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ISPAD GUIDELINES

ISPAD clinical practice consensus guidelines 2022: Management of children and adolescents with diabetes requiring surgery

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1 | WHAT IS NEW OR DIFFERENT

- Management of youth with different types of diabetes undergoing surgery
- Use of diabetes technologies (pumps and sensors) in youth undergoing surgery
- Management of youth with type 2 diabetes (T2D) treated with new oral medications
- Management of diabetes in youth undergoing bariatric surgery

2 | EXECUTIVE SUMMARY AND RECOMMENDATIONS

Glycemic goals for surgery are to

- Maintain blood glucose level (BGL) in a range of 5–10 mmol/L (90–180 mg/dl). **C**
- Prevent hypoglycemia. **E**
- Prevent the development of diabetic ketoacidosis (DKA). **E**

Assessment of youth prior to surgery and/or anesthesia

- We recommend that young people with diabetes have a diabetes consultation prior to all types of surgery or anesthesia. **E**
- We recommend that young people with diabetes be formally reviewed by their diabetes team several days before elective surgery or a procedure under anesthesia for a thorough assessment of glycemia, ketones (urine/blood), and to create a formal plan for diabetes management prior to, during and after surgery and/or anesthesia. **E**
- If glycemia is suboptimal and surgery cannot be delayed, consider admission to hospital before surgery for acute optimization of glycemia. **C**

Preoperative care for youth with T1D, T2D or other types of diabetes requiring insulin

- Consider admission to hospital or day clinic with an anesthesiology team that has protocols for the management of diabetes, if receiving general anesthesia. **E**

- If outpatient surgery is planned, aim for glycemia to be in the target range and preoperative communication with the youth with diabetes and their families is essential. **E**
- The anesthesiologist is expected to be experienced in the management of insulin therapy in youth with diabetes and to have contact with the diabetes team in advance. **E**
- It is recommended that surgery is preferably scheduled as the first case of the day or on the surgical list, especially if performed in a day care setting. **E**
- An intravenous (iv) site for use pre- or intra-operatively to treat hypoglycemia is required. **E**
- The insulin regimen may need specific adjustments based on the procedure (major or minor surgery) and the pre-existing glycemia status. **E**
- If treated with an oral anti-hyperglycemic medication, this may also need to be modified. **E**
- Insulin is required, even if fasting, to avoid DKA. **A**
- BGL testing is required at least hourly to detect and prevent hypo- and hyperglycemia. **E**
- Measurement of urine or blood ketone level is advised if hyperglycemia >14 mmoL/L (250 mg/dl) is present. **E**
- Continuous subcutaneous insulin infusion (CSII) therapy can be continued in certain cases of minor elective surgery. **E**

Intraoperative care

- Monitor BGLs at least hourly during and in the immediate postoperative recovery phase. **E**
- Continuous glucose monitoring (CGM) can be used intraoperatively if deemed appropriate by the anesthesia provider and point-of-care (POC) BGL is validated concurrently. **E**
- Limited data exist on interactions between anesthetic agents and CGM, thus concurrent POC BGL monitoring is required. **E**
- Consider using iv infusion with dextrose (5% dextrose/0.9% sodium chloride) together with iv insulin infusion during any major surgery, and for young people treated with NPH insulin **E**.
- Consider an iv infusion of 0.9% sodium chloride, initially without dextrose, during minor surgery or procedures lasting less than 2 h if the young person with diabetes is treated with a multiple daily injection (MDI) regimen or CSII. **C**
- Adjust dextrose infusion and subcutaneous insulin to maintain BGL in the range 5–10 mmol/L (90–180 mg/dl). **C**
- If there is an unexpected acute hypotensive episode, 0.9% sodium chloride must be infused rapidly, however avoid potassium-containing fluids. **E**

