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ISPAD CLINICAL PRACTICE CONSENSUS GUIDELINES 2018

ISPAD Clinical Practice Consensus Guidelines 2018: Management of children and adolescents with diabetes requiring surgery

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1 | WHAT'S NEW?

- Further consideration of different types of diabetes
- Increasing availability of insulin pumps
- Increasing use of glucose monitoring
- Increasing availability of new medications

2 | EXECUTIVE SUMMARY AND RECOMMENDATIONS

2.1 | Glycemic and metabolic goals for surgery

- To maintain blood glucose in a range of 5 to 10 mmol/L (90-180 mg/dL) [C].
- To avoid hypoglycemia [E].
- To prevent the development of keto-acidosis [E].

2.2 | Assessment of children and adolescents prior to surgery and/or anesthesia

- All children with diabetes should have a diabetes assessment prior to all types of surgery or anesthesia [E].
- Prior to elective surgery, children and adolescents with diabetes should ideally be formally assessed several days beforehand: to allow for a thorough assessment of glycemic control, electrolyte status, ketones (urine/ blood), and a formal plan for diabetes management made for surgery and/or anesthesia [E].
- If glycemic control is known to be poor and surgery cannot be delayed reasonably, consider admission to hospital before surgery for acute stabilization of glycemic control [C].

2.3 | Preoperative care for children with type 1 or type 2 diabetes treated with insulin

- Must be admitted to hospital if receiving general anesthesia [E].
- Scheduled as a first case of the day or the surgical list [E].
- Require intravenous (IV) site for use pre- or intraoperatively to treat hypoglycaemia [E].
- Require specific adjustment of insulin regimen considered according to major or minor surgery and glycemic control.

Abbreviations: BOHB, ß-hydroxybutyrate; CSII, continuous subcutaneous insulin infusion; GA, general anesthetic; ICU, intensive care unit; IV, intravenous; T1D, type 1 diabetes; T2D, type 2 diabetes

- Require insulin (albeit titrated/reduced), even if fasting, to avoid ketoacidosis [A].
- Require blood glucose testing at least hourly preoperatively to detect and prevent hypo- and hyper-glycaemia [E].
- Should have urine or blood ketone measurement if hyperglycaemia >14 mmol/L (250 mg/dL) is present [E].
- Can continue continuous subcutaneous insulin infusion (CSII) therapy, without any adverse effect on their blood sugar control or surgery/anesthesia, in certain cases of minor elective surgery [E].

2.4 | Intraoperative care

- Blood glucose should be monitored at least hourly during and in the immediate postoperative recovery phase [E].
- IV infusion with dextrose (5% dextrose/0.9% sodium chloride) during any major surgery and for patients treated with neutral protamin hagendorn (NPH) insulin [E].
- Consider an IV infusion initially without dextrose during minor surgery or procedures lasting for less than 2 hours if treated with basal/bolus insulin regimen or CSII [C].
- Adjust dextrose infusion and insulin accordingly to maintain blood glucose in the range 5 to 10 mmol/L (90-180 mg/dL) [C].
- If there is an unexpected acute hypotension, 0.9% sodium chloride must be infused rapidly, however, avoid potassium-containing fluids [E].

2.5 | Postoperative care

- Once the child is able to resume oral nutrition, resume the child's usual diabetes regimen [E].
- Give short- or rapid-acting insulin (based on the child's usual insulin: carbohydrate ratio and correction factor) [E].
- Note that insulin requirement may be increased after surgery due to stress, pain and inactivity, therefore more frequent blood glucose measurements are recommended for 24 to 48 hours following surgery [E].

3 | SPECIAL SITUATIONS

3.1 | Acute or emergency surgery [E]

- If ketoacidosis is present (pH <7.3 and/or bicarbonate <15 mmol/L), follow an established treatment protocol for diabetic ketoacidosis (DKA) and delay surgery (if possible) until acidosis, circulating volume and electrolyte deficits are stable or sufficiently corrected.
- DKA may mimic an acute abdomen, so correction of DKA and reassessment is prudent.
- If not in DKA, start IV fluids and insulin management as for elective surgery.
- During emergency major surgery in an acutely unwell child, CSII therapy should be discontinued.[1]

3.2 | Type 2 diabetes patients on oral medication alone

- Discontinue metformin 24 hours before major surgery (lasting at least 2 hours) and on the day of surgery for minor surgery [C].
- Discontinue sulfonylureas, thiazolidinedione, DPP-IV inhibitors, SGLT-2 inhibitors, and GLP-1 analogs on the day of surgery [E].
- Patients undergoing a major surgical procedure expected to last at least 2 hours should be monitored with hourly glucose tests and adjustment of dextrose infusion or insulin accordingly to maintain blood glucose in the range 5 to 10 mmol/L (90-180 mg/dL) [E].
- Restart medications once fully orally feeding other than metformin which should be withheld for 48 hours after surgery and until normal renal function has been confirmed.

