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Management of children and adolescents with diabetes requiring surgery

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This article is a chapter in the *ISPAD Clinical Practice Consensus Guidelines 2014 Compendium*. The complete set of guidelines can be found for free download at www.ispad.org. The evidence grading system used in the ISPAD Guidelines is the same as that used by the American Diabetes Association. See page 3 (the Introduction in *Pediatric Diabetes* 2014; 15 (Suppl. 20): 1-3).

Executive summary and Recommendations

Glycemic targets for surgery

Aim to maintain blood glucose in the range of 5–10 mmol/L (90–180 mg/dL) during surgical procedures in children (C).

Presurgical assessment

- Presurgical assessment should be done several days before surgery to allow for an assessment of glycemic control, electrolyte status, and ketones (urine or blood) (E).
- If glycemic control is known to be poor and surgery is not urgent, delay the procedure until glycemic control has improved. If surgery cannot be delayed, consider admission to the hospital before surgery for stabilization of glycemic control (E).

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

Children and adolescents with type 1 or type 2 diabetes treated with insulin:

- Must be admitted to the hospital if receiving general anesthesia (GA) (E).
- Should be scheduled as the first case of the day (E).
- Need insulin, even if fasting, to avoid ketoacidosis (A).
- May initially receive an intravenous (IV) infusion without dextrose for minor surgery or procedures (lasting for less than 2 h) if treated with basal/bolus insulin regimen or continuous subcutaneous insulin infusion (CSII) (C).
- Should initially receive an IV infusion with dextrose for major surgery or procedures (lasting for at least 2 h) or if treated with NPH insulin (E).
- Require careful blood glucose monitoring before the procedure to detect hypoglycemia and hyperglycemia (E).
- Should coordinate the timing of preoperative food and fluid restrictions with the anesthetist (E).
- Require specific adjustment of their insulin schedule depending on the type of surgery (major or minor), the patient's insulin regimen, and the time of the surgical procedure (morning or afternoon) (E).

Intraoperative care

- Monitor blood glucose concentration at least hourly during and immediately after GA (E).

- Use an IV infusion with dextrose during any major surgery (lasting for at least 2 h) or for patients treated with NPH insulin (E).
- Use an IV infusion initially without dextrose during minor surgery or procedures (lasting for less than 2 h) if treated with basal/bolus insulin regimen or CSII (C).
- Adjust dextrose infusion and insulin to maintain blood glucose in the range 5–10 mmol/L (90–180 mg/dL) (C).
- If there is an unexpected acute drop in blood pressure, normal saline (NS) (0.9% NaCl) or Ringer's lactate must be infused rapidly. In this circumstance, potassium-containing fluids must *not* be infused rapidly (E).

Postoperative care

- 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. (E)

Special situations

Emergency surgery (E). Before emergency surgery, always check blood glucose, blood ß-hydroxybutyrate (if available) or urinary ketone concentration, serum electrolytes, and blood gases if ketone or blood glucose levels are high. 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. If there is no ketoacidosis, start IV fluids and insulin management as for elective surgery.

Type 2 diabetes patients on oral medication alone.

- Discontinue metformin 24 h before major surgery (lasting at least 2 h) and on the day of surgery for minor surgery (C).
- Discontinue sulfonylureas, thiazolidinediones, dipeptidyl peptidase-4 (DPP-4) inhibitors, and Glucagon-like peptide-1 (GLP-1) analogs on the day of surgery (E).
- Patients undergoing a major surgical procedure expected to last at least 2 h should be started on an IV insulin infusion as described above (E).

General recommendations

- Whenever possible, surgery on children and adolescents with diabetes should be performed in centers with appropriate personnel and facilities to care for children with diabetes (E).
- To ensure the highest level of safety, careful liaison is required between surgical, anesthetic, and children's diabetes care teams before admission to the hospital for elective surgery and as soon as possible after admission for emergency surgery (E).
- Centers performing surgical procedures on children with diabetes should have written protocols for postoperative management of diabetes on the wards where children are admitted (E).