Postoperative care

- Once the young person can tolerate oral nutrition, resume their usual insulin regimen. **E**
- Give short- or rapid-acting insulin (based on the usual insulin: carbohydrate ratio and correction factor). **E**
- It may be appropriate to give the first postoperative dose of insulin after initial oral intake to be sure that food is tolerated. **E**
- Insulin requirements may vary after surgery due to change in oral intake, nausea, stress, pain, and inactivity; therefore, frequent CGM/BGL measurements are recommended for 24–48 h following surgery. **E**
- Some CGM systems can provide false readings when exposed to specific medications (including acetaminophen), thus concurrent POC BGL monitoring may also be indicated. **C**
- BGL target of 7.8–10 mmol/L (140–180 mg/dl) in the postsurgery intensive care unit (ICU) setting is suggested. **C**

Special situations

Acute or emergency surgery

- DKA can mimic an acute abdomen. If DKA is present (pH < 7.3 and/or bicarbonate <18 mmol/L, and ketosis), follow an established treatment protocol for DKA and, if possible, delay surgery until acidosis, ketosis, circulating volume and electrolyte deficits are stable or sufficiently corrected. **E**
- If not in DKA, start iv fluids and insulin management as for elective surgery. **E**
- During emergency major surgery in an acutely ill child, discontinue CSII therapy. **E**

T2D or other types of diabetes requiring oral medications alone

- Discontinue metformin on the day of surgery. **C**
- Discontinue sulfonylureas, thiazolidinedione, DPP-iv inhibitors, and GLP-1 analogs on the day of surgery. **E**
- For young people with diabetes undergoing a major surgical procedure, expected to last at least 2 h, monitor hourly BGLs and adjust dextrose infusion or iv insulin to maintain BGL in the range 5–10 mmol/L (90–180 mg/dl). **E**
- Restart medications once oral intake is tolerated, except metformin, which should be withheld for 24 h after a major surgery, and until normal renal function has been confirmed. Metformin can be restarted once oral intake is tolerated after minor surgery. **E**

General recommendations and considerations

- Whenever possible, plan surgery to be performed in centers with appropriate personnel and facilities to provide optimal care for young people with diabetes. **E**
- To ensure the highest level of safety, careful liaison is required between surgical, anesthesiology and diabetes care teams before admission to hospital for elective surgery and as soon as possible after admission for emergency surgery. **E**
- It is recommended that centers performing surgical procedures on young people with diabetes have perioperative management protocols. **E**
- Individual hospitals need to formalize guidance on the management of people with diabetes receiving CSII therapy, to allow

individuals the choice to continue their CSII during surgery when appropriate. **E**

- Use of CGM systems is recommended to trend glucose levels perioperatively, but routinely verify CGM data by POC BGL measurements. **E**

Minor surgery/procedures

- Young people undergoing minor surgery/procedures can be managed with basal insulin (glargine or reduced NPH insulin) and may not need iv insulin infusion. **E**
- Intravenous access must be placed. **E**
- May be suitable to continue with CSII providing basal insulin or with a temporary basal rate reduction. **E**
- Can leave CSII attached to the individual with diabetes as long as it is not in the surgical field or diathermy plane (especially with metal cannula). **E**

Major surgery

- An iv infusion with dextrose is required to keep glucose in the range 5–10 mmoL/L (90–180 mg/dl) during major surgery. **E**
- Monitor hourly BGL monitoring before, during, and after the procedure. **E**
- Coordination of the timing of preoperative food and fluid restrictions with the anesthesiologist is needed. **E**
- Require specific adjustment of the insulin schedule. **E**
- Require iv insulin infusion. **E**

3 | INTRODUCTION

The management of diabetes in young people now includes a wide array of insulin analogs, insulin delivery devices, and CGM. Safe management of young people 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 the young person's specific diabetes treatment regimen, glycemia status, anticipated postoperative course, and the environment where they will be discharged. Therefore, it is essential that the surgeon and anesthetist (in particular) liaise with the diabetes team prior to and after any planned and especially any acute major surgery.