3.3 | General recommendations and considerations

Whenever possible, surgery on children and adolescents with diabetes should be performed in centers with appropriate personnel and facilities to care for children with diabetes [E].

To ensure the highest level of safety, careful liaison is required between surgical, anesthesia and children's diabetes care teams before admission to hospital for elective surgery and as soon as possible after admission for emergency surgery [E].

Centers performing surgical procedures on children with diabetes should have written protocols for postoperative management of diabetes on the wards where children are admitted [E]. Individual hospitals need to formalize guidance on the management of patients receiving CSII therapy, to allow patients the choice to continue their therapy during surgery, as appropriate [E].

Based on current data, consider use of intermittent glucose monitoring and/or continuous glucose monitoring (CGM) systems perioperatively with caution, preferably under prospective follow-up research protocols only and with additional blood glucose assessments [E].

3.4 | Minor surgery/procedures [E]

In general, minor surgery or procedures are short, usually less than 2 hours (and often less than 30 minutes), with/without sedation or anesthesia, where rapid recovery is anticipated, and the child is expected to be able to eat by the next meal (within 2-4 hours). For example: endoscopic biopsies, magnetic resonance imaging (MRI) scanning or insertion of grommets.

- Can be managed with background basal insulin (glargine or reduced NPH insulin).
- IV to be sited.
- May be suitable to continue with CSII basal insulin or temporary basal reduction.
- Can leave CSII attached to patient as long as not in surgical field or diathermy plane (especially with metal cannula).

3.5 | Major surgery [E]

In general includes all surgery or investigations under anesthesia that is more than minor, generally >2 hours, have a high likelihood of postoperative nausea, vomiting, or inability to feed adequately postoperatively.

- Should receive an IV infusion with dextrose.
- Require blood glucose (BG) monitoring before, hourly during, and after the procedure to detect hypo- and hyperglycemia.
- Must coordinate the timing of preoperative food and fluid restrictions with anesthetist.
- Require specific adjustment of their insulin schedule.
- Require IV insulin infusion.

4 | INTRODUCTION

The management of diabetes in children now includes a wide array of insulin analogs, insulin delivery devices, insulin regimens, different types of insulin pumps, continuous and intermittent glucose monitoring. Safe management of the child with diabetes in the perioperative period requires not only an understanding of the pathophysiology of the condition requiring surgery but also a thoughtful consideration of each child's specific diabetes treatment regimen, glycemic control, anticipated postoperative course, and the nature of the environment into which they will be discharged. Therefore, it is essential that the surgeon and anesthetist (in particular) liaise with the child's diabetes team prior to any planned and especially any acute major surgery. Evidence-based controlled studies of perioperative care specifically for children with diabetes are generally lacking.

The current, revised guidelines are based on the 2009 and 2014 ISPAD Consensus Guidelines.[2,3] They are also informed by The National Evidence-Based Clinical Care Guidelines for type 1 diabetes for children, adolescents and adults from the Australasian Pediatric Endocrine Group and Australian Diabetes Society,[4] the Canadian Diabetes Association: Clinical Practice Guidelines for the Prevention and Management of Diabetes in Canada,[5] and the Association of Children's Diabetes Clinicians Care of Children under 18 years with Diabetes Mellitus Undergoing Surgery,[6] Association of Children's Diabetes Clinicians (ACDC).[7]

They include recommendations from a comprehensive review of perioperative management for children with diabetes published in the anesthesiology literature.[8] Because there are few relevant scientific papers on management of children during surgery, the recommendations are mostly based on expert opinion, according to the available pediatric studies and relevant adult literature. Where appropriate, guidelines for perioperative managements of adults with diabetes are considered and used to inform these recommendations.

