

Diabetes UK Position Statements and Care Recommendations

NHS Diabetes guideline for the perioperative management of the adult patient with diabetes*

K. Dhatariya¹, N. Levy², A. Kilvert³, B. Watson⁴, D. Cousins⁵, D. Flanagan⁶, L. Hilton⁷, C. Jairam⁸, K. Leyden³, A. Lipp¹, D. Lobo⁹, M. Sinclair-Hammersley¹⁰ and G. Rayman¹¹ for the Joint British Diabetes Societies

¹Norfolk and Norwich University Hospitals, Norwich, ²West Suffolk Hospital, Bury St Edmonds, ³Northampton General Hospital, Northampton, ⁴Queen Elizabeth Hospital, Kings Lynn, ⁵National Patient Safety Agency, London, ⁶Plymouth Hospital, Plymouth, ⁷Bolton Primary Care Trust, Bolton, ⁸Charing Cross Hospital, London, ⁹Queens Medical Centre, Nottingham, ¹⁰John Radcliffe Hospital, Oxford and ¹¹Ipswich Hospital and NHS Diabetes, National Clinical Lead for Inpatient Diabetes, Ipswich, UK

Accepted 11 January 2012

Abstract

These Joint British Diabetes Societies guidelines, commissioned by NHS Diabetes, for the perioperative management of the adult patient undergoing surgery are available in full in the Supporting Information.

This document goes through the seven stages of the patient journey when having surgery. These are: primary care referral; surgical outpatients; preoperative assessment; hospital admission; surgery; post-operative care; discharge. Each stage is given its own considerations, outlining the roles and responsibilities of each group of healthcare professionals. The evidence base for the recommendations made at each stage, discussion of controversial areas and references are provided in the report.

This document has two key recommendations. Firstly, that the management of the elective adult surgery patients should be with modification to their usual diabetes treatment if the fasting is minimized because the routine use of a variable rate intravenous insulin infusion is not recommended. Secondly, that poor preoperative glycaemic control leads to post-outcomes and thus, where appropriate, needs to be addressed prior to referral for surgery.

Diabet. Med. 29, 420–433 (2012)

Keywords diabetes, guidelines, perioperative management, surgery, variable rate intravenous insulin infusion

Summary of key points

Organization and planning of care

K1. Careful planning, taking into account the specific needs of the patient with diabetes, is required at all stages of the patient pathway from general practitioner referral to post-operative discharge.

- K2. The patient should be involved in planning for all stages.
- K3. Hospital patient administration systems should be able to identify all patients with diabetes so they can be prioritized on the operating list.
- K4. High-risk patients (poor glycaemic control/complications of diabetes) should be identified in surgical outpatients or at preoperative assessment and plans should be put in place to manage their risk.
- K5. Early preoperative assessment should be arranged to determine a perioperative diabetes management strategy and to identify and optimize other co-morbidities.
- K6. Routine overnight admission for preoperative management of diabetes should not be necessary.
- K7. Starvation time should be minimized by prioritizing patients on the operating list.
- K8. Surgical and anaesthetic principles of the Enhanced Recovery Partnership Programme should be implemented to promote earlier mobilization, with

Correspondence to: Dr Ketan Dhatariya, Elsie Bertram Diabetes Centre, Norfolk and Norwich University Hospitals NHS Foundation Trust, Colney Lane, Norwich, NR4 7UY, UK. E-mail: ketan.dhatariya@nnuh.nhs.uk

*This document is an abridged and modified version of Management of Adults with Diabetes Undergoing Surgery and Elective Procedures: Improving Standards. It has been adapted specifically for Diabetic Medicine.

This article [NHS Diabetes guideline for the perioperative management of the adult patient with diabetes] was written by [K. Dhatariya, N. Levy, A. Kilvert, B. Watson, D. Cousins, D. Flanagan, L. Hilton, C. Jairam, K. Leyden, A. Lipp, D. Lobo, M. Sinclair-Hammersley and G. Rayman] of NHS UK. It is published with the permission of the Controller of HMSO and the Queens Printer for Scotland.

resumption of normal diet and return to usual diabetes management.

- K9. Multi-modal analgesia should be combined with appropriate anti-emetics to enable an early return to normal diet and usual diabetes regimen.
- K10. The patient should resume diabetes self management as soon as possible where appropriate.
- K11. A policy which includes plans for diabetes management should be in place for safe discharge.
- K12. Outcomes should be audited regularly.

Diabetes specialists

- K13. Clear guidelines should indicate when the diabetes specialist team should become involved.
- K14. All hospitals should implement a Diabetes Inpatient Specialist Nurse service.