The current revised guidelines are based on the 2018 ISPAD Consensus Guidelines.[1] They are also informed by The National Evidence-Based Clinical Care Guidelines for T1D for Children, Adolescents and Adults from the Australasian Pediatric Endocrine Group and Australian Diabetes Society,[2] the Canadian Diabetes Association: Clinical Practice Guidelines for the Prevention and Management of Diabetes in Canada,[3] and the Association of Children's Diabetes Clinicians Care of Children under 18 years with Diabetes Mellitus Undergoing Surgery.[4] They also include recommendations from a comprehensive review of perioperative management for children with diabetes published in the anesthesiology literature.[5] Because there are few high-quality scientific papers on the management of young people with diabetes during surgery, the recommendations in this guideline are mostly based on expert opinion, in accordance with available evidence from pediatric studies and relevant adult literature. Where appropriate, guidelines for perioperative management of adults with diabetes used to inform these recommendations.

4 | PERIOPERATIVE GLYCEMIC GOALS

The stress associated with surgery leads to a complex neuroendocrine response characterized by hyperglycemia and a catabolic state, which may affect glucose homeostasis in people with and without diabetes. In adults undergoing cardiac surgery, repeated postoperative episodes of hyperglycemia, when compared with a single episode of hyperglycemia or normoglycemia, were 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 BGL management protocol.[6]

While there is limited evidence on the impact of preoperative suboptimal versus optimal glycemic management on surgical outcomes in young people with diabetes, studies in adults suggest that there is an increased risk of hyperglycemia-related postoperative complications.[7] Adults with T2D had an approximately 10-fold increased risk of postoperative wound infections[8] and, in this population, preoperative hyperglycemia was an independent predictor of infectious complications and length of hospital stay.[9] One recent study on postoperative outcomes in children with diabetes undergoing orthopedic surgery[10] reported that the 30-day complication, reoperation, and readmission rates for non-insulin treated children with diabetes were higher than for those without diabetes.

Based on the results of adult studies, to improve elective (non-urgent) major surgery outcomes, admission to hospital prior to elective surgery for the assessment and stabilization of people who do not achieve optimal glycemic targets should be considered, as well as adjustment of insulin doses prior to major surgery and for several days postoperatively.[11]

With regards to optimal perioperative glycemic targets, there are currently sufficient data in adults without diabetes, but few randomized clinical trials (RCT) in the pediatric population to give strong recommendations. Thus, this topic remains controversial. A study among critically ill adults showed benefits of intensive insulin therapy and tight glycemic management, based on a single center experience.[12] However, subsequent data are not consistent, and even suggest harm associated with tight glycemia in adult populations.[13] Furthermore, a large multi-center randomized international trial showed that a glycemic target of 8–10 mmol/L compared with a lower target of 4.4–7 mmol/L was associated with decreased 90-day mortality.[14] A Cochrane database systematic review found insufficient evidence to support strict glycemic management versus conventional management for the prevention of surgical site infections.[15]

5 | IS 5–10 mmol/L (90–180 mg/dl) AN APPROPRIATE BGL TARGET IN YOUNG PEOPLE WITH DIABETES UNDERGOING SURGERY?

Some studies in adults with diabetes suggest that perioperative hyperglycemia is an independent risk factor for postoperative mortality and morbidity[16,17] Maintaining BGLs after surgery at <11.1 mmol/L (200 mg/dl) significantly reduced the incidence of deep wound infections in adults with diabetes undergoing coronary artery bypass.[18,19] However, tighter glucose management may carry a greater risk of both absolute and relative hypoglycemia in these individuals.[20] Such hypoglycemia may be particularly dangerous as people with diabetes may experience both unawareness and autonomic instability.[21,22] A Cochrane database review did not demonstrate significant differences for most outcomes when comparing intensive perioperative with conventional glycemic management. However, intensive glycemic management was associated with an increased number of hypoglycemic episodes.[19] Therefore, protocols with intensive glycemic targets (near-normal BGL) for individuals with diabetes undergoing surgical procedures are currently not supported.