5 | PERIOPERATIVE GLYCEMIC GOALS

The stress of surgery leads to a complex neuroendocrine stress response characterized by hyperglycemia and a catabolic state, and may thus affect glucose homeostasis in both populations with and without diabetes. In adult patients undergoing cardiac surgery, repeated postoperative hyperglycemia was associated with increased rates of infectious complications (12.1% vs 8.2%), stroke (4.9% vs 1.5%), and mortality (6.1% vs 2.1%), despite use of a tight blood glucose control protocol [B].[9] While there are no published data on impact of poor vs good glycemic control of diabetes in surgical outcomes in children, studies in adults suggest that there is an increase in postoperative complications. Hyperglycemia among poorly controlled individuals with diabetes has also been associated with an increased risk of postoperative infection.[10] Large studies of adults with type 2 diabetes had an approximately 10-fold increased risk of postoperative wound infections.[11] Furthermore, a retrospective report [C] comparing patients with and without diabetes mellitus undergoing similar surgery, demonstrated that preoperative hyperglycemia was an independent predictor of infectious complications and length of hospital stay.[12] A meta-analysis including comprehensive integration and analysis of eight studies revealed a significant correlation between higher preoperative HbA1c levels and risk of target vessel revascularization progression (odds ratio [OR] 1.36, 95% confidence interval [CI] 1.03-1.82) and non-fatal myocardial infarction after Percutaneous Coronary Intervention (OR 2.47, 95% CI 1.38-4.44). However, no significant association was found between HbA1c levels and major adverse cardiovascular events, all-cause mortality, or cardiac death [B].[13]

Since the adult literature shows that outcomes are affected by the state of patients with diabetes before undergoing surgery, these studies allow us to make the following recommendation: to improve an elective (non-urgent) major surgery outcome, consider admission to hospital prior to elective surgery for assessment, and stabilization if glycemic control is poor [C]. As a rule, insulin dosage may need to be adjusted significantly at/or around major surgery and for several days after surgery.[14]

Only a few reports regarding the appropriate glycemic targets during the perioperative period are available in the pediatric age group with or without diabetes. There are currently sufficient data in the adult non-diabetes population, but few RCT's in the pediatric population to give recommendations, so this topic is still relatively controversial.

Initial evidence among adult critically ill patients showed benefits of intensive insulin therapy and tight glycemic control, based on a one center experience [B].[15] However, subsequent data are not consistent and even suggest harm of tight glycemic control in adult populations [A, B].[16] Furthermore, a large multicenter randomized international trial showed that a glycemic target of 8 to 10 mmol/L compared with intensive insulin treatment of 4.4 to 7 mmol/L was associated with decreased 90-day mortality [A].[17] A Cochrane database systematic review found insufficient evidence to support strict glycemic control vs conventional management for the prevention of surgical site infections.[18]

6 | IS THIS TARGET OF 5 TO 10 MMOL/L (90-180 MG/DL) APPROPRIATE IN PATIENTS WITH DIABETES MELLITUS UNDERGOING SURGERY?

Some studies in adults suggest that perioperative hyperglycaemia is an independent risk factor for postoperative mortality and morbidity.[19,20] Maintaining the blood glucose level after surgery at <11.1 mmol/L significantly reduced the incidence of deep wound infection in adults with diabetes undergoing coronary artery bypass.[21,22] However, tighter glucose control may carry a greater risk of both absolute and relative hypoglycemia in these patients.[23] Such hypoglycemia may also be particularly dangerous as patients may experience both unawareness and autonomic instability, especially with recent hypoglycemia.[24,25] A Cochrane database review on the topic of perioperative glycemic control for individuals with diabetes undergoing surgery did not demonstrate significant differences for most of the outcomes when targeting intensive perioperative glycemic control compared with conventional glycemic control.

However, intensive glycemic control was associated with an increased number of patients experiencing hypoglycemic episodes.[22] Therefore, Intensive glycemic control protocols with near-normal blood glucose targets for patients with diabetes mellitus undergoing surgical procedures are currently not supported by an adequate scientific basis. A prospective one center interventional study explored more liberal blood glucose management in critically ill patients with diabetes, allowing a range of 10 to 14 mmol/L (180-250 mg/dL) in comparison with the conventional protocol of 8 to 10 mmol/L (150-180 mg/dL) among 80 intensive care unit (ICU) adult in-patients with diabetes [C].[26] The liberal protocol resulted in a significantly lower number of patients experiencing >30% decrease in glucose compared with their premorbid glycemic average, without significantly increasing the incidence of glucose ≥14 mmol/L (250 mg/dL).

