ISPAD CLINICAL PRACTICE CONSENSUS GUIDELINES 2022:

Management of children and adolescents with diabetes requiring surgery

Thomas Kapellen¹, Juliana Chizo Agwu², Lizabeth Martin³, Seema Kumar⁴, Marianna Rachmiel⁵, Declan Cody⁶, Nirmala SVSG⁷, M. Loredana Marcovecchio⁸

¹Department for Women and Child Health, Hospital for Children and Adolescents, Liebigstrasse 20 Leipzig; Childrens hospital Am Nicolausholz, Bad Kösen, University of Leipzig, Germany
²Department of Paediatrics, Sandwell and West Birmingham, NHS Trust, United Kingdom
³University of Washington Department of Anesthesiology, Division of Pediatric Anesthesia, Seattle Children’s Hospital, Seattle, Washington, United States
⁴Division of Pediatric Endocrinology, Department of Pediatric and Adolescent Medicine, Mayo Clinic, Rochester, MN, United States
⁵Pediatric Endocrinology and Diabetes Institute, Shamir (Assaf Haroffeh) Medical Center, Zerifin, Sackler School of Medicine, Tel Aviv University, Israel
⁶Children’s Hospital Ireland Crumlin Dublin, University College Dublin
⁷Department of Pediatric and Preventive Dentistry. Narayana Dental College and Hospital, Nellore, Andhra Pradesh, India
⁸Department of Paediatrics, University of Cambridge and Cambridge University Hospitals, NHS Foundation Trust, Cambridge, UK

Corresponding Author:

Thomas Kapellen, Pediatric Endocrinologist, MD

Median Childrens Hospital “Am Nicolausholz” Bad Kösen, Elly Kutscher-Strasse 16 06628 Naumburg, Germany (+49-34463-43150) email: thomas.kapellen@median-kliniken.de

Key Words: diabetes, surgery, children, anesthesia, guidelines

Abbreviations: ICU, intensive care unit; IV, intravenous; GA, general anesthetic; BOHB, β-hydroxybutyrate; CSII, continuous subcutaneous insulin infusion; T1D, type 1 diabetes; T2D, type 2 diabetes
1. WHAT’S NEW OR DIFFERENT?

- Further considerations on the 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

• To maintain blood glucose (BG) in a range of 5 – 10 mmol/l (90 – 180 mg/dl). C
• To prevent hypoglycemia. E
• To prevent the development of keto-acidosis. E

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

• All children and adolescents with diabetes should have a diabetes consultation prior to all types of surgery or anesthesia. E
• Prior to an elective surgery, children and adolescents with diabetes should ideally be formally assessed by their diabetes team several days beforehand for a thorough assessment of glycemic control, electrolyte status, ketones (urine/blood), and a formal plan for diabetes management prior to, during and after surgery and/or anesthesia. E
• If glycemic control is known to be suboptimal and surgery cannot be delayed, consider admission to hospital before surgery for acute stabilization of glycemic control. C

Preoperative Care for Children with T1D, T2D or other types of diabetes requiring Insulin

• Consider admission to hospital or day-clinic with an anesthetic team having protocols for the management of diabetes, if receiving general anaesthesia. E
• If outpatient surgery is planned, glycemic control should be in-range and young people with diabetes and their families should be prepared. The anesthesiologist should be experienced in the management of insulin in youth with diabetes and should have contact with the diabetes team in advance. E
• Surgery should be scheduled preferably as the first case of the day or of the surgical list, especially if performed in a day-care setting and not a hospital. E
• An intravenous 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 glycemic control. E
• If treated additionally with an oral anti-hyperglycemic medication, this may also need to be modified. E
• Insulin (albeit reduced) is required, even if fasting, to avoid ketoacidosis. A
• BG testing is required at least hourly to detect and prevent hypo- and hyper-glycemia. E
• Measurement of urine or blood ketone 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

• BG should be monitored at least hourly during and in the immediate post-operative recovery phase. E

• CGM can be used intraoperatively if deemed appropriate by the anesthesia provider and POC BG is validated concurrently. E

