 carbohydrate loading studies reported little difference in gastric emptying and adverse effects between patients with and without diabetes [49]. Although carbohydrate loading has been studied in patients with diabetes with some success, more data are needed to assess perioperative glycemia, insulin response, outcome data, and enhanced recovery to inform best practices [43,49,50].

5. Medication considerations

There are many medications available to treat diabetes, including oral and injection therapies. There are 12 classes of drugs approved to treat diabetes, with some of the classes less commonly used such as dopaminergic agonists and bile acid sequestrants [16]. A review of medications, both prescription and non-prescription, is necessary preoperatively with consideration of which therapies should be adjusted or withheld prior to surgery. Table 1 outlines common diabetes medications including drug action profiles. Patient education is critical as errors are not uncommon and clear directions with a discussion of how to manage medication is necessary for the patient undergoing surgery [51,52].

5.1. Metformin

Metformin is a common oral medication that has been available for decades and is a first-line medication used in Type 2 diabetes treatment. There are several mechanisms for the action profile of metformin, but the primary mechanism includes the inhibition of gluconeogenesis with a role in insulin sensitization [7]. Metformin is not metabolized and is cleared via the kidneys [17,53]. Consideration of renal function is imperative when deciding on metformin management preoperatively as an estimated glomerular filtration rate of >30 ml/min is needed for safe use [54]. Gastrointestinal irritation consisting of abdominal pain, nausea, and diarrhea occurs with metformin, and an estimated 10% of patients are unable to tolerate metformin at any dose [55,56]. A rare side effect of metformin includes lactic acidosis, especially with severe renal dysfunction. Overall, metformin has a good safety profile and is often first line in patients with Type 2 diabetes.

Some guidelines advocate for withholding metformin on the day of surgery, while others promote continuation if renal function is stable. Table 2 outlines guidelines and opinions of how to manage metformin preoperatively. Typically, metformin not administered on the day of surgery and the ADA has embraced this practice. Other preoperative guidelines advocate withholding metformin when kidney function is compromised and if the use of contrast dye during perioperative radiological studies is anticipated [56,57].

5.2. Insulin secretagogues - sulfonylureas and meglitinides

Insulin secretagogues promote the pancreas to release endogenous insulin. The medications that promote insulin production from the pancreatic beta cell include the sulfonylureas and meglitinides (Table 1). These medications have been available for several decades and require pancreatic beta-cell functioning as the medications work to increase insulin production. The specific mechanism involves the inhibition of the K-ATP channel, provoking calcium influx into the beta cell [56]. Sulfonylureas are insulin secretagogues, have a long half-life with metabolized drug that is cleared by the kidney, and should be used with caution in the elderly and those with chronic kidney disease [57]. Meglitinides work by the same mechanism as a sulfonylurea and are insulin secretagogues but with a short duration of action. The action profile of both

Table 1. Pharmacological agents for glycemic control.

Class	Generic Name	Mechanism	Metabolism	Comments for Post- Surgery	Reference
Sulfonylurea Meglitinide	Glipizide Glimepiride Glyburide Glibenclamide Gliclazide Repaglinide Nateglinide	Stimulation of insulin secretion from pancreas by inhibition of K-ATP channel, provoking calcium influx into the β cell	Hepatically metabolized and renally excreted Glyburide and Glibenclamide very long half-life especially in elderly and renal dysfunction	Restart after food intake is resumed	[2,60,61]
Biguanide	Metformin	Inhibition of hepatic glucose production and intestinal absorption improves insulin sensitivity by increasing peripheral glucose uptake and utilization	Unmetabolized and renal excretion	Consideration if patient needs contrast dye or declining renal function Restart after 24 hours with stabilize renal function	[2,56–60]
Thiazolidinedione	Pioglitazone Rosiglitazone	Enhanced insulin sensitivity by activation of peroxisome proliferator-activated receptors – PPAR-γ	Metabolized with some renal excretion	Edema with increased risk of heart failure, fractures, weight gain Restart after food intake is resumed	[61,68–70]
Alpha-glucosidase inhibitor	Acarbose Miglitol Voglibose	Inhibition of intestinal glucose absorption	Low systemic bioavailablity	Restart after food intake is resumed	[66,68]
Dipeptidyl Peptidase-4 Inhibitors	Sitagliptin Saxagliptin Alogliptin Linagliptin Vildagliptin	Inhibition of endogenous GLP-1 degradation	Minimal metabolism, excreted by kidneys except Linagliptin	Restart after food intake is resumed	[61,68]
Sodium Glucose cotransporter 2 inhibitors (SGLT-2i)	Canaglifozin Dapagliflozin Empagliflozin Ertugliflozin	Inhibition of renal glucose reabsorption, promoting glucosuria	Metabolized via glucuronidation to inactive metabolites	Resume when hydrated and renal function stable	[62–67]
Glucagon like peptide-1 (GLP-1) Agonists	Exenatide Liraglutide Semaglutide Dulaglutide Lixisenatide	Activates GLP-1 receptor, increased insulin secretion, suppresses glucagon, delayed gastric emptying, increased satiety	Rapidly metabolized and inactivated by the enzyme dipeptidyl peptidase	Assure no nausea and vomiting and restart after food intake resumed.	[71–74]
Insulin	Variety	Work equally to endogenous insulin	Metabolized to amino acids	Basal insulin in reduced doses may be required and mealtime insulin can be restarted after food intake is resumed	[75–78]