The management of diabetes in children now includes a wide array of insulin analogs, insulin delivery devices, and regimens. Safe management of the child with diabetes in the perioperative period requires not only an understanding of the pathophysiology of the disease but also a thoughtful consideration of each child's specific diabetes treatment regimen, glycemic control, intended surgery, and anticipated postoperative course. Therefore, it is essential that the surgeon and anesthetist liaise with the child's diabetes team prior to any planned surgery. Evidence-based controlled studies of perioperative care specifically for children with diabetes are lacking.

The current, revised guidelines are based on the 2009 ISPAD Consensus Guidelines (1). 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 (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 yr with Diabetes Mellitus Undergoing Surgery (4). They include recommendations from a recent comprehensive review of perioperative management for children with diabetes published in the anesthesiology literature (5). Because there are few relevant scientific papers on management of children during surgery, the recommendations are mostly based on expert opinion. Where appropriate, guidelines for perioperative managements of adults with diabetes are also used to inform these recommendations.

Glycemic targets for surgery

The appropriate glycemic targets during the perioperative period remain controversial. The stress of surgery leads to a complex neuroendocrine stress response characterized by hyperglycemia and a catabolic state. To achieve optimal glycemic control, insulin dosage may need to be increased on the day of major surgery and for approximately 2 d after surgery (6). Hyperglycemia has been associated with an increased risk of postoperative infection (7).

In a study of 23 000 patients in 1973, adults with diabetes had an approximately 10-fold increased risk of postoperative wound infections (8). However, a recent systematic review of the adult literature found insufficient evidence to support strict glycemic control versus conventional management for the prevention of surgical site infections (9).

A recent meta-analysis showed that adult patients in surgical intensive care units (ICUs) appear to benefit from intensive insulin therapy and tight glycemic control, whereas patients in other ICU settings may not (10). Therefore, a consensus statement from the American Association of Clinical Endocrinologists and American Diabetes Association (11) recommends that an insulin infusion should be used to control hyperglycemia in the majority of critically ill patients in the ICU setting, with a starting glycemic threshold of no higher than 10 mmol/L (180 mg/dL). Once intravenous (IV) insulin therapy has been initiated, blood glucose should be maintained between approximately 8 and 10 mmol/L (140 and 180 mg/dL). Without prospective data from randomized controlled trials to establish specific guidelines in non-critically ill patients treated with insulin, premeal glucose targets should generally be <8 mmol/L (140 mg/dL) and random blood glucose values <10 mmol/L (180 mg/dL) as long as these targets can be safely achieved.

Few pediatric trials to date are available to inform these ranges and are limited to the critical care setting (12, 13). Vlasselaers et al., for example, showed shorter length of stay, attenuated inflammatory response, and decreased mortality in patients randomized to targeting of age-adjusted normoglycemia (14); however, the rate of severe hypoglycemia (<40 mg/dL, <2.3 mmol/L) was 25%. More recently, Macrae et al. conducted a multicenter trial in 13 centers in England involving critically ill children in pediatric ICUs (15). Tight glycemic control did not have a significant effect on major clinical outcomes and was, again, associated with a higher rate of hypoglycemia than conventional glucose control. In a systematic review and meta-analysis of the four randomized clinical trials of tight glycemic control with intensive insulin therapy in critically ill children, Srinivasan and Agus (13) reported that, while acquired infection was reduced, there was no decrease in 30-d mortality and a higher incidence of hypoglycemia was observed. Similarly, a systematic review and meta-analysis of 12 randomized trials in adults found intensive blood glucose control in the perioperative period did not significantly improve postoperative outcomes but was associated with a risk of hypoglycemia in *post-hoc* analyses (16).

Appropriate perioperative glycemic targets for minor surgical procedures are less clear. However, studies in adults that compared different methods of achieving glycemic control during minor and moderate surgery did not demonstrate any adverse effects of maintaining perioperative glycemic levels between 5 and 11 mmol/L (~90–200 mg/dL) (17–19).

Therefore, based on the available data, it seems reasonable to aim for blood glucose in the range of 5–10 mmol/L (90–180 mg/dL) during surgical procedures in children. However, the benefits of tightening glycemic control must be weighed against the risk of perioperative hypoglycemia, which may not be recognized during anesthesia. This risk can be mitigated, however, by frequent intra- and post-operative blood glucose monitoring.