Pediatric reports in individuals without diabetes include older retrospective studies which have consistently shown an association between both hyperglycemia and hypoglycemia and poor outcomes in the pediatric critical care setting [C],[27–30] and more recent RCTs with more specific glucose ranges among critically ill children, including post cardiac surgery (tight control was 4.4 to 6.1 mmol/L/80-110 mg/dL) and post burns [A,B].[31–3435–37]

A single center report [A] showed shorter length of hospital stay, and decreased mortality in pediatric patients randomized to targeting age-adjusted normo-glycemia; however, the rate of severe hypoglycemia (<2.3 mmol/L/<40 mg/dL) was 25%.[34] A multicenter trial [A] demonstrated tight glycemic control that did not have a significant effect on major clinical outcomes, but was associated with a higher rate of hypoglycemia than conventional glucose control.[35] Systematic reviews and meta-analysis [B] have shown that, while acquired infection was reduced, there was no decrease in 30-day mortality and a higher incidence of hypoglycemia was observed.[33,38] A multicenter randomized controlled trial (RCT) [A] using CGM in pediatric critically ill patients was stopped prior to enrolment completion due to lack of benefit and evidence of harm in low target arm (4.4-6.1 mmol/L/80-110 mg/dL, median 109) compared with the higher target arm (8-10 mmol/L/150-180 mg/dL). No significant differences were observed in mortality, severity of organ dysfunction, or the number of ventilator-free days, while patients in the lower-target group had higher rates of health care-associated infections and higher rates of severe hypoglycemia.[39]

The American College of Physicians developed guidelines for glycemic control in hospitalized adult patients with or without diabetes. Their Best Practice Advice includes target blood glucose level of 7.8 to 11.1 mmol/L (140-200 mg/dL), and avoiding targets less than 7.8 mmol/L (<140 mg/dL).[40] The American Association of Clinical Endocrinologists and American Diabetes Association recommends that an insulin infusion should be used to control hyperglycemia in the ICU setting, with a starting glycemic threshold of no higher than 10 mmol/L (180 mg/dL).[41] Once intravenous (IV) insulin therapy has been initiated, blood glucose should be maintained between ~8 and 10 mmol/L (140 and 180 mg/dL).

Our recommendation for glucose target in the pediatric diabetes population is similar. Although appropriate perioperative glycemic targets for minor surgical procedures are less clear, studies in adults that compared different methods of achieving glycemic control during minor and moderate surgery did not demonstrate any adverse effects of maintaining perioperative glycemic levels between 5 and 11 mmol/L (∼90-200 mg/dL).[42,43]

Therefore, based on the available data, it seems reasonable to aim for blood glucose in the range 5 to 10 mmol/L (90-180 mg/dL) during all surgical procedures in children, followed by a treatment target of 7.8 to 10 mmol/L (140-180 mg/dL) in the postsurgery ICU setting [C].

7 | IS THERE A ROLE FOR SUBCUTANEOUS GLUCOSE MONITORING DURING THE PERIOPERATIVE PERIOD?

The most frequently used methods for perioperative blood glucose monitoring are repeated venous, arterial line, or capillary blood glucose assessments, which may miss inter-measurement variability. We may overcome the challenge of glucose variability and hypoglycemia in the perioperative setting by the use of subcutaneous glucose monitoring such as CGM and intermittent glucose monitoring. Given the benefits of maintaining euglycemia during surgery, CGM provides a potential option of intensively monitoring glucose before, during and after surgery.

However, evidence for the accuracy, readability and effect on glucose control and prognosis using CGM in operative setting is still lacking. The overall accuracy and reliability of CGM systems during and postsurgery may be inaccurate (Pearson correlation coefficient between CGM and conventional glucose monitoring methods ranges from 0.69 to 0.92). A single center study of a small cohort using CGM with and without diabetes undergoing cardiac surgery demonstrated limited reliability due to incorrect hypoglycemic readings in the postoperative period [C].[44] A small study of children without diabetes undergoing cardiac surgery showed high measurement failure rate in the operating theater which was thought to be due to interference with electrical equipment (correlated in time to use of electrocautery by the operating surgeon), though not affected by hypoglycemia, inotrope use or edema [C].[45]