• Limited data exist on interactions of anesthetic medications and CGM, thus concurrent POC BG monitoring is required. E

• IV infusion with dextrose (5% dextrose/0.9% sodium chloride) should be used during any major surgery with IV insulin infusions, and for young people treated with 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 subcutaneous insulin accordingly to maintain BG 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 child is able to tolerate oral nutrition, resume the child’s usual insulin regimen. E

• Give short- or rapid-acting insulin (based on the child’s usual insulin: carbohydrate ratio and correction factor). E

• It may be appropriate to give the first post-operative dose of insulin after initial oral intake to be sure that food is tolerated. E

• Insulin requirement may vary after surgery due to change in oral intake, nausea, stress, pain and inactivity, therefore frequent CGM/BG measurements are recommended for 24-48 hours following surgery. E

• Some CGM systems can have false readings when exposed to specific medications (including acetaminophen), thus concurrent POC BG monitoring may also be indicated. C

• BG target of 7.8 – 10 mmol/l (140-180 mg/dl) in the post-surgery ICU setting is suggested. C
**Special Situations**

**Acute or Emergency surgery:**

- If diabetic ketoacidosis (DKA) is present (pH < 7.3 and/or bicarbonate < 15 mmol/l, and positive ketones), follow an established treatment protocol for DKA and delay surgery (if possible) until acidosis, ketosis, 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.

**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
- Young people with diabetes undergoing a major surgical procedure expected to last at least 2 hours should be monitored with hourly BG and adjustment of dextrose infusion or intravenous insulin accordingly to maintain BG 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 hours after a major surgery and until normal renal function has been confirmed. E In minor surgeries, metformin can be restarted once oral intake is tolerated.

**General Recommendations and Considerations**

- Whenever possible, surgery on children and adolescents with diabetes should be performed in centres 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 young people with diabetes should 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, as appropriate. E
• Use of intermittently scanned CGM (isCGM) and/or real-time CGM (rtCGM) systems can be recommended to trend glucose levels peri-operatively, but CGM data should routinely be verified by POC BG measurements.

**Minor surgery/procedures**

In general, minor surgery includes short procedures (less than 2 hours), 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).

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

**Major surgery**

In general, major surgery includes all surgery or investigations under anesthesia that last >2 hours, or have a high likelihood of post-operative nausea, vomiting or inability to feed adequately post-operatively.

- Should receive an IV infusion with dextrose to keep glucose in the range 5 – 10 mmol/l (90 – 180 mg/dl).
- Require hourly BG monitoring before, during, and after the procedure.
- Must coordinate the timing of preoperative food and fluid restrictions with the anesthetist.
- Require specific adjustment of the insulin schedule.
- Require IV insulin infusion.

3. **Introduction**

The management of diabetes in children now includes a wide array of insulin analogs, insulin delivery devices, and intermittent (isCGM) or real-time continuous glucose monitoring (rtCGM) systems. 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 child’s specific diabetes treatment regimen, glycemic control, anticipated postoperative course, and the nature of the environment where 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.
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 Paediatric 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 anaesthesiology 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 are considered and 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% versus 8.2%), stroke (4.9% versus 1.5%), and mortality (6.1% versus 2.1%), despite use of a tight BG control protocol (6).

While there is limited evidence on the impact of pre-operative suboptimal versus good glycemic control on surgical outcomes in young people with diabetes, studies in adults suggest that there is an increased risk of hyperglycemia-related post-operative 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).

Of note, there is one recent study on postoperative outcomes in children with diabetes undergoing orthopedic surgery (12), reporting 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 with suboptimal glycemic control 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 control, based on a single centre experience (13). However, subsequent data are not consistent, and even suggest harm associated with tight glycemic control in adult populations (14). 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 (15). A Cochrane database systematic review found insufficient evidence to support strict glycemic control versus conventional management for the prevention of surgical site infections (16).