Classification of procedures and presurgical assessment

In the management of children with diabetes undergoing surgery it is helpful to divide procedures into two categories:

Minor surgery

Minor surgery requires brief general anesthesia (GA) (or heavy sedation), usually of less than 2 h duration, and should not have a major impact on glycemic control. Examples include common day surgery procedures: endoscopies, duodenal biopsy, adenotonsillectomy, grommet insertion, and simple orthopedic procedures.

The child will usually be discharged from the 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.

Major surgery

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

Whenever possible, surgery should be performed when diabetes is under optimal control. If circumstances permit a presurgical assessment, this should, ideally, be done several days before the surgery to allow for an assessment of glycemic control, electrolyte status, and ketones (urine or blood). If glycemic control is known to be poor and surgery is not urgent, the procedure should be delayed until glycemic control has improved. If glycemic control is uncertain or poor and surgery cannot be delayed, consider admission to the hospital prior to surgery for assessment and stabilization of glycemic control.

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

Children and adolescents with type 1 or type 2 diabetes treated with insulin:

- Must be admitted to the hospital if receiving GA.
  - In cases with documented good control, it should be possible to admit early on the day of surgery for both minor and major procedures. Otherwise, it is preferred to admit in the afternoon before surgery to give time for correction of metabolic status overnight.
- Should be scheduled as the first case of the day.
- Need insulin, even if fasting, to avoid ketoacidosis.
- May initially receive an IV infusion without dextrose for minor surgery or procedures (lasting for less than 2 h) if treated with basal/bolus insulin regimen or continuous subcutaneous insulin infusion (CSII).
- Should initially receive an IV infusion with dextrose for major surgery or procedures (lasting for at least 2 h) or if treated with NPH insulin.
- Require hourly capillary blood glucose monitoring to detect hypoglycemia and hyperglycemia before the procedure. If the blood glucose exceeds 14 mmol/L (~250 mg/dL), a conservative dose of rapid-acting insulin or short-acting insulin (regular) should be administered to restore blood glucose to the target range.
- Should coordinate the timing of preoperative food and fluid restrictions with the anesthetist.
  - The usual recommendation is no solid food for at least 6 h before surgery (20). Clear fluids (and breast milk) may be allowed up to 4 h before surgery (check with anesthetist).
- Require specific adjustment of the insulin schedule depending on the type of surgery (major or minor), the patient's insulin regimen, and the time of the surgical procedure (morning or afternoon). Guidelines for each scenario are presented.

Major surgery (as defined above)

- On the evening before surgery:
  - Give the usual evening and/or bedtime insulin(s) and bedtime snack.
  - Monitor blood glucose and measure blood ß-hydroxybutyrate (BOHB) or urinary ketone concentration if blood glucose is >14–20 mmol/L (>250–360 mg/dL).
- Omit the usual morning insulin dose.
- At least 2 h before surgery, start an IV insulin infusion [e.g., dilute 50 units regular (soluble) insulin in 50 mL normal saline, 1 unit = 1 mL] and provide IV maintenance fluids consisting of 5% dextrose and half-normal saline (0.45% NaCl) (see Table 1).
- Monitor blood glucose levels at least hourly before surgery and as long as the patient is receiving IV insulin.
- Aim to maintain blood glucose between 5 and 10 mmol/L (90–180 mg/dL) by adjusting the IV insulin dose or the rate of dextrose infusion during surgery.
- 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. For more detail, see reference (5).

(i) Patients treated with twice daily basal (NPH, insulin detemir, or insulin glargine) and rapid- or short-acting insulins:

- Morning operations
  - On the morning of the procedure, give 50% of the usual morning dose of intermediate-acting insulin (NPH) or the full usual morning dose of long-acting insulin (detemir or glargine). With premixed insulin, give only 50% of the equivalent dose of the basal (NPH) component.
  - Omit the short- or rapid-acting insulin unless it is needed to correct hyperglycemia.
  - Commence IV fluids containing dextrose 5–10%, as necessary, to prevent hypoglycemia.
  - Alternatively, IV insulin infusion may be started as described above.
- Afternoon operations (if unavoidable)
  - On the morning of the procedure, give 50% of the usual dose of intermediate-acting insulin (NPH) or the full usual morning dose of long-acting insulin (detemir or glargine). With premixed insulin, give only 50% of the equivalent dose of the basal component (NPH).
  - The dose of short- or rapid-acting insulin will depend on whether the child is permitted to eat breakfast.
  - Alternatively, give 30–40% of the usual morning insulin dose of short- or rapid-acting insulin (but no intermediate- or long-acting insulin) and use an IV insulin infusion beginning at least 2 h before surgery (Table 1).