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.[23–26] More recent RCTs with more specific glucose ranges among critically ill children, including post cardiac surgery (tight glycemia was 4.4 to 6.1 mmol/L; 80–110 mg/dl) and post burns, showed that children do not benefit from tight versus more liberal glycemic targets.[27–32] Systematic reviews and meta-analysis have shown that, while acquired infection was reduced, there was no decrease in 30-day mortality and a higher incidence of hypoglycemia was observed.[29,33] A multicenter RCT using CGM in pediatric critically-ill individuals was stopped prior to enrolment completion due to lack of benefit and evidence of harm in the low target arm (4.4–6.1 mmol/L; 80–110 mg/dl, median 109 mg/dl) 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 participants in the lower-target group had higher rates of health care–associated infections and higher rates of severe hypoglycemia.[34]

The American Diabetes Association (ADA) published their guidelines for care in hospitalized adults with diabetes. The ADA recommends target BGL of 7.8–10 mmol/L (140–180 mg/dl) for most critical and non-critical ill people with diabetes. More stringent targets, such as 110–140 mg/dl (6.1–7.8 mmol/L), may be appropriate for selected individuals with diabetes if hypoglycemia can be avoided.[35] Glycemic targets for individuals with diabetes in the perioperative period should be 80–180 mg/dl (4.4–10.0 mmol/L).[35] Once iv insulin therapy has been initiated, BGL 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 quite similar. Although appropriate perioperative glycemic targets for minor surgical procedures are less clear, studies in adults that compared different methods of achieving glycemic management 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). Therefore, based on the available data, it seems reasonable to aim for BGL in the range 5–10 mmol/L (90–180 mg/dl) during all surgical procedures in children with diabetes, followed by a treatment target of 7.8–10 mmol/L (140–180 mg/dl) in the postsurgery ICU.

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

The most frequently used methods for perioperative glucose monitoring are still repeated venous, arterial, or capillary BGLs, which may minimize intermeasurement variability. Individuals may be particularly prone to glucose variability and hypoglycemia in the perioperative setting, given fasting requirements, variation in insulin administration, and physiologic derangements, including surgical stress.

CGM provides a potential option of intensively monitoring glucose levels before, during, and after surgery, where there are benefits to maintaining euglycemia. However, evidence for the accuracy, readability, and effect on glycemia and prognosis using CGM in the operative setting is still limited. The overall accuracy and reliability of CGM systems during and postsurgery may be variable (correlation coefficient between CGM and conventional glucose monitoring methods ranges from 0.69 to 0.92). A small study in children without diabetes undergoing cardiac surgery showed a high measurement failure rate in the operating theater, which was thought to be due to interference with electrical equipment, though not affected by hypoglycemia, inotrope use or edema.[36] A more recent study in 12 adults, comparing Dexcom G6 factory-calibrated CGM with BGL obtained during elective abdominal surgery, reported encouraging results, with a mean absolute relative difference (MARD) of 12.7 ± 8.7%, 99.2% of CGM measurements within Clarke error grid zones A and B, and CGM overestimated reference glucose by 1.1 ± 0.8 mmol/L.[37]

Another option is the use of intermittently scanned CGM (isCGM) (FreeStyle Libre system).[38] Intermittent glucose monitoring using the FreeStyle Libre system was assessed among 8 critically ill adults with diabetes and showed high test–retest reliability and acceptable accuracy when compared with arterial BGL measurement.[39] However Freestyle Libre should not be used during Magnetic Resonance Imaging (MRI), Computed Tomography (CT) scan, or high frequency electrical heat (diathermy) treatment as stated by the manufacturer. This applies also to Dexcom CGM.

Some drugs can interfere with CGM results. In particular, high doses of acetaminophen (paracetamol) are known to cause false elevations of glucose values (maximum up to 61 mg/dl difference) for up to 8 h.[40] Possible interference has been reported for hydroxyurea with Dexcom G6 and drugs like lisinopril, albuterol and atenolol with Medtronic Guardian and Dexcom G4 systems.[41,42] Further studies are

needed to investigate CGM accuracy with commonly used anesthetic agents.