sulfonylureas and meglitinides can lead to hypoglycemia that is a clinical issue in the fasting state as a patient prepares for surgery. Depending on the glucose control as well as the half-life and duration of insulin secretagogue, caution in use of these agents the day before and certainly the day of surgery. Severe hypoglycemia that continues even after treatment with glucose has been reported, especially with older sulfonylurea drugs (glyburide, glibenclamide), and therefore should be avoided, especially in renal dysfunction and the elderly.

5.3. Sodium glucose co-transporter 2 (SGLT-2) inhibitors

There are several SGLT-2 inhibitors available for diabetes treatment and Table 1 outlines the different agents in this class. SGLT-2 inhibitors have become widely used for the treatment of Type 2 diabetes while providing cardiovascular protection and benefits for heart failure. SGLT-2 inhibitors have been shown to improve cardiac function via a decrease in preload [58,59]. Various organizations recommend withholding SGLT-2 inhibitors before and the day of surgery due to the development of euglycemic ketoacidosis [60,61]. With the action of an SGLT-2 inhibitor that prevents the reabsorption of glucose by blocking sodium-dependent glucose transporter in the proximal convoluted tubule, glucose levels can be normal while metabolic issues are occurring, especially when a patient is in the fasting state. There are is increased glucagon secretion and suppression of insulin production with reduced clearance of ketones with increased body reabsorption [62]. Euglycemic ketoacidosis has been reported with the SGLT-2 inhibitors, a concern for patients with diabetes undergoing surgery [60,61]. Precipitating factors include acute infection, dehydration, surgery, pregnancy, patients being NPO and alcohol use [62,63]. Other side effects of SLGT-2 inhibitors include genital mycosis and urinary tract infections.

The drug manufacturer and the ADA recommend discontinuation of SLGT-2 inhibitors at least 3 days before surgery except for ertugliflozin that should be held 4 days before surgery [2]. The ADS similarly recommends holding SGLT-2 inhibitors, however, only 1 day before and the day of surgery or 2 days before surgery requiring inpatient stay and for patients having a colonoscopy. The ADS [33] gave additional recommendations on when to resume SGLT-2 inhibitors, which was lacking in the ADA guideline [2], restarting an SGLT-2 inhibitor 2 days after major surgery (if the patient is consuming a full diet) and allowing a one-day window of restarting an SLGT-2 inhibitor for minor surgery. The ADS recommended holding all oral and non-insulin injectable medications the day before and the day of surgery, except for SGLT-2 inhibitors [33]. Similarities and differences exist among the guideline recommendations that institutions and

geographic regions use to care for patients preoperatively. The guidelines outlined in Table 2 have not all incorporated recent recommendations, on the length of time to hold SGLT-2 inhibitors prior to surgery.

5.4. Thiazolidinedione

The thiazolidinedione class of medications work at the peroxisome proliferator activated receptor (PPAR-γ), resulting in increased insulin sensitivity that occurs very slowly [64]. There is increased glucose uptake in numerous tissues including adipose, muscle, and liver [57]. Pioglitazone is available while others in the class have been taken off the market due to complications related to risk of increased cardiovascular events and poor safety profile [64,65]. Rosiglitazone has limited availability and only obtainable through the Avandia-Rosiglitazone Medicines Access Program. The drug class can cause fluid accumulation in the form of edema and weight gain, along with risk of worsening heart failure, bladder cancer, and macular edema [66]. In patients undergoing surgery, careful assessment of drug use prior to surgery is needed as the medication has a long half-life. In general, discontinuation of pioglitazone on the day of surgery is recommended.