Table 1. Infusion guide for surgical procedures

(i) Maintenance fluid guide

- Dextrose (for major surgery and any surgery when NPH has been given)
  5% dextrose; 10% if there is concern about hypoglycemia. If blood glucose is high (>14 mmol/L, 250 mg/dL), use half-normal saline (0.45% NaCl) without dextrose and increase insulin supply but add 5% dextrose when blood glucose falls below 14 mmol/L (250 mg/dL).
- Sodium
  There is evidence that the risk of acute hyponatremia may be increased when hypotonic maintenance solutions (i.e., <0.9% NaCl) are used in hospitalized children (27). Many centers, therefore, use saline 0.45–0.9% (77–154 mmol Na/L). A compromise would be to give 0.45% saline with 5% dextrose, carefully monitor electrolytes, and change to 0.9% saline if plasma Na concentration is falling.
- Potassium
  Monitor electrolytes. After surgery, add potassium chloride 20 mmol to each liter of intravenous fluid. Some centers add potassium routinely only if infusion is required for more than 12 h.

Example of calculation of maintenance requirements:

	Body weight (kg)	**Fluid requirement per 24 h**
For each kg between	3–9	100 mL/kg
For each kg between	10–20	Add an additional 50 mL/kg
For each kg over	20	Add an additional 20 mL/kg
(Maximum 2000 mL female, 2500 mL male)		

(ii) Insulin infusion

- Add soluble (regular) insulin 50 units to 50 mL normal saline (0.9% NaCl), making a solution of 1 unit insulin/mL; attach to syringe pump and label clearly
- Start infusion at 0.025 mL/kg/h (i.e., 0.025 U/kg/h) if blood glucose is <6–7 mmol/L (~110–140 mg/dL), 0.05 mL/kg/h if 8–12 mmol/L (~140–220 mg/dL), 0.075 mL/kg/h between 12 and 15 mmol/L (~220–270 mg/dL and 0.1 U/kg/h if >15 mmol/L (~270 mg/dL).
- Aim to maintain blood glucose between 5 and 10 mmol/L (90–180 mg/dL) by adjusting insulin infusion hourly
- Blood glucose must be measured at least hourly when the patient is on IV insulin
- **Do not stop the insulin infusion** if blood glucose <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 is <4 mmol/L (55 mg/dL) but not >10–15 min.

IV, intravenous.

  - If the anesthetist 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) should commence 2 h before surgery or no later than midday (Table 1).

(ii) Patients treated with once daily basal/bolus insulin regimens:

Children on basal/bolus regimens benefit from not discontinuing their basal insulin before minor surgical procedures. This is particularly relevant for children requiring repeated procedures.

- Morning operations
  - On the morning of the procedure, give the usual dose of long-acting insulin (glargine or 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%.
  - Omit the short- or rapid-acting insulin unless needed to correct hyperglycemia.
  - Commence IV fluids. Patients with a normal blood glucose may initially utilize IV fluids without dextrose. With an appropriately titrated basal rate and careful monitoring, this approach may be more physiologic (21, 22).
  - 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.
  - If the anesthetist 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) should commence 2 h before surgery or no later than midday (Table 1).

(iii) Patients treated with CSII:

- If possible, and provided the anesthetist agrees, use of CSII 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 GA is short (<2 h), 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 min to correct any episodes of mild hypoglycemia.
- Do not give a bolus dose of rapid-acting insulin unless necessary to correct hyperglycemia.
- Commence 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 (21, 22).
- 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 drop the blood pressure. Therefore, blood pressure should be carefully monitored.

Monitor blood glucose measurements at least hourly during and immediately 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 (Table 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, NS (0.9% NaCl) or Ringer's lactate must be infused rapidly. In this case, potassium-containing fluids must *not* be infused rapidly.

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.