Perioperative use of intravenous insulin

- K15. The term 'variable rate intravenous insulin infusion' should replace the ambiguous term 'sliding scale'.
- K16. Patients with a planned short starvation period (no more than one missed meal in total) should be managed by modification of their usual diabetes medication, avoiding a variable rate intravenous insulin infusion wherever possible.
- K17. Patients expected to miss more than one meal should have a variable rate intravenous insulin infusion.
- K18. The recommended first-choice substrate solution for a variable rate intravenous insulin infusion is 0.45% sodium chloride with 5% glucose and either 0.15% potassium chloride or 0.3% potassium chloride.
- K19. Insulin should always be prescribed according to National Patient Safety Agency recommendations for safe use of insulin.

Perioperative blood glucose monitoring

- K20. Capillary blood glucose levels should be monitored and recorded at least hourly during the procedure and in the immediate post-operative period.
- K21. Hospitals should have clear guidelines for the management of blood glucose when it is outside the acceptable range.
- K22. Training for blood glucose measurement and diabetes management should be introduced for clinical staff caring for patients with diabetes.
- K23. The World Health Organization surgical safety checklist bundle should be implemented. The target blood glucose should be 6–10 mmol/l (acceptable range 4–12 mmol/l).

Introduction

Diabetes affects at least 4–5% of people in the UK and affects more than 10% of people undergoing surgery [1]. Work has

been previously been undertaken to try and raise standards of care for inpatients with diabetes [2–4].

Diabetes leads to increased morbidity and length of stay of the surgical patient. The perioperative mortality rate is reported to be up to 50% higher than that of the population without diabetes [5]. The reasons for these adverse outcomes are multifactorial but include:

- hypo- and hyperglycaemia [5–7];
- multiple co-morbidities, including microvascular and macrovascular complications [8–14];
- complex polypharmacy, including misuse of insulin [15];
- management errors when converting from the intravenous insulin infusion to usual medication;
- perioperative infection [5];
- failure to appreciate that patients with diabetes need a higher level of care [8,16,17];
- failure to identify patients with diabetes [2,18,19];
- lack of institutional guidelines for management of diabetes [5,20];
- poor knowledge of diabetes amongst staff delivering care.

The impact of surgery on diabetes

Surgery is frequently accompanied by a period of starvation, both of which induce a catabolic state [21]. This can be attenuated in patients with diabetes by an infusion of insulin and glucose [22,23].

Major surgery leads to metabolic stress, with an increase in catabolic hormone secretion and inhibition of anabolic hormones, particularly insulin. In patients without diabetes this can lead to transient hyperglycaemia. The initial inhibition of insulin secretion is followed post-operatively by a period of insulin resistance, so that major surgery results in a state of functional insulin insufficiency [21]. People with Type 1 diabetes undergoing surgery have no insulin secretory capacity and are unable to respond to the increased demand for insulin. People with Type 2 diabetes have pre-existing insulin resistance with limited insulin reserve, reducing their ability to respond to the increased demand.

Patients with diabetes are more susceptible to infection and poor perioperative glycaemic control has a significant impact on the risk of post-operative infection across a variety of surgical specialties [5,24].

The role of the diabetes inpatient specialist team

The Diabetes National Service Framework concluded that inpatient services could be improved by the provision of a diabetes inpatient specialist nurse service, supported by diabetologists [25].

A diabetes inpatient specialist nurse service has been shown to reduce the length of stay for patients with diabetes, whatever the reason for admission [26–29]. There is also good evidence

to show that the early involvement of the diabetes specialist team leads to shorter length of stay, with a significant increase in the proportion of day cases. Diabetes UK recommends that all trusts should implement such a diabetes inpatient specialist nurse service at a level of 1.0 whole time equivalent per 300 beds.

The diabetes specialist team can play a pivotal role through teaching, training and support, to ensure that other members of staff are able to facilitate the pathway.

Safe use of insulin

Errors in insulin prescribing are very common and insulin has been identified as one of the top five high-risk medications in the inpatient environment [30,31]. One third of all inpatient medical errors leading to death within 48 h of the error involve insulin administration [32].

Iatrogenic complications from errors of insulin prescribing are common [33–35]. As a result of these issues and the increased awareness of the harm associated with insulin errors, the Department of Health has added insulin maladministration to the list of ‘never events’ for 2011–2012 [36], as well as the National Patient Safety Agency issuing Rapid Response Reports on the safe prescribing of insulin [15,37].

NHS Diabetes has recently launched an e-learning module for the safe use of intravenous insulin [38]. This will allow compliance with National Patient Safety Agency guidance [37].

Strategies to maintain glycaemic control

Classically, glycaemic control has been achieved with concurrent administration of intravenous infusions of insulin and glucose. During the 1980s, this was using the glucose, insulin and potassium (‘GIK’) or ‘Alberti’ regimen [23], but more recently, the insulin has been delivered independently using a variable rate intravenous insulin infusion. The use of a variable rate intravenous insulin infusion does have advantages. These include:

- accurate delivery of insulin via syringe driver;
- allowing tight blood glucose control in the intra-operative starvation period when used appropriately;
- flexibility for independent adjustment of fluid and insulin.