Another option is the use of intermittent glucose monitoring system, the subcutaneous FreeStyle Libre blood glucose measurement system. Intermittent glucose monitoring was shown to have similar overall mean absolute relative difference as CGM systems in at-home conditions among type 1 diabetes mellitus patients [C].[46] Intermittent glucose monitoring system was assessed among eight adult critically ill patients with diabetes and showed high test-retest reliability and acceptable accuracy when compared with arterial blood glucose measurement [C].[47]

Our recommendation is to use intermittent glucose monitoring and CGM systems peri-operatively with caution, preferably under prospective follow-up research protocols only and with additional blood glucose assessments [E]. We anticipate additional data to inform this recommendation in the near future.

8 | CLASSIFICATION OF PROCEDURES AND PRESURGICAL ASSESSMENT

In the management of children with diabetes undergoing surgery it is helpful to divide procedures into two categories: major and minor surgery. Considering this, it must be taken into account that coordination for "major" surgery in a well-controlled child with diabetes may be less complex than for "minor" surgery in a poorly controlled child with limited social support.

(A) **Minor surgery** or procedures that require a brief general anesthesia (GA) [or heavy sedation], usually of less than 2 hours duration, and which should not have a major impact on glycemic control. Examples include common day surgery procedures: endoscopies, duodenal biopsy, adeno-tonsillectomy, grommet insertion, and simple orthopedic procedures.

The child will usually be discharged from hospital on the day of the procedure. Likewise, repeated minor procedures performed on hospitalized patients receiving treatment for cancer or patients with severe burns are of short duration (eg, dressing changes) and may also be considered minor.

(B) **Major surgery** that requires more prolonged GA is associated with greater risks of metabolic decompensation, and the child is unlikely to be discharged from hospital on the day of the procedure. These surgeries are typically expected to last for at least 2 hours.

All children with diabetes should have a diabetes assessment prior to all types of surgery or anesthesia.

Prior to elective surgery, children and adolescents with diabetes should be formally assessed several days beforehand: to allow for a thorough assessment of glycemic control, electrolyte status, ketones (urine/blood), and a formal plan for diabetes management made for surgery and/or anesthesia [E].

If glycemic control is known to be poor and surgery cannot be delayed reasonably, consider admission to hospital before surgery for acute stabilization of glycemic control [E].

9 | PREOPERATIVE CARE FOR CHILDREN WITH TYPE 1 OR TYPE 2 DIABETES TREATED WITH INSULIN

- Must be admitted to hospital before surgery if receiving general anesthesia [E]
- If the patient has other reasons to be in hospital or diabetes is not well controlled, then admission before surgery would be warranted [E].
- Should be scheduled as a first case of the day or the surgical list [E].
- Require IV sited for use pre- or intraoperatively to treat hypoglycemia [E].
- Require specific adjustment of insulin regimen considered according to major or minor surgery and glycemic control.
- Require insulin (albeit titrated/reduced), even if fasting, to avoid ketoacidosis [A].
- Require blood glucose testing at least hourly pre- during and post-operatively to detect and prevent hypo- and hyperglycemia [E].
- Should have urine or blood ketone measurement if hyperglycemia >14 mmol/L (250 mg/dL) is present [E].
- Can continue CSII therapy, without any adverse effect on their blood sugar control or surgery/anesthesia, in certain cases of minor elective surgery [E].

10 | MAJOR SURGERY (AS DEFINED ABOVE)

10.1 | On the evening before surgery

- Give the usual evening and/or bedtime insulin(s) and bedtime snack (some institutions reduce glargine [U100] by 50%).
- If on CSII, most continue normal insulin basal rates, (some reduce basal at 0300 by 20% if there is concern over hypoglycemia).
- Monitor blood glucose and measure blood ß-hydroxybutyrate (BOHB) or urinary ketone concentration if blood glucose is >14 mmol/L (250 mg/dL).

10.2 | Omit the usual morning insulin (short and long acting) on the day of surgery and start insulin infusion

- At least 2 hours before surgery, start an IV insulin infusion (eg, dilute 50 units regular [soluble] insulin in 50 mL of 0.9% sodium chloride, 1 unit = 1 mL) and provide IV maintenance fluids consisting of 5% dextrose and 0.9% sodium chloride (see Appendices A and B).
- Patients on CSII should discontinue CSII insulin delivery when the insulin infusion is started.
- Monitor blood glucose levels at least hourly before surgery and as long as the patient is receiving IV insulin, dependent on recovery, level of consciousness and ability to have clear fluids.