Special circumstances

Emergency surgery

Although the majority of surgical procedures are elective, both minor and major surgical procedures may occur as emergencies. It is important to remember that diabetic ketoacidosis 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.

Type 2 diabetes patients on oral medication alone

For patients with type 2 diabetes treated with insulin, follow the insulin guidelines as for elective surgery, depending on type of insulin regimen. For pediatric patients with type 2 diabetes on metformin, the timing of discontinuation will depend on the expected length of the procedure. Use of metformin has been associated with lactic acidosis, with risk that is increased by renal insufficiency (23). As lactic acidosis is both a rare and life threatening event, limited data are available to inform guidelines for perioperative management (24, 25). Therefore recommendations are that for major surgery (lasting at least 2 h) when conditions predisposing to additional risk factors, such as renal insufficiency or tissue hypoperfusion are most likely to be present, metformin should be discontinued 24 h before the procedure. Further, in the event of emergency surgery and <24 h since the last dose, it is essential to maintain hydration with IV fluids before, during, and after surgery. For minor surgery (i.e., less than 2 h), metformin may be discontinued on the day of the procedure. In all cases, metformin should be withheld for 48 h after surgery and until normal renal

function has been confirmed before restarting. For sulfonylureas, thiazolidinediones, DPP-4 inhibitors, and GLP-1 analogs, stop the medication on the day of surgery. Patients 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, 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 h.

Conclusion

Whenever possible, surgery on children and adolescents with diabetes should be performed at centers with appropriate personnel and facilities to care for children with diabetes. To ensure the highest level of safety, careful liaison is required between surgical, anesthetic, and children's diabetes care teams before admission to the hospital for elective surgery and as soon as possible after admission for emergency surgery. Centers performing surgical procedures on children with diabetes should have written protocols for postoperative management of diabetes on the wards where children are admitted. Elective surgery should be scheduled as the first case on a surgical list, preferably in the morning. IV access, infusion of dextrose, and frequent blood glucose monitoring are essential whenever GA is given. Dextrose 5% is usually sufficient; dextrose 10% may be necessary when there is an increased risk of hypoglycemia. Elevated blood ketone and blood glucose concentrations require extra insulin and, possibly, additional IV fluid for correction. In these situations, consider whether it is appropriate to delay and reschedule an elective surgical procedure. A bedside meter that measures BOHB levels can be useful to guide management of these patients (26).

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Conflict of interest

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References

1. Betts P, Brink S, Silink M, Swift PG, Wolfsdorf J, Hanas R. Management of children and adolescents with diabetes requiring surgery. Pediatr Diabetes 2009: 10 (Suppl. 12): 169–174.
2. Craig ME, Twigg SM, Donaghue KC, Cheung NW, Cameron FJ, Conn J, Jenkins AJ, Silink M, for the Australian Type 1 Diabetes Guidelines Expert Advisory Group. National evidence-based clinical care guidelines for type 1 diabetes in children, adolescents and adults, Australian Government Department of Health and Ageing, Canberra 2011 (available from http://www.nhmrc.gov.au/guidelines/publications/ext4).
3. Wherrett D, Huot C, Mitchell B, Pacaud D. Canadian Diabetes Association 2013 Clinical Practice Guidelines for the prevention and management of diabetes in Canada: type 1 diabetes in children and adolescents. Can J Diabetes 2013: 37: S153–S162.
4. Association of Children's Diabetes Clinicians. Care of children under 18 years with diabetes mellitus undergoing Surgery 2013 (available from http://www.a-c-d-c.org/wp-content/uploads/2012/08/ACDC_surgery_guideline2014-pdf.pdf).
5. Rhodes ET, Ferrari LR, Wolfsdorf JI. Perioperative management of pediatric surgical patients with diabetes mellitus. Anesth Analg 2005: 101: 986–999.
6. Kaufman FR, Devgan S, Roe TF, Costin G. Perioperative management with prolonged intravenous insulin infusion versus subcutaneous insulin in children with type I diabetes mellitus. J Diabetes Complications 1996: 10: 6–11.
7. Dronge AS, Perkal MF, Kancir S, Concato J, Aslan M, Rosenthal RA. Long-term glycemic control and postoperative infectious complications. Arch Surg 2006: 141: 375–380.
8. Cruse PJ, Foord R. A five-year prospective study of 23,649 surgical wounds. Arch Surg 1973: 107: 206–210.
9. Kao LS, Meeks D, Moyer VA, Lally KP. Perioperative glycaemic control regimens for preventing surgical site infections in adults. Cochrane Database Syst Rev 2009: 3: CD006806.
10. Griesdale DE, de Souza RJ, van Dam RM et al. Intensive insulin therapy and mortality among critically ill patients: a meta-analysis including NICE-SUGAR study data. CMAJ 2009: 180: 821–827.
11. Moghissi ES, Korytkowski MT, DiNardo M et al. American Association of Clinical Endocrinologists and American Diabetes Association consensus statement on inpatient glycemic control. Endocr Pract 2009: 15: 353–369.
12. Agus MS. Tight glycemic control in children – is the target in sight? N Engl J Med 2014: 370: 168–169.
13. Srinivasan V, Agus MS. Tight glucose control in critically ill children – a systematic review and meta-analysis. Pediatr Diabetes 2014: 15: 75–83.
14. Vlasselaers D, Milants I, Desmet L et al. Intensive insulin therapy for patients in paediatric intensive care: a prospective, randomised controlled study. Lancet 2009: 373: 547–556.
15. Macrae D, Grieve R, Allen E et al. A randomized trial of hyperglycemic control in pediatric intensive care. N Engl J Med 2014: 370: 107–118.
16. Buchleitner AM, Martinez-Alonso M, Hernandez M, Sola I, Mauricio D. Perioperative glycaemic control for diabetic patients undergoing surgery. Cochrane Database Syst Rev 2012: 9: CD007315.