5.5. Alpha-glucosidase inhibitors

The action of alpha-glucosidase in the gut includes the breakdown of disaccharides into more easily absorbed monosaccharides [57]. The peak of glucose from food intake is reduced when alpha-glucosidase inhibitors are used, reducing the total amount of carbohydrate digestion and absorption [65]. The primary side effect of an alpha glucosidase inhibitor is flatulence and is due to the mechanism of action. If hypoglycemia occurs, the use of a pure form of glucose such as glucose tablets or gel is for treatment. In general, alpha-glucosidase inhibitors should be discontinued on the day of surgery.

5.6. Dipeptidyl peptidase-4 (DPP-4) inhibitors

Glucagon-like peptide-1 is a hormone secreted by the gastrointestinal tract and is an incretin hormone with a truly short half-life of 1–2 min [64]. The DPP-4 inhibitors are oral agents that work in the incretin pathway and inhibit the enzyme DPP-4 that breaks down GLP-1. Nasopharyngitis, upper respiratory tract infection, and headache are side effects with DPP-4 inhibitors. While these drugs lower glucose, the class does not offer cardiovascular benefits from studies done post-marketing and there are associated pancreatitis and pancreatic cancer reported [57]. The DPP-4 inhibitors should be withheld on the day of surgery.

5.7. Glucagon Like Peptide (GLP)-1 agonist

There are many actions of GLP including enhancing glucose-dependent insulin secretion from the pancreas, inhibiting glucagon secretion from the alpha cells and reducing gastric emptying that promotes satiety [57]. Table 1 includes the GLP-1 agents available that have become tremendously popular in diabetes and obesity treatment. Tirzepatide works with both glucose-dependent insulinotropic peptide (GIP) and at GLP-1 [67]. The primary side effects of these agents include nausea and vomiting. These injectable drugs are very potent and approved for type 2 diabetes and weight loss. Since many of the drugs in the GLP-1 injectable class are administered weekly (semaglitide, dulaglitide, tirzepatide), careful planning will be needed preoperatively to ensure timing optimal drug discontinuation [68]. An oral form of semaglutide is also available. For the GLP-1 agents administered daily, the patient should discontinue the medication on the day of surgery. Concerns regarding delayed gastric emptying and risk of regurgitation and pulmonary aspiration of gastric contents during anesthesia have led to recent recommendations from the American Society of Anesthesiologists Task Force to consider holding weekly GLP-1 agonist 1 week prior to surgery [69]. GLP-1 agonists have also been associated with biliary disease, pancreatitis, bowel obstruction, and gastroparesis [70]. Case reports of delayed gastric emptying include a proposed mechanism involving the activation of the vagal afferent nerves and the impact of GLP-1 receptors on gastric mucosal cells [71]. The guidelines covered in Table 2 have not incorporated this new information on weekly GLP-1 agonists.

5.8. Insulin

There are several approaches to managing insulin therapy for patients with diabetes during the preoperative period. Patients need some amount of insulin if they chronically maintain their diabetes with daily insulin dosing that can include both basal and mealtime insulin [72]. After determining the type of diabetes that the patient has and their usual insulin therapy, there is usually a reduction of insulin necessary on the day of surgery [73]. The use of fast or short acting mealtime (prandial) insulin on the day of surgery is not necessary since the patients are NPO and instructed to take nothing by mouth. Table 2 contains an overview of several guidelines on the management of insulin the evening before and day of surgery. There also needs to be consideration of renal function and risk of hypoglycemia.

Management of insulin and perioperative glycemic control for patients undergoing surgery was assessed in a Cochrane Review and found that intensive glycemic control with insulin was associated with more hypoglycemic events with a target glucose of 120 to 150 mg/dl (6.6 to 8.32 mmol/L), among 12 studies [74]. There was not adequate scientific evidence to recommend a near normal glucose goal for patients with diabetes in the Cochrane analysis. However, a meta-analysis in patients undergoing cardiac surgery with diabetes and on insulin concluded that strict glycemic control defined as a glucose <140 mg/dl (7.8 mmol/L) was associated with lower risk of atrial fibrillation and sternal wound infection compared to moderate glucose control of 140 to 180 mg/dl (7.8 to 10 mmol/L) [75].