- Aim to maintain blood glucose between 5 and 10 mmol/L (90-180 mg/dL) by adjusting the IV insulin dose or the rate of dextrose infusion during surgery.
- If BG <4 mmol/L (70 mg/dL)—give bolus of IV 10% dextrose 1-2 mL/kg; re-check BG 15 minutes later and repeat if necessary. If still <4 mmol/L (70 mg/dL), stop IV insulin for 15 minutes and recheck and discuss with diabetes team.
- When oral intake is not possible, the IV dextrose infusion should continue for as long as necessary.

11 | MINOR SURGERY (AS DEFINED ABOVE)

Algorithms for different types of insulin regimens are suggested below in general. For more detail, see Reference.7

11.1 | For all insulin regimens—if the following occurs

BG <4 mmol/L (70 mg/dL)—give bolus of IV 10% dextrose 2 mL/kg; re-check BG 15 minutes later and repeat if necessary.

BG >14 mmol/L (250 mg/dL) for >1 hour—consider subcutaneous rapid-acting insulin using the patient's usual correction factor or 5% to 10% of the child's usual total daily dose. Urine or blood ketones should be measured and an IV insulin infusion considered if significant ketone production is present (most units consider serum ketones of >0.6 mmol/L significant).

1. Patients treated with twice daily basal (NPH, insulin detemir, or glargine) and rapid- or short-acting insulin, or once daily basal-bolus regimen using multiple daily injections.

Morning operations

- On the morning of the procedure, give the usual dose of long-acting insulin (glargine, detemir) if usually given at this time. If preoperative evaluation shows a pattern of low blood glucose values in the morning, consider reducing the dose of long-acting insulin by 20%-30% (both doses if twice daily long acting).
- In general omit the rapid-acting insulin (eg, insulin aspart, insulin lispro, and glulisine) in the morning until after procedure when they can have it with the late breakfast. Consider rapid-acting insulin, however, to correct significant hyperglycemia and/or significant ketone (>0.1 mmol/mol) production is present.
- Reduce morning NPH by 30% to 50% depending on the length of the procedure.
- Consider commencing IV fluids: Some centers will use IV fluids routinely; others will consider on individual basis pending length of operation and current glucose concentration. Patients on basal/bolus with a target range blood glucose may initially utilize IV fluids without dextrose. However, IV infusion with dextrose (5% dextrose/0.9% sodium chloride) should be started for all patients treated with NPH insulin.
- Alternatively, IV insulin infusion may be started as described above.

Afternoon operations (if unavoidable)

- On the morning of the procedure, give the usual dose of long-acting insulin (if usually given at this time).
- If allowed to eat breakfast, give the usual dose of rapid-acting insulin or 50% of the usual short-acting insulin, and if applicable, give the usual dose of NPH insulin. If morning oral intake will be limited, consider reducing the morning NPH by 30%.
- If the anesthetist allows the child to eat a light breakfast and to consume clear liquids up to 4 hours before the procedure, IV fluid administration (and IV insulin infusion, if applicable) should commence 2 hours before surgery or no later than midday (see Appendices A and B) if that is the diabetes team choice of management.

2. Patients treated with CSII

- If possible, and provided the anesthetist agrees, use of continuous subcutaneous insulin infusion may be continued during a surgical procedure. If the anesthetist is not confident with CSII (pump) management, it is safest to remove the insulin pump and substitute an IV insulin infusion to deliver insulin, as described above.
- When a child on CSII goes to the operating theater, it is important to secure the subcutaneous infusion cannula to prevent dislodgement and interruption of insulin delivery during the procedure.
- If the GA is short (<2 hours), the pump can continue to infuse insulin at the basal rate appropriate for the time of day.
- Basal rate can be suspended, if necessary, for no more than 30 minutes to correct any episodes of mild hypoglycemia.
- Do not give a bolus dose of rapid-acting insulin unless necessary to correct hyperglycemia and/or significant ketone production as above.
- Consider commencing IV fluids. Patients with a target range blood glucose may initially utilize IV fluids without dextrose. With an appropriately titrated basal rate, this approach may be more physiologic.[48,49]
- Alternatively, IV insulin infusion may be started as described above.