Users of CGM in the perioperative setting should be aware of the possible time lag between sensor readings and BGL especially in situations of rapidly changing BGLs. An effect of compression on the sensor known as "compression artifact" should be also taken into account and the position of the sensor on the operating table should be free of possible compression and, as far away as possible from the operative field.

Looking to the future, the availability of CGM glucose measurement at least every 5 min and the additional information provided by CGM glucose trends have the potential to improve perioperative glycemic management for children and adolescents with diabetes.

7 | CLASSIFICATION OF PROCEDURES AND PRESURGICAL ASSESSMENT

For the management of young people with diabetes undergoing surgery, it is helpful to divide procedures into two main categories: major and minor surgery. It is important to note that sometimes management of "major" surgery in a child with stable diabetes may be less complex than a "minor" surgery in a child with suboptimal glycemia and/or limited social support.

(a) *Minor Surgery* refers to short procedures, (usually less than 2 h), with/without sedation or anesthesia, where rapid recovery is anticipated, and the child is expected to be able to eat by the next mealtime (within 2–4 h). Examples include day clinic and ambulatory procedures like endoscopies, imaging studies, adeno-tonsillectomy, grommet insertion, or simple procedures for hospitalized individuals such as dressing changes or cancer treatments.

(b) *Major Surgery* includes any surgery or investigation under anesthesia that is more than minor, typically >2 h, have a high likelihood of postoperative nausea, vomiting or inability to adequately feed postoperatively.

Prior to elective surgery, young people with diabetes should have a thorough assessment of glucose profile, and when appropriate ketone measurement (urine/blood), and a formal plan for diabetes management formulated for surgery and/or anesthesia. If major surgery is planned, electrolyte status should also be assessed.

If glycemia is known to be sub-optimal and surgery cannot be delayed, admission to hospital before surgery for acute stabilization of glycemia should be considered.

8 | PREOPERATIVE CARE FOR YOUNG PEOPLE WITH DIABETES TREATED WITH INSULIN

- Whenever possible, surgery should be scheduled as the first case in the morning so that prolonged fasting is avoided and diabetes treatment regimens can be most easily adjusted.
- Based on the hospital regulations, young people with diabetes can attend the hospital or day clinic on the same day or be admitted before surgery if receiving general anesthesia. If outpatient surgery is planned, glycemic status should be in target. If the person with diabetes has other reasons to be in hospital or diabetes is not well controlled, then admission before surgery is recommended.
- The anesthesiologist should be experienced in the treatment of insulin dependent diabetes and have contact to the diabetes team in advance.
- Specific adjustment of insulin regimen depending on major or minor surgery and glycemia status are required. Insulin (dose may need to be adjusted) is required, even if fasting, to prevent ketosis and DKA.
- Intravenous access pre- or intra-operatively is required to treat hypoglycemia.
- BGL monitoring at least hourly perioperatively is needed to detect and prevent hypo- and hyperglycemia. Urine or blood ketone measurements need to be performed if hyperglycemia >14 mmol/L (250 mg/dl) is present.
- In certain cases of minor elective surgery, youth can continue to receive insulin via CSII.

9 | MAJOR SURGERY (AS DEFINED ABOVE)

On the evening before surgery

- Give the usual evening and/or bedtime insulin(s) (some endocrinologists may recommend reducing the bedtime basal insulin amount by 20–30%). If on CSII, continue usual insulin basal rates (consider reducing basal at 0300 by 20% if there is concern about hypoglycemia).
- Monitor BGL and measure blood ß-hydroxybutyrate (BOHB) or urinary ketone concentration if BGL is >14 mmol/L (250 mg/dl).