5.9. Other diabetes medications

There are other prescription medications used to treat diabetes not outlined above. The ADA recommends a hold on all

Table 2. Preoperative guidelines from international organizations.

Preoperative Practice	American Diabetes Association	Australian Diabetes Society	Centre for Perioperative Care
Reference	2	34	8
A1C assessment for elective cases	target is < 8%	Measure within the preceding 3 months (preferably within 4–6 weeks prior); target < 9%	3 months before DOS; target is < 8.5%
Referral to a diabetes specialist	For hospitalized patients with diabetes	A1C ≥ 8.5%	For patients with A1C > 8.5% or on insulin pump
DOS blood glucose assessment	Check the DOS; target range for perioperative period is 100–180 mg/dl (5.5–10 mmol/L) within 4 hours of surgery	Check the DOS; Target range perioepratively is 90–180 mg/dl (5–10 mmol/L); pregnancy 72–106 mg/dl (4–6 mmol/L) and requiring high target 135–216 mg/dl (7.5–12.5 mmol/L) such as emergency surgery with previous poor glycemic control, hypocalcemia unawareness, prolonged QT interval or autonomic neuropathy, and >75 years old	Check DOS; Target range perioperatively is 6-10 mmol/L with up to 12 mmol/L may be acceptable
Long-acting insulin	75–80% doses or insulin pump basal insulin based on the type of diabetes and clinical judgment the day of surgery	Insulin regimen should be continued up to and including the night before surgery except where bowel preparation is required Reduce basal insulin by 20% if with recent overnight hypoglycemia	Recommendations depend on the frequency and time of administration. Prior to the day of surgery, only the morning administration has no dose adjustment, all other time of frequency requires administration of 80% of usual dose. On the DOS, several recommendations noted; however, the usual dose in AM insulin decreased by 20%.
Intermediate-acting insulin or mixed insulin	Half NPH dose on morning of surgery	Calculate the total dose of all insulins for morning and lunch. For AM surgery: Half of the total insulin dose should be given as an intermediate acting insulin only in the morning. For PM surgery: half of the total insulin should be given as an intermediate acting insulin only in the morning. Half of the morning rapid-acting insulin can be given with a light breakfast.	Mixed insulin has no dose adjustment prior to the day of surgery. On the day of surgery, half the premixed insulin dose while self-mix insulin requires taking the half of the total dose of intermediate acting insulin.
Short-acting insulin		For morning surgery: Hold morning and lunch dose For afternoon surgery: Half of dose with light breakfast.	No dose adjustment necessary day before surgery. On DOS, omit dose if no breakfast for morning surgery while take usual dose with breakfast for afternoon/evening surgery
Oral agents and non-insulin injectables	Hold all on DOS, except for SGLT2i, stop 3–4 days before DOS and DOS	Hold all on DOS except SGLT-2 Inhibitors For all surgeries, including cases needing bowel preparation such as colonoscopy, stop SGLT2i 2 days before DOS and on DOS For minor surgeries without bowel preparation, only hold during DOS	Except for SGLT-2 inhibitors that is omitted on the day before surgery, all non-insulin diabetes medication are taken as usual a day before the surgery. Morning dose of acarbose, meglitinide, metformin, and sulfonylureas should be omitted on the DOS Take as normal pioglitazone, DPP-4 inhibitors, and daily GLP-1 receptor agonist on the day of surgery. SGLT-2 inhibitors are omitted on the day of surgery.

A1c = hemoglobin A1c, DOS = Date of Surgery, SGLT-2i = Sodium Glucose Transport 2 inhibitor.

oral and non-insulin injectable antidiabetics on the day of surgery (except the class of SGLT-2 inhibitors and weekly GLP-1 medications). In general, the use of diabetes medication can be held on the day of surgery if there are no institution or specific guidelines recommended. In addition, cardiovascular medications should be considered in preoperative medication assessment [76].