11.2 | Intraoperative care

- Surgical stress may cause hyperglycemia and increased insulin requirements.
- Anesthesia may cause vasodilatation and hypotension.
- Monitor blood glucose measurements at least hourly, but preferably every 30 minutes, during and immediately 1 to 2 hours after GA.

If necessary, begin dextrose infusion or increase dextrose concentration of IV fluids from 5% to 10% to prevent hypoglycemia. Adjust dextrose infusion and insulin dose (by subcutaneous injection of rapid-acting insulin for minor surgery) to maintain blood glucose in the range 5 to 10 mmol/L (90-180 mg/dL). For those receiving an IV insulin infusion, a single correction bolus of IV insulin (either using the child's usual correction factor or 5%-10% of the child's usual total

daily insulin dose, depending on the severity of hyperglycemia) may be given at the start of the infusion to correct hyperglycemia.

Thereafter, correction of hyperglycemia should be based on adjustment of the rate of the IV insulin infusion (Appendix A). If the blood glucose exceeds 14 mmol/L (>250 mg/dL), urine or blood ketones should also be measured. If there is an unexpected acute drop in blood pressure, 0.9% sodium chloride is the preferred IV fluid and care should be taken to avoid fluids with potassium.

11.3 | Postoperative care

After surgery, start oral intake or continue IV dextrose infusion depending on the child's condition. Continue the IV insulin infusion or additional short- or rapid-acting insulin as necessary until oral intake is resumed.

Once the child is able to resume oral nutrition, resume the child's usual diabetes treatment regimen.

Give short- or rapid-acting insulin (based on the child's usual insulin: carbohydrate ratio and correction factor), if needed, to reduce hyperglycemia or to match food intake. Keep in mind that insulin requirement could be higher due to postoperative stress, additional medications, pain, and inactivity.

11.4 | Special circumstances

11.4.1 | Emergency surgery

Although the majority of surgical procedures are elective, however, both minor and major surgical procedures may occur as emergencies. It is important to remember that DKA may present as an "acute abdomen" and that acute illness may precipitate DKA.

Before emergency surgery in a child with diabetes, always check blood glucose, blood BOHB (if available) or urinary ketone concentration, serum electrolytes, and blood gases if ketone or blood glucose levels are high.

Do not give fluid, food or medication by mouth because, in some emergency situations, the stomach must be emptied by a nasogastric tube. Always secure IV access and check weight before anesthesia. If ketoacidosis is present, follow an established treatment protocol for DKA and delay surgery, if possible, until circulating volume and electrolyte deficits are corrected and, ideally, until acidosis has resolved. If there is no ketoacidosis, start IV fluids and insulin management as for elective surgery.

11.4.2 | Type 2 diabetes patients on oral medication alone

For patients with type 2 diabetes treated with insulin, follow the insulin guidelines as for elective surgery, depending on type of insulin regimen. For pediatric patients with type 2 diabetes on metformin, the timing of discontinuation will depend on the expected length of the procedure. Use of metformin has been associated with lactic acidosis, with risk that is increased by renal insufficiency.[50] As lactic acidosis is both a rare and life-threatening event, limited data are available to inform guidelines for perioperative management, and metformin may be useful in the postoperative hyperglycemic state.[51,52] Therefore recommendations are that for major surgery (lasting at least 2 hours) when conditions predisposing to additional risk factors (acute or chronic renal insufficiency, dehydration), metformin should be discontinued 24 hours before the procedure.

For minor surgery (ie, less than 2 hours), metformin may be discontinued on the day of the procedure. In all cases, metformin should be withheld for 48 hours after surgery and until normal renal function has been confirmed. For sulfonylureas, thiazolidinedione, DPP-IV inhibitors GLP-1 analogs, and SGLT-2 inhibitors stop the medication on the day of surgery. Patients undergoing a major surgical procedure expected to last at least 2 hours should be started on an IV insulin infusion as described above. For those undergoing minor procedures, monitor blood glucose hourly and if greater than 10 mmol/L (180 mg/dL), treat with subcutaneous rapid-acting insulin (0.1 unit/kg up to 10 units) no more frequently than every 3 hours.

11.5 | Cystic fibrosis diabetes on insulin

- Treat as per T1D with regular glucose monitoring and tailored insulin regimen.
- Rare to develop ketoacidosis, but test for urine or blood ketones if BG >14 mmol/L (250 mg/dL).

