ISPAD Clinical Practice Consensus Guidelines 2018

Management of children and adolescents with diabetes requiring surgery

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Abbreviations: ICU, intensive care unit; IV, intravenous; GA, general anesthetic; BOHB, β-hydroxybutyrate; CSII, continuous subcutaneous insulin infusion; flash glucose monitoring (FGM); T1M, type 1 diabetes; T2D, type 2 diabetes.

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What's new?

- Further consideration of different types of diabetes
- Increasing availability of insulin pumps
- Increasing use of and glucose monitoring
- Increasing availability of new medications
- Surgery in resource limited countries
Executive Summary and Recommendations

Glycemic and metabolic goals for surgery

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

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

• All children with diabetes should have a diabetes assessment prior to all types of surgery or anaesthesia. [E]

• 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 anaesthesia [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].
Preoperative Care for Children with Type 1 (T1D) or Type 2 Diabetes (T2D) treated with Insulin

- Must be admitted to hospital if receiving general anaesthesia [E]
- Should be scheduled as a first case of the day or the surgical list [E].
- Require IV sited for use pre- or intra-operatively to treat hypoglycaemia [E].
- Require specific adjustment of insulin regime 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-operatively 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/ anaesthesia, in certain cases of minor elective surgery [E].
Intraoperative Care

Blood glucose should be monitored at least hourly during and in the immediate post-operative recovery phase [E].

IV infusion with dextrose (5% dextrose/ 0.9% sodium chloride) during any major surgery and for patients 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 insulin accordingly to maintain blood glucose in the range 5 – 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].
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 24-48 hours following surgery. [E]
Special Situations

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).

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 and started on an IV insulin infusion [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.
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].

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 [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].

Consider use of flash glucose monitoring (FGM) and/or continuous glucose monitoring (CGM) systems peri-operatively with caution, preferably under prospective follow up research protocols only and with additional blood glucose assessments [E].

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, MRI scanning or 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).
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 post-operative nausea, vomiting or inability to feed adequately post-operatively.

• Should receive an IV infusion with dextrose.
• Require BG monitoring before 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.

Key Words: diabetes, surgery, children, anesthesia, guidelines
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 flash 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 Paediatric 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.

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 diabetic and non-diabetic populations. In adult patients undergoing cardiac surgery, repeated postoperative hyperglycemia was 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 tight blood glucose control protocol [B][9]. While there are no published data on impact of poor versus good glycemic control of diabetes in surgical outcomes in children, studies in adults suggest that there is an increase in post-operative complications. Hyperglycemia among poorly controlled diabetics 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 in the diabetic population preoperative hyperglycemia was an independent predictor of infectious complications and length of hospital stay(12). A meta-analysis including comprehensive integration and analysis of 8 studies revealed a significant correlation between higher preoperative HbA1c levels and risk of target vessel revascularization progression (OR 1.36, 95% CI 1.03-1.82) and nonfatal 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 there is a degree of dependence on outcome on the pre-existing, pre-surgery state of patients with diabetes, 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).

There are only a few reports regarding the appropriate glycemic targets during the perioperative period in the pediatric diabetic and non-diabetic population. There is currently sufficient data in the adult non-diabetic 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 centre 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 multi-center randomized international trial showed that a glycemic target of 8–10 mmol/L compared with intensive insulin treatment of 4.4-7 mmol/l was associated with decreased 90-day mortality [A](17). A Cochrane database systematic
review found insufficient evidence to support strict glycemic control versus conventional management for the prevention of surgical site infections(18).

**Is this target of 5-10 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 post-operative 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 diabetic patients 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 glycaemic control was associated with an increased number of patients experiencing hypoglycaemic episodes(22). Therefore, Intensive glycaemic 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 centre interventional study explored more liberal blood glucose management in critically ill patients with diabetes, allowing a range of 10-14 mmol/l (180 – 250 mg/dl) in comparison with the conventional protocol of 8-10 mmol/l (150 – 180 mg/dl) among 80 ICU diabetic adult inpatients [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 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](31-34) (35-37).
A single centre 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 RCT [A] using continuous glucose monitoring (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 - 11.1 mmol/l (140 - 200 mg/dl), and avoiding targets less than 7.8 mmol/l (<140mg/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 – 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 – 10 mmol/l (90 – 180 mg/dl) during all surgical procedures in children [C].