5. Is 5-10 mmol/l (90-180 mg/dl) an appropriate BG target in young people with diabetes undergoing surgery?

Some studies in adults with diabetes suggest that perioperative hyperglycemia is an independent risk factor for post-operative mortality and morbidity (17, 18). Maintaining BG levels after surgery at <11.1 mmol/L significantly reduced the incidence of deep wound infections in adults with diabetes undergoing coronary artery bypass (19, 20). However, tighter glucose control may carry a greater risk of both absolute and relative hypoglycemia in these individuals (21). Such hypoglycemia may be particularly dangerous as people with diabetes may experience both unawareness and autonomic instability (22, 23). A Cochrane database review did not demonstrate significant differences for most outcomes when comparing intensive perioperative with conventional glycemic control. However, intensive glycemic control was associated with an increased number of hypoglycemic episodes (20). Therefore, intensive glycemic control protocols with near-normal BG targets 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 (24-27). 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, showed that children do not benefit from tight versus more liberal glycemic control (28-33). 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 (30, 35). 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 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 participants in the lower-target group had higher rates of health care–associated infections and higher rates of severe hypoglycemia (36).

The American Diabetes Association have published their guidelines for care in hospitalized adults with diabetes. Their advice includes target BG level of 7.8 -10 mmol/l (140 -180 mg/dl) for most critical and
non-critical ill people with diabetes. More stringent goals, 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 (3). Glycemic targets for individuals with diabetes in the perioperative period should be 80–180 mg/dL (4.4–10.0 mmol/L) (37). Once intravenous (IV) insulin therapy has been initiated, BG 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 control during minor and moderate surgery did not demonstrate any adverse effects of maintaining perioperative glycemic levels between 5 – 11 mmol/l (~90 – 200 mg/dl). Therefore, based on the available data, it seems reasonable to aim for BG 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 post-surgery intensive care unit (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 BG assessments, which may minimize inter-measurement 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 and intermittent glucose monitoring provide a potential option of intensively monitoring glucose before, during and after surgery, where there are benefits to maintaining euglycemia.

CGM devices are now extensively used in daily practice in many children and adolescents, even for sick days management (38). However, evidence for the accuracy, readability and effect on glucose control and prognosis using CGM in the operative setting is still limited. The overall accuracy and reliability of CGM systems during and post-surgery may be variable (correlation coefficient between CGM and conventional glucose monitoring methods ranges from 0.69 to 0.92). A single center study where CGM was used in a small cohort with and without diabetes undergoing cardiac surgery demonstrated limited reliability due to incorrect hypoglycemic readings in the post-operative period (39). A small study in children without diabetes undergoing cardiac surgery showed high measurement failure rate in the operating theatre, which was thought to be due to interference with electrical equipment, though not affected by hypoglycemia, inotrope use or edema (40). In a more recent study in 12 adults, comparing Dexcom G6 factor calibrated CGM with BG levels obtained during elective abdominal surgery, reported encouraging results, with a mean absolute relative difference (ARD) 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 (41).
Another option is the use of intermittently scanned CGM (isCGM) (FreeStyle Libre system) (42). 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 BG measurement (43). 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.

There is evidence that 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 61mg/dl difference) for up to 8 hours (44). Possible interference has been reported for Hydroxyurea with Dexcom G6 and drugs like lisinopril, albuterol and atenolol with Medtronic Guardian and Dexcom G4 readings (45, 46). Further studies are needed to investigate CGM accuracy with commonly used anaesthetic agents.

Users of CGM in perioperative settings should be aware of the possible time lag between sensor readings and BG especially in situations of fast changing BG levels. An effect of compression on the sensor known as “compression artifact” should be also taken into account and position of the sensor on the operating table should be free of possible compression and, as far as possible from the operative field.

Looking to the future, the availability of CGM glucose measurement at least every five minutes 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 Pre-surgical 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 well-controlled diabetes may be less complex than a “minor” surgery in a child with suboptimal glycemic control and/or limited social support.

(A) Minor Surgery are short procedures, (usually less than 2 hours), 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). 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 hours, have a high likelihood of post-operative nausea, vomiting or inability to adequately feed post-operatively.