6. Postoperative medication considerations

In general, medications may be restarted after normal food intake is resumed and the patient is discharged. Depending on a patient's glucose levels after refeeding, medication should be carefully added back into the maintenance regimen [4]. If patients need coverage of elevated glucose post-operatively, sliding scale or intravenous infusion of regular insulin guided by routine blood glucose checks is used

7. Conclusion

New medications are routinely prescribed and require a consensus approach for best practice. The management of diabetes medications is important in the preoperative setting and follow-up. Metformin is a common diabetes medication that is often the first line of defense for diabetes and requires assessment along with other frequently used diabetes medications. SGLT-2 inhibitor should be discontinued at least 3 days prior to surgery, if possible. Patients taking insulin will

need adjustment to their regimen, with most guidelines advocating at least half the basal dose the day of surgery.

Anesthesia administration and management in patients with diabetes focus on obtaining perioperative glycemic control; associated signs and symptoms; laboratory, electrophysiological, and radiological studies; and physical assessment. Guidelines for perioperative care are dependent on testing protocols and outcomes to formulate best practices. Glycemic control in the perioperative period is one of the foundational aspects in anesthesia practice because of the hemodynamic changes and airway and pulmonary management for patients with diabetes. Perioperative care coordination is necessary to ensure optimal patient care and outcomes and is best facilitated by preoperative preparation in a collaborative process. Measurable outcomes contribute to the safe anesthesia practice for patients with diabetes.

8. Expert opinion

Research contributes to the decisions of anesthesia providers in individually tailoring antidiabetic agents to decrease unintended perioperative outcomes. Standardized approaches and protocols for glucose monitoring are not uncommon for institutional implementation among surgical patients [77]. Multidisciplinary teams and pre-assessment clinics for preoperative evaluation enhance patient care for those undergoing surgery [2,5]. Ideally, a preoperative history and examination are conducted a few days before a planned surgery allowing less unanticipated findings on the the day of surgery. There are usually no interventions for improving modifiable medical conditions that require a longer time frame to optimally prepare a patient for surgery especially, to improve glucose and blood pressure, if not at goal [71,78]. Avoiding extreme changes in glucose too quickly is equally important to assure the patient is not at risk for side effects, especially cardiovascular [11].

The multitude of guidelines for preoperative approaches have similarities and controversies. Regional differences in practice, population characteristics and experts influence how guidelines are implemented. Institutional policies usually refer to their specific nation's guideline with policy development for diabetes care during the perioperative period; therefore, anesthesia providers' primary source of guidance on diabetes care during the perioperative period depends on the presence of their institutions' direction. Glycemic control will continue to be the focus of future interventions to be used for recommendations among organizations publishing guidelines. Avoiding hypoglycemia and glucose variability is equally important to address [79] Research and studies that are adequately powered will be needed to drive a consensus for the use of preoperative A1C for preoperative work up and the need to delay elective cases if patients are not at goal [11]. Optimal glucose optimization for the intraoperative and postoperative phases of surgery must also be consistent with recommendations. Meanwhile, the availability of continuous glucose monitoring (CGM) devices that provide real-time glucose values is becoming widespread. CGMs avoid some of the limitations of finger stick capillary blood glucose monitoring. Patients with diabetes have found CGM devices useful in glycemic control [80]. The dynamic impact of a CGM to assess the time in the target range will be included in future algorithms for diabetes [81]. Consensus will need to include guidance on the administration of pharmacological agents for glycemic control perioperatively. However, whatever information is gathered preoperatively, anesthesia providers must be able to find and synthesize all pertinent information so that they can produce an individually tailored anesthesia management plan that includes the medication management of patients with diabetes [12]. In the future, technological innovations, such as the use of artificial intelligence (AI), will help with research and decision structures for providers.

Advances are emerging in the future of preoperative anesthesia management for the diabetes population. Moreover, current technologies aim to support the decision-making process of anesthesia providers. Mobile devices may help in searching for guidelines in diabetes management. Overall, guidelines can usually be accessed freely. Documentation in electronic medical records is designed to show all patient information pertinent to anesthesia and alert providers of valuable information. The development of prediction models that stratify patient risk and decision-support technologies using artificial intelligence are being investigated [82]. Mobile apps developed for perioperative diabetes management. By classifying the status of diabetes, the app can recommend perioperative approaches, including insulin delivery [83]. The advent of AI is anticipated to accelerate literature search, creation, and access to data repositories, as well as development of decision support structures. The use of decision support structures should focus on approaches to glycemic control, prediction, and early detection of intraoperative and postoperative outcomes.

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Authors contribution

J.K.K. and C.F.G. were involved in data interpretation and drafting the manuscript. All authors contributed to the manuscript write-up and have approved the final version. All authors agree to be accountable for all aspects of the work.

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