**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 flash glucose monitoring (FGM). 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 post-surgery 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 in diabetic and non-diabetic patients undergoing cardiac surgery demonstrated limited reliability due to incorrect hypoglycemic readings in the post-operative period [C](44). A small study of non-diabetic children 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 hypoglycaemia, inotrope use or edema [C] (45).

Another option is the use of flash glucose monitoring (FGM) system, the subcutaneous FreeStyle Libre blood glucose measurement system. FGM 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). FGM system was assessed among 8 adult critically ill diabetic patients and showed high test-retest reliability and acceptable accuracy when compared with arterial blood glucose measurement [C] (47).

Our recommendation is to use FGM and CGM systems perioperatively with caution, preferably under prospective follow up research protocols only and with additional blood glucose assessments [E].
Classification of Procedures and Pre-surgical 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 two 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 (e.g., 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 two hours.

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

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 anaesthesia [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].

Preoperative Care for Children with Type 1 (T1D) or Type 2 Diabetes (T2D) treated with Insulin
- Must be admitted to hospital if receiving general anaesthesia [E]
- Should be scheduled as a first case of the day or the surgical list [E].
- Require IV sited for use pre- or intra-operatively to treat hypoglycaemia [E].
- Require specific adjustment of insulin regime 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-operatively 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/anaesthesia, in certain cases of minor elective surgery [E].

**Major surgery (as defined above)**

**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, continue normal insulin basal rates, some reduce basal at 0300 by 20%.
- Monitor blood glucose and measure blood β-hydroxybutyrate (BOHB) or urinary ketone concentration if blood glucose 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**

- At least 2 hours before surgery, start an IV insulin infusion (e.g., 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 1 and 2).
- 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 – 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 1-2ml/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 and discuss with diabetes team.

When oral intake is not possible, the IV dextrose infusion should continue for as long as necessary.
Minor surgery (as defined above)

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

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 stat subcutaneous rapid-acting insulin using 80% of the patient’s usual correction factor or 5-10% 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.

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 (e.g. 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 hyperglycaemia and/or significant ketone production if present.
- Reduce morning NPH by 30-50% depending on the length of the procedure.
- Consider commencing IV fluids: Some centres will use IV fluids routinely; others will consider on individual basis pending length of operation and glucose status. Patients on basal/bolus with a normal 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) if that is the diabetes team choice of management.

**2) Patients treated with continuous subcutaneous insulin infusion (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 theatre, it is important to secure the subcutaneous infusion cannula to prevent dislodgement and interruption of insulin delivery during the procedure.
- 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.
- Do not give a bolus dose of rapid-acting insulin unless necessary to correct hyperglycaemia and/or significant ketone production as above.
- Consider commencing IV fluids. Patients with a normal 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.
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 1-2 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 5–10 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 1). 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.
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.

Special Circumstances

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 diabetic ketoacidosis (DKA) may present as an “acute abdomen” and that acute illness may precipitate diabetic ketoacidosis.

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 diabetic ketoacidosis 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.
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. 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. 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 (i.e., 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.

**Cystic fibrosis diabetes on insulin**

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

Surgery or general anesthesia in children and adolescents with diabetes should be performed at centres with appropriate personnel and facilities to manage pre-, intra- and post-operative 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. 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.

Acknowledgements: This is a chapter in the ISPAD Clinical Practice Consensus Guideline 2018 Compendium. The evidence grading system is the same as that used by the American Diabetes Association.
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 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 (i.e. 0.45% Sodium chloride) are used in hospitalized children (many centres, therefore, use 0.9% Sodium chloride due to concern over acute hyponatremia).

Potassium

Hyperkalemia (confirmed with repeat measurement and electrocardiogram) and renal insufficiency are absolute contraindications to potassium infusion.