Prior to elective surgery, children and adolescents with diabetes should have a thorough assessment of glycemic control including ketone measurement (urine/blood), and a formal plan for diabetes
management made for surgery and/or anaesthesia. If major surgery is planned, electrolyte status should also be assessed.

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

8. Preoperative Care for young people with diabetes treated with Insulin

- These young people should be admitted to hospital or day clinic before surgery if receiving general anaesthesia. If outpatient surgery is planned, glycemic control should be in target. The anesthesiologist should be experienced in the treatment of insulin dependent diabetes and should have contact to the diabetes team in advance.
- If the person with diabetes has other reasons to be in hospital or diabetes is not well controlled, then admission before surgery is recommended.
- 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.
- Specific adjustment of insulin regimen depending on major or minor surgery and glycemic control are required. Insulin (albeit titrated/ reduced) is required, even if fasting, to avoid ketoacidosis.
- An IV access pre- or intra-operatively is required to treat hypoglycemia.
- BG monitoring at least hourly perioperatively is needed to detect and prevent hypo- and hyperglycaemia. Urine or blood ketone measurements need to be performed if hyperglycaemia >14 mmol/l (250 mg/dl) is present.
- For youths using CSII, this can be continued, in certain cases of minor elective surgery

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 by 20-30%). If on CSII, continue normal insulin basal rates (consider reducing basal at 0300 by 20% if there is concern over hypoglycemia).
- Monitor BG and measure blood β-hydroxybutyrate (BOHB) or urinary ketone concentration if BG 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 (e.g., dilute 50 units regular [soluble] insulin in 50 ml of 0.9% Sodium chloride, 1 unit per 1 ml) 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 placing of the CSII cannula regarding the operation field, this can be left in place or may need to be removed.

• Monitor BG levels at least hourly in the perioperative period. Aim to maintain BG between 5 – 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 2ml/kg; re-check BG 15 minutes later and repeat if necessary. If still <4 mmol/l (70 mg/dl), stop IV insulin for 15 min and recheck.

• When oral intake is not possible, the IV dextrose infusion should continue for as long as necessary.

10. Minor surgery (as defined above)

Algorithms for different types of insulin regimens are suggested below.

For all insulin regimens – If the following occurs

• BG <4 mmol/l (70 mg/dl) – give bolus of IV 10% Dextrose 2ml/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 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 basal-bolus regimen using multiple daily injections, 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) if usually given at this time. If preoperative evaluation shows a pattern of low BG values in the morning, consider reducing the dose of long-acting insulin by 20 – 30% (both doses if twice daily long-acting) (47). There is no exact evidence on the dose reduction of
degludec, however based on the experience of other long-acting insulins a dose reduction of 20-30% on the day before surgery may be considered.

- In general, omit the usual pre-breakfast rapid-acting insulin (e.g. insulin aspart, insulin lispro and glulisine) in the morning until after the procedure, when it can be administered with the late breakfast. Consider rapid-acting insulin only to correct hyperglycemia.
- Reduce morning NPH by 30-50% depending on the length of the procedure.
- Consider commencing IV fluids: Individuals on basal/bolus regimen with BG 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. 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 would be safer (47).
- 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) could commence 2 hours 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 anesthetist 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 theatre, 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 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.
- 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 ketone production as above.

• Consider commencing IV fluids: individuals with BG above target range may initially require IV fluids without dextrose. An approach based on basal rate insulin titration may be more physiologic (4, 5). 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 suspending the AID during operation.

11. Intraoperative Care

• Surgical stress may cause hyperglycemia and increased insulin requirements. Regular BG 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 BG in the range 5–10 mmol/l (90–180 mg/dl). Rapid acting subcutaneous insulin should not be given more often than every 2 hours to avoid “stacking” and subsequent hypoglycemia.

• For major surgery or uncontrolled hyperglycemia during minor procedures, IV insulin infusion should be titrated to maintain BG between 5-10 mmol/l (90–180 mg/dl) (Appendix 1).

• If BG 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 child’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 child’s 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 child’s usual diabetes treatment regimen can be re-started, once the child is 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 that acute illness may precipitate DKA.