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

- Start an iv insulin infusion and provide iv maintenance fluids consisting of 5% dextrose and 0.9% sodium chloride (see Appendices 1 and 2).
- Children on CSII should discontinue CSII insulin delivery when the insulin infusion is started.
- Depending on the placement of the CSII cannula in relation to the operation field, this can be left in place or may need to be removed
- Monitor BGLs at least hourly in the perioperative period. Aim to maintain BGL 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 BGL <4 mmol/L (70 mg/dl), give a bolus of iv 10% dextrose, 2 ml/kg; re-check BGL 15 min later and repeat if necessary. If still <4 mmol/L (70 mg/dl), stop iv insulin for 15 min and recheck.

- After surgery, when oral intake is not possible, the iv dextrose infusion should continue until the child is able to resume eating and drinking.

10 | MINOR SURGERY (AS DEFINED ABOVE)

Algorithms for different types of insulin regimens are suggested below.

For all insulin regimens—If the following occurs

- BGL <4 mmol/L (70 mg/dl)—give bolus of iv 10% dextrose 2 ml/kg; re-check BGL 15 min later and repeat if necessary.
- BGL >14 mmol/L (250 mg/dl) for >1 h—consider subcutaneous rapid-acting insulin using the child's usual correction factor or 5–10% of the child's usual total daily dose. Blood or urine 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. People with diabetes treated with a regimen using multiple daily injections (MDI), twice or once daily basal (NPH, detemir, degludec or glargine) and rapid- or short-acting insulin

Morning operations

- On the morning of the procedure, give the usual dose of long-acting basal insulin (glargine, detemir, degludec) if usually given at this time. If preoperative evaluation shows a pattern of low BGLs in the morning, consider reducing the dose of long-acting insulin by 20%–30% (both doses if twice daily long-acting).[43] There is no evidence to inform the appropriate dose reduction of degludec; however based on the experience using other long-acting insulins a dose reduction of 20–30% on the day before surgery may be considered.
- In general, omit the usual prebreakfast rapid-acting insulin (e.g. insulin aspart, insulin lispro, and glulisine) until after the procedure, when it can be administered with a late breakfast. Consider rapid-acting insulin only to correct hyperglycemia.
- Consider commencing iv fluids: Individuals on an MDI regimen with BGL above target range may initially require iv fluids without dextrose. However, iv fluids with dextrose (5% dextrose/0.9% sodium chloride) should be started for everyone treated with NPH insulin to mitigate risk of hypoglycemia (because NPH insulin has a broad peak action). Alternatively, iv insulin infusion may be started as described above for major surgery.

Afternoon operations (if unavoidable)

- On the morning of the procedure, give the usual dose of long-acting insulin (if usually given at this time). For some individuals a 20–30% reduction of the dose will decrease risk of hypoglycemia.[43]
- If the anesthesiologist allows the child to eat a light breakfast and to consume clear liquids up to 4 h before the procedure, iv fluid administration (and iv insulin infusion, if applicable) could commence 2 h before surgery or no later than midday (see Appendices) if that is the diabetes team's choice of management.

2. Young people treated with continuous subcutaneous insulin infusion (CSII)

- In young people on CSII, this may be continued during a surgical procedure. However, if the anesthesiologist is not confident with CSII management, it is safest to remove the insulin pump and substitute an iv insulin infusion, 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. The insertion site should be away from the surgical field and in a non-compressible location. Ideally, the cannula should be changed the day before surgery and should not be in place for more than two days.
- If the general anesthesia is short (<2 h), CSII 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 min to correct any episodes of mild hypoglycemia.
- In case of hypoglycemia, dextrose should be administered (see above general recommendation)
- Do not give a bolus dose of rapid-acting insulin unless necessary to correct hyperglycemia and/or significant ketonemia as above.
- Consider commencing iv fluids: individuals with BGL above target range may initially require iv fluids without dextrose. An approach based on basal rate insulin titration may be more physiologic.[44,45] Alternatively, iv insulin infusion may be started as described above, instead of the CSII (make sure it is suspended or removed).
- Although advanced automated insulin delivery (AID) systems are available, there is no evidence on the perioperative use of these systems, and it is preferable to change to manual mode or iv insulin and suspend the AID during the operation.