However, the use of a variable rate intravenous insulin infusion together with infusion of a separate solution containing glucose and potassium is not without its potential complications. These include:

- delayed introduction of the variable rate intravenous insulin infusion;
- administration of insulin and/or glucose-containing solutions without an electronic infusion control device;
- incorrect setting of infusion pumps and syringe drivers;
- failure to monitor blood glucose regularly or to adjust the rate of insulin infusion if the blood glucose is consistently outside the target range;
- ketoacidosis, resulting from insulin omission in fasting patients, usually with Type 1 diabetes;
- severe hypoglycaemia, if glucose infusions or enteral feeds are discontinued but the insulin infusion is continued;
- subcutaneous insulin administered by the patient just prior to or at the same time as the variable rate intravenous insulin infusion is commenced, leading to hypoglycaemia;
- hyponatraemia;
- use of the wrong insulin protocol; hospitals may have several variable rate intravenous insulin infusion protocols for use in different circumstances;
- delays and errors in transferring back to the patient’s normal regimen from an insulin infusion: this may prolong length of stay [39].

Because of these and other issues, many units are now successfully managing the perioperative glucose control in the elective surgical patient by manipulating the patient’s usual diabetes medication [40]. Successful modification of the usual glucose-lowering agents can only be utilized if the starvation period is short and other criteria are fulfilled. These are listed in Box 1.

Safe use of variable rate intravenous insulin infusions

Variable rate intravenous insulin infusions are often poorly managed in the perioperative setting and thus require explicit guidelines [20,41]. See Appendix 5 and Appendix 7 of the Supporting Information for detailed guidance [42].

If the patient is normally treated with insulin, the variable rate intravenous insulin infusion should not be discontinued until a short -acting bolus has been given and background insulin is in place. See Appendix 7 of the Supporting Information, which provides guidance for transfer from a variable rate intravenous insulin infusion to subcutaneous insulin or oral therapy [42].

Treatment requirements may differ from usual in the immediate post-operative period where there is a risk of

Box 1 Factors favouring perioperative diabetes control by modification of usual glucose-lowering medications

- Good diabetes control prior to admission ($HbA_{1c} < 69$ mmol/mol, 8.5%)
- High probability that the patient will be capable of self managing their diabetes during the immediate post-operative period
- Short starvation period (only one missed meal)
- Surgery/procedure can be carried out early on a morning or afternoon list

glycaemic instability and clinical staff may need to take decisions about diabetes management. The diabetes specialist team should be consulted if there is uncertainty about treatment selection or if the blood glucose targets are not achieved and maintained. Guidelines should be in place to ensure that the ward staff know when to call for specialist help.

Diabetes and the Enhanced Recovery Partnership Programme [43]

Enhanced recovery of patients undergoing surgery has particular relevance for patients with diabetes [44–46]. The ethos of the Enhanced Recovery Partnership Programme has been embraced by these guidelines and is summarized in Box 2.

Enhanced Recovery Partnership Programme and the use of oral carbohydrate loading

The Enhanced Recovery Partnership Programme recommends the administration of high-carbohydrate drinks prior to surgery. This may compromise blood glucose control and is not recommended for people with insulin-treated diabetes.

Pathway of care for elective surgery

A pathway of care for elective surgery is shown in Fig. 1.

Primary care

Aims

- Ensure that the potential effects of diabetes and associated co-morbidities on the outcome of surgery are considered before referral for elective procedures.
- Ensure that the relevant medical information is communicated fully at the time of referral.
- Ensure that diabetes and co-morbidities are optimally managed before the referral [47].

Action plan

1. Provide the current HbA_{1c}, blood pressure and weight measurements, with details of relevant complications and medications in the referral letter.
2. Optimize glycaemic control before referral if possible.
3. Consider referral to the diabetes specialist team for advice if the HbA_{1c} is > 69 mmol/mol (8.5%). A high HbA_{1c} is an

indication for intensive blood glucose control, but it may not be realistic to delay referral until the HbA_{1c} measurement has been repeated.

4. Patients with hypoglycaemic unawareness should be referred to the diabetes specialist team irrespective of HbA_{1c}.
5. Optimize other diabetes-related co-morbidities.
6. Provide written advice to patients undergoing investigative procedures requiring a period of starvation.

Surgical outpatients

Aims

- Arrange preoperative assessment as soon as possible after the decision is taken to proceed with surgery.
- Avoid overnight preoperative admission to hospital wherever possible.