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

If DKA is present, an established treatment DKA protocol 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 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 post-operative hyperglycemic state (48, 49). 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 hours after surgery and until normal renal function has been confirmed. For minor surgery, metformin can be restarted after oral intake is tolerated.

GLP1 agonist: should be withheld 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 hours should be started on an IV insulin infusion as described above. For those undergoing minor procedures, it is advisable to monitor BG hourly and if greater than 10 mmol/l (180 mg/dl), treatment with subcutaneous rapid-acting insulin (0.1 unit/kg up to 10 units) no more frequently than every 3 hours 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 BG 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 endogenous incretin, GLP1, mainly after Roux-en-Y gastric bypass (50). These individuals may be 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 post-operatively, starting with half of the recommended pre-operative dose only if BG values 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 than those with T1D, including regular glucose monitoring and tailored insulin regimen. Even though DKA may be uncommon in CFRD, testing for urine or blood ketones is suggested if BG>14 mmol/l (250 mg/dl).

**14. Conclusion**

Surgery or general anesthesia in children and adolescents with diabetes should be performed in centres 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. Centres performing surgical procedures on children with diabetes should have written protocols for post-operative management of diabetes on the wards where children are admitted.
Appendix 1. 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 BG is high (>14 mmol/l, 250 mg/dL), use 0.9% Sodium chloride without dextrose and increase IV insulin; consider adding 5% dextrose when BG 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 (i.e. 0.45% Sodium chloride) are used in hospitalized children. Therefore, 0.9% Sodium chloride should be used.

Potassium

Monitoring of electrolytes perioperatively is recommended in young people with diabetes who are metabolically unstable. Potassium levels may become elevated, and use of potassium-containing IV fluids should be avoided intraoperatively to avoid excessive fluid resuscitation with potassium-containing fluids. 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.

Example of calculation of maintenance requirements:

<table>
<thead>
<tr>
<th>Body Weight</th>
<th>Fluid Requirement/24h</th>
</tr>
</thead>
<tbody>
<tr>
<td>For each kg between</td>
<td>3 – 9 kg</td>
</tr>
<tr>
<td>For each kg between</td>
<td>10 – 20 kg</td>
</tr>
<tr>
<td>For each kg over</td>
<td>20 kg</td>
</tr>
</tbody>
</table>

(Maximum 2000 ml/24 hours female, 2500 ml/24 hours male)

Dextrose Saline

The percentage is a mass percentage, so a 5% glucose/dextrose solution contains 50g/l of glucose/dextrose or 5g/100ml. 1 (one) Unit of insulin generally utilises 5-10 grams of dextrose/hour, so a child on 40 ml/hour of 5% dextrose is being infused 2 grams/hour dextrose, which will require 0.1 to 2 Units/hour insulin (or as below for insulin infusion 0.025U/kg/hour insulin).
Appendix 2. 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 >4mmol/l (>70 mg/dl)
  
  o 0.025 ml/kg/hour (i.e., 0.025 Units/kg/hour) if BG is <6 – 7.9 mmol/l (110-143 mg/dl)
  o 0.05 ml/kg/hour (i.e. 0.05 Units/kg/hour) if BG is between 8 – 11.9 mmol/l (144 – 215 mg/dl)
  o 0.075 ml/kg/hour (i.e. 0.075 Units/kg/hour) if BG is between 12 – 14.9 mmol/l (216 – 269 mg/dl)
  o 0.1 ml/kg/hour (i.e. 0.1 Units/kg/hour) if BG is ≥15mmol/l (above 270 mg/dl)

• Titrate infusion by 0.01-0.03 units/kg/hr to achieve BG target range of 5 – 10 mmol/l (90 – 180 mg/dl)

• BG must be measured at least hourly when the individual is on IV insulin. Increase to every 30 minutes after a change in therapy or every 15 minutes for BG < 5 mmol/l (80mg/dL).

• Do not stop the insulin infusion if BG is between 5 – 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 BG <4 mmol/l (70 mg/dl) but not for more than 15 min.
References


medicine. 2012;23(6):564-74.