11 | INTRAOPERATIVE CARE

- Surgical stress may cause hyperglycemia and increased insulin requirements. Regular BGL measurements at least hourly, and more frequently for hyper- or hypoglycemia (as described below), are recommended. If necessary, begin dextrose infusion or increase dextrose concentration of iv fluids from 5% to 10% to prevent hypoglycemia, or if an insulin infusion is initiated.
- Subcutaneous rapid-acting insulin may be used for minor surgery to maintain BGLs in the range 5–10 mmol/L (90–180 mg/dl). Rapid-acting subcutaneous insulin should not be given more often than every 2 h to avoid "stacking" and subsequent hypoglycemia.
- For major surgery or uncontrolled hyperglycemia during minor procedures, iv insulin infusion should be titrated to maintain BGL between 5 and 10 mmol/L (90–180 mg/dl) (Appendix A).

- If BGL 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.

12 | POSTOPERATIVE CARE

After surgery, based on the young person's conditions, oral intake can restart, or iv dextrose infusion continued until food is tolerated. Similarly, based on the clinical conditions, either iv insulin infusion should be continued or short- or rapid-acting insulin (based on the usual insulin: carbohydrate ratio and correction factor) given, if needed, to reduce hyperglycemia or to match food intake. Insulin requirement may vary due to delayed oral intake, nausea, postoperative stress, additional medications, pain, and inactivity. For the first meal after surgery, it is preferable to give insulin after the oral intake, to make sure food is well tolerated without nausea or vomiting.

The young person's usual diabetes treatment regimen can be restarted, once they are able to resume oral nutrition.

13 | SPECIAL CIRCUMSTANCES

Emergency surgery

Most 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, vice versa, acute illness may precipitate DKA.

Before emergency surgery in young people with diabetes, it is recommended to always check BGL, blood ketones (if available), or urinary ketones, serum electrolytes, and blood gases if ketone or BGLs are high.

If DKA is present, the ISPAD DKA protocol *(see ISPAD 2022 Consensus Guidelines Chapter 13 on Diabetic Ketoacidosis and Hyperglycemic Hyperosmolar State)* should be followed and surgery delayed, if possible, until circulating volume and electrolyte deficits are corrected and, ideally, until acidosis has resolved. If there is no DKA, start iv fluids and insulin management as for elective surgery.

T2D on oral medication alone

For young people with T2D treated with insulin, the same insulin guidelines as for elective surgery, depending on the type of insulin regimen, can be followed. For those on oral medications, the approach may vary based on the specific medication in use.

Metformin: the timing of discontinuation will depend on the expected length of the procedure. Metformin use has been associated with lactic acidosis, with risk increasing in the presence of renal insufficiency. 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.[46,47] Therefore, for major and minor surgery, metformin should be discontinued on the day of the procedure. For major surgery, metformin should be withheld for 24 h after surgery and until normal renal function has been confirmed. For minor surgery, metformin can be restarted after oral intake is tolerated.

Glucagon-like peptide (GLP-1) agonist: withhold on the morning of surgery.

All other glucose lowering drugs should be withheld on the morning of surgery.

Young people with T2D undergoing a major surgical procedure expected to last at least 2 h should be started on an iv insulin infusion as described above. For those undergoing minor procedures, it is advisable to monitor BGLs hourly and if greater than 14 mmol (250 mg/dl), treatment with subcutaneous rapid-acting insulin (0.1 unit/kg up to 10 units) no more frequently than every 3 h should be considered.