12 | CONCLUSION

Surgery or GA in children and adolescents with diabetes should be performed at centers with appropriate personnel and facilities to manage pre-, intra- and postoperative care at the highest standard available. Children with diabetes have increasingly complex devices to deliver insulin and measure glucose levels, as well as having marked variation in their degree of acute and chronic diabetes control.

Crucial to ensuring the highest level of safety is careful liaison between surgical, anesthesia and children's diabetes care teams before admission to hospital for elective surgery and as soon as possible after admission for emergency surgery. Centers performing surgical procedures on children with diabetes should have written protocols for postoperative management of diabetes on the wards where children are admitted.

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APPENDIX A: INFUSION GUIDE FOR SURGICAL PROCEDURES

MAINTENANCE FLUID GUIDE

0.9% sodium chloride with 5% dextrose

- Major surgery and any surgery when NPH has been given
- If blood glucose is high (>14 mmol/L/ 250 mg/dL), use 0.9% sodium chloride without dextrose and increase insulin; consider adding 5% dextrose when blood glucose falls below 14 mmol/L (250 mg/dL).
- Use maintenance rate (as outlined below).

Sodium

There is evidence that the risk of acute hyponatremia may be increased when hypotonic maintenance solutions (ie, 0.45% sodium chloride) are used in hospitalized children (many centers, therefore, use 0.9% sodium chloride due to concern over acute hyponatremia).

Potassium

Monitoring of electrolytes pre- and postoperatively is recommended. Only after completion of surgery and when the patient's vital signs are stable, consider adding potassium chloride 20 mmol/L of intravenous fluid. In case of urgent need for fluid resuscitation it is potentially dangerous to add potassium to the IV fluid, therefore hyperkalemia (confirmed with repeat measurement and electrocardiogram) and renal insufficiency are absolute contraindications to potassium infusion.

Children undergoing a brief procedure with a baseline normal serum potassium concentration and well-controlled diabetes have a small risk of hypokalemia. Those undergoing more prolonged surgeries or emergent surgeries during which metabolic decompensation is more likely, require intraoperative assessment of electrolytes and appropriate adjustment of the electrolyte composition of their IV solution.

Example of calculation of maintenance requirements

	Body weight	Fluid requirement/24 h
For each kg between	3-9 kg	100 mL/kg/24 h (for 5 kg child: ~20 mL/h)
For each kg between	10-20 kg	Add an additional 50 mL/kg/24 h (for 10 kg child: ~40 mL/h
For each kg over	20 kg	Add an additional 20 mL/kg/24 h

Maximum 2000 mL/24 h female, 2500 mL/24 h male.

Dextrose saline

The percentage is a mass percentage, so a 5% glucose/dextrose solution contains 50 g/L of glucose/dextrose or 5 g/100 mL. One unit of insulin utilizes 5 to 10 g of dextrose/h, so a child on 40 mL/h of 5% dextrose is being infused 2 g/h dextrose, which will require 0.1 to 0.2 units/h insulin (or as below for insulin infusion 0.025 U/kg/h insulin).

APPENDIX B: INSULIN INFUSION

• Add soluble (regular) insulin 50 units to 50 mL 0.9% sodium chloride, making a solution of 1 unit insulin/mL; attach to syringe pump and label clearly as such.

- Start infusion as follows once BG >4 mmol/L (>70 mg/dL)
- 0.025 mL/kg/hour (ie, 0.025 units/kg/h) if BG is <6 to 7 mmol/L (110-140 mg/dL)
- 0.05 mL/kg/h if BG is between 8 and 12 mmol/L (140-220 mg/dL)
- 0.075 mL/kg/h if BG is between 12 and 15 mmol/L (220-270 mg/dL)
- 0.1 mL/kg/h if BG is >>15 mmol/L (250 mg/dL)
- Aim to maintain blood glucose in range between 5 and 10 mmol/L (90-180 mg/dL) by adjusting insulin infusion hourly.
- Blood glucose must be measured at least hourly when the patient is on IV insulin.
- Do not stop the insulin infusion if blood glucose is between 5 and 6 mmol/L (90 mg/dL) as this will cause rebound hyperglycemia. Reduce the rate of infusion.
- The insulin infusion may be stopped temporarily if blood glucose <4 mmol/L (70 mg/dL) but not more than 10 to 15 minutes.