In general adding potassium should generally be avoided because of the danger of inadvertent intraoperative administration of large quantities of potassium during fluid resuscitation. Monitor electrolytes pre- and post-operatively, only after surgery consider adding potassium chloride 20 mmol per liter of intravenous fluid.

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:

<table>
<thead>
<tr>
<th>Body Weight</th>
<th>Fluid Requirement/24h</th>
</tr>
</thead>
<tbody>
<tr>
<td>For each kg between 3 – 9 kg</td>
<td>100 ml/kg</td>
</tr>
<tr>
<td>For each kg between 10 – 20 kg</td>
<td>add an additional 50 ml/kg</td>
</tr>
<tr>
<td>For each kg over 20 kg</td>
<td>add an additional 20 ml/kg</td>
</tr>
</tbody>
</table>

(Maximum 2000 ml female, 2500 ml male)

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)
  - 0.025 ml/kg/hour (i.e., 0.025 Units/kg/hour) if BG is <6 – 7 mmol/l (110-140 mg/dl)
  - 0.05 ml/kg/hour if BG is between 8 – 12 mmol/l (140 – 220 mg/dl)
  - 0.075 ml/kg/hour if BG is between 12 – 15 mmol/l (220 – 270 mg/dl)
  - 0.1 ml/kg/hour if BG is > >15 mmol/l (250 mg/dl)

- Aim to maintain blood glucose in range between 5 – 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 – 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 10-15 min.
**Limited Care Appendix-1**

1. Children with type 1 diabetes requiring major surgery should be referred to a centre with sufficient resources to provide safe care.

2. Elective surgery should be scheduled as the first case of the day, preferably in the morning.

3. If it is possible to delay surgery, diabetic ketoacidosis, ketosis or severe hyperglycaemia should first be corrected.

4. Children with type 1 diabetes requiring surgery need insulin, even if fasting, to prevent ketoacidosis. At least half of the usual basal insulin dose should be given before surgery.

5. Children undergoing major surgery (expected to last at least 2 hours) or who have received NPH insulin should receive dextrose in their IV infusion to prevent hypoglycemia. Children undergoing minor surgery or procedures (lasting for less than 2 hours) may initially receive an IV infusion without dextrose if treated with basal/bolus insulin regimen or continuous subcutaneous insulin infusion.

6. Blood glucose monitoring should be performed before, during and immediately after general anesthesia to detect hypo- and hyperglycemia. Aim for blood glucose in the range 5 – 10 mmol/l (90 – 180 mg/dL).

7. The usual recommendation is no solid food for at least 6 hours before surgery. Clear fluids and breast milk may be allowed up to 4 hours before surgery (check with the anesthetist).

8. Emergency surgery:
   
a. If ketoacidosis is present, follow an established treatment protocol for diabetic ketoacidosis and delay surgery, if possible, until circulating volume and electrolyte deficits are corrected.

   b. If there is no ketoacidosis, start IV fluids and insulin management as for elective surgery.
Limited Care Appendix-2

Management of children and adolescents with diabetes requiring surgery in resource limited countries

1. Whenever possible follow the guidelines described in the full chapter for recommended care

2. Children with type 1 diabetes requiring major surgery should be referred to a centre with sufficient resources to provide safe care (including but not limited to: infusion pumps, insulin analogues, blood gases, urea and electrolytes and bedside glucometers).

3. Insulin can be infused using burettes connected to IV fluids bags and adding 50 to 100 units of regular insulin to 50 to 100 ml of 0.9% sodium chloride (1 ml = 1 unit) and given on a separate line or with a Y-connection, that should be changed every 6 hours.

4. Alternatively, insulin can be given subQ hourly in the same dose as the infusion. NPH insulin given once or twice can give a good basal dose.

5. In absence of blood gases use urine ketone in a freshly voided urine and in case of general anaesthesia a temporary urinary catheter can be used.

6. Where there are no facilities for urea and electrolytes, use clinical signs of hydration status and urine output and avoid adding potassium if patient is oliguria. If no glucometer available use (fresh) urine glucose to monitor the patient. If no facilities for IV fluids use oral rehydration solution.
References


7. Agwu JC, Ng SM, Edge J., and al. e. 2014.