Young people with diabetes undergoing bariatric surgery

Individuals with T2D undergoing bariatric surgery may have significant improvement in insulin resistance and decrease in insulin needs shortly after surgery, even before weight loss occurs. Therefore, in these individuals, it is advisable to monitor BGLs closely after surgery and adjust insulin doses promptly. Interestingly, most remissions in adults occur almost immediately following operation, due to a dramatic increase in postprandial concentrations of the endogenous incretin, GLP1, mainly after Roux-en-Y gastric bypass.[48] These individuals are often on a clear liquid diet for several days after surgery and therefore the dose of basal insulin may need to be decreased to at least 50% of the preoperative dose. It is also suggested that the short-acting insulin dose be reduced postoperatively, starting with only half of the recommended preoperative dose if BGLs are elevated. Extended-release medications (such as metformin XR) should be converted to immediate release preparations after bariatric surgery.

Cystic fibrosis related diabetes (CFRD) on insulin

Young people with CFRD on insulin should receive the same perioperative management as those with T1D, including regular glucose monitoring and an individually tailored insulin regimen. Even though DKA may be uncommon in CFRD, testing for urine or blood ketones is suggested if BGL > 14 mmol/L (250 mg/dl).

14 | CONCLUSION

Surgery or general anesthesia in children and adolescents with diabetes should be performed in centers with appropriate personnel and facilities to support pre-, intra-, and post-operative care at the highest standard. Crucial to ensuring the highest level of safety is a careful liaison between the surgical, anesthesia and diabetes care teams before elective surgery and as soon as possible after admission for emergency surgery. Centers performing surgical procedures on young people with diabetes should have written protocols for postoperative management of diabetes on the wards where children are admitted.

CONFLICT OF INTEREST

The authors have declared no relevant conflicts of interest.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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APPENDIX A: INTRAVENOUS FLUID INFUSION GUIDE FOR SURGICAL PROCEDURES

A.1 | Maintenance fluid guide

A.1.1. | 0.9% Sodium chloride with 5% dextrose

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

A.1.2. | Sodium

There is evidence that the risk of acute hyponatremia may be increased when hypotonic maintenance solutions (i.e., 0.45% sodium chloride) are used in hospitalized children. Therefore, 0.9% sodium chloride should be used.

A.1.3. | Potassium

Monitoring of electrolytes perioperatively is recommended in young people with diabetes with unstable glucose levels. Potassium levels may become elevated, and use of potassium-containing iv fluids should be avoided intraoperatively to avoid a possible risk of excessive potassium administration in the event of emergency fluid resuscitation. Those undergoing more prolonged surgeries or emergency surgeries, during which metabolic decompensation is more likely, require intraoperative assessment of electrolytes and appropriate adjustment of the electrolyte composition of their iv solution.

A.1.4. | 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)

A.2 | 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. 1 (one) Unit of insulin generally disposes 5–10 grams of dextrose/h; 5% dextrose at a rate of 40 ml/h provides 2 grams dextrose per h, which will

require 0.1 to 2 units/h insulin (or as below for insulin infusion 0.025 U/kg/h insulin).[5]

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 BGL >4 mmol/L (>70 mg/dl)
  - 0.025 ml/kg/h (i.e., 0.025 units/kg/h) if BGL is <6–7.9 mmol/L (110–143 mg/dl)
  - 0.05 ml/kg/h (i.e., 0.05 units/kg/h) if BGL is between 8 and 11.9 mmol/L (144–215 mg/dl)
  - 0.075 ml/kg/h (i.e., 0.075 units/kg/h) if BGL is between 12 and 14.9 mmol/L (216—269 mg/dl)
  - 0.1 ml/kg/h (i.e., 0.1 units/kg/h) if BGL is ≥15 mmol/L (above 270 mg/dl)
- Titrate infusion by 0.01–0.03 units/kg/h to achieve BGL target range of 5–10 mmol/L (90–180 mg/dl).
- BGL must be measured at least hourly when the individual is on iv insulin. Increase to every 30 min after a change in therapy or every 15 min for BGL <5 mmol/L (80 mg/dl).
- Do not stop the insulin infusion if BG is between 5 and 6 mmol/L (90 mg/dl) as this will cause rebound hyperglycemia. Reduce the rate of infusion by 50%.
- The insulin infusion may be stopped temporarily if BGL <4 mmol/L (70 mg/dl) but not for more than 15 min.