17. Hemmerling TM, Schmid MC, Schmidt J, Kern S, Jacobi KE. Comparison of a continuous glucose-insulin-potassium infusion versus intermittent bolus application of insulin on perioperative glucose control and hormone status in insulin-treated type 2 diabetics. J Clin Anesth 2001: 13: 293–300.
18. Christiansen CL, Schurizek BA, Malling B, Knudsen L, Alberti KG, Hermansen K. Insulin treatment of the insulin-dependent diabetic patient undergoing minor surgery. Continuous intravenous infusion compared with subcutaneous administration. Anaesthesia 1988: 43: 533–537.
19. Raucoules-Aime M, Lugrin D, Boussofara M, Gastaud P, Dolisi C, Grimaud D. Intraoperative glycaemic control in non-insulin-dependent and insulin-dependent diabetes. Br J Anaesth 1994: 73: 443–449.
20. Brady M, Kinn S, Ness V, O'Rourke K, Randhawa N, Stuart P. Preoperative fasting for preventing perioperative complications in children. Cochrane Database Syst Rev 2009: 4: CD005285.
21. Mucha GT, Merkel S, Thomas W, Bantle JP. Fasting and insulin glargine in individuals with type 1 diabetes. Diabetes Care 2004: 27: 1209–1210.
22. Al-Khawari M, Al-Ruwayeh A, Al-Doub K, Allgrove J. Adolescents on basal-bolus insulin can fast during Ramadan. Pediatr Diabetes 2010: 11: 96–100.
23. Eppenga WL, Lalmohamed A, Geerts AF et al. Risk of lactic acidosis or elevated lactate concentrations in metformin users with renal impairment: a population-based cohort study. Diabetes Care 2014: [Epub 19 May 2014].
24. Baradari AG, Habibi MR, Khezri HD et al. Does high-dose metformin cause lactic acidosis in type 2 diabetic patients after CABG surgery? A double blind randomized clinical trial. Heart Int 2011: 6: e8.
25. Sirvinskas E, Kinduris S, Kapturauskas J, Samalavicius R. Perioperative use of metformin in cardiac surgery. Medicina 2010: 46: 723–729.
26. Rewers A, McFann K, Chase HP. Bedside monitoring of blood beta-hydroxybutyrate levels in the management of diabetic ketoacidosis in children. Diabetes Technol Ther 2006: 8: 671–676.
27. Choong K, Kho ME, Menon K, Bohn D. Hypotonic versus isotonic saline in hospitalised children: a systematic review. Arch Dis Child 2006: 91: 828–835.