Action plan

1. Systems should be in place to allow early preoperative assessment to identify people with suboptimal diabetes control.
2. Clear institutional plans based on British Association of Day Surgery Directory of Procedures should be in place to facilitate day-of-surgery admission and prevent unnecessary overnight preoperative admission [48].
3. Hospital patient administration systems should be able to identify all patients with diabetes so they can be prioritized on the operating list.
4. Patients undergoing investigative procedures requiring a period of starvation should be identified and provided with written information about diabetes management.
5. The surgeon in the outpatient clinic should ensure that patients with diabetes are not scheduled for an evening list. This avoids prolonged starvation times, the use of a variable rate intravenous insulin infusion and an unnecessary overnight stay.

Preoperative assessment

Aims

- Ensure that glycaemic control is optimized prior to surgery.
- Establish an individualized diabetes management plan, agreed with the patient, for the pre-admission and perioperative period.

Box 2 Pertinent elements of the Enhanced Recovery Partnership Programme

- Optimize preoperative health, commencing in primary care
- Anaesthetic preoperative assessment with medical optimization, risk stratification and discharge planning
- Admission on the day of surgery with prior patient engagement and appropriate medication adjustment
- Minimal perioperative physiological trespass
- Early post-operative nutrition and return to normal medicines
- Discharge once predetermined criteria met and patient in agreement

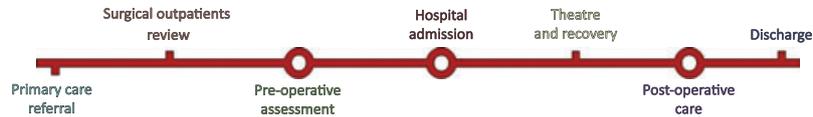


FIGURE 1 Pathway of care for elective surgery.

- Ensure that co-morbidities are recognized and optimized prior to admission.
- Ensure plans are in place to modify other treatments during the pre-admission and perioperative period; e.g. bridging therapy for warfarin, renal replacement therapy.
- Identify high-risk patients requiring critical care management.

Action plan

1. All patients with diabetes scheduled to undergo an elective procedure necessitating a period of starvation should attend a preoperative assessment clinic as soon as possible.
2. Preoperative assessment clinic staff should:
 - 2.1. Assess adequacy of glycaemic control. The risks of proceeding when control is suboptimal should be balanced against the urgency of the procedure.
 - 2.2. Consider referral to the diabetes specialist team according to local policy [49]. This should include all patients with hypoglycaemia unawareness and may include those with $HbA_{1c} > 69$ mmol/mol (8.5%).
 - 2.3. Identify other co-morbidities with referral to the appropriate team for optimization where necessary.
 - 2.4. Plan inpatient admission including:
 - 2.4.1. Timing of admission.
 - 2.4.2. Location.
 - 2.4.3. Timing of surgery.
 - 2.4.4. Preadmission management of medications.
 - 2.4.5. Availability of usual insulin (patient may need to bring if non-formulary).
 - 2.4.6. Plans for Enhanced Recovery Programme in the context of diabetes.
 - 2.5. Ensure the patient is fully consulted and engaged in the proposed plan of management.
 - 2.6. Give the patient written instructions with the changes they need to make to their medication prior to admission explicitly highlighted.
 - 2.7. Plan initial preoperative management of diabetes.
 - 2.8. Ensure that patients with diabetes are not placed on an evening list. This avoids prolonged starvation times, the use of a variable rate intravenous insulin infusion, and potentially an unnecessary overnight stay.
 - 2.9. During venous thromboembolism risk assessment ensure there are no contraindications to anti-embolism stockings; e.g. patients with peripheral vascular disease or neuropathy [50].
 - 2.10. Plan duration of stay and make preliminary discharge arrangements.
 - 2.11. Ensure that admission ward staff are appraised of plans and able to activate them on the day of admission.

- 2.12. Consider the need for home support following discharge, and involve the primary care team in discharge planning.

Hospital admission

Aims

- Ensure that an agreed and documented individual patient plan is communicated to all involved in the care pathway including:
 - the patient;
 - relevant specialists (including anaesthetist, surgeon, diabetologist);
 - staff in all relevant clinical areas.
- Minimize the metabolic consequences of starvation and surgical stress.
- Maintain optimal blood glucose control throughout the admission.
- Prevent hospital-acquired foot pathology.

Action plan

1. Provide written guidelines for hospital staff and patients for the modification of commonly used diabetes treatment regimens on the day prior to and day of surgery.
2. Identify high-risk patients (poor glycaemic control/complications of diabetes) and make arrangements for post-operative admission to critical care if indicated.
3. Base management on Enhanced Recovery Programme principles, but omit the preoperative high-carbohydrate drink in people with insulin-treated diabetes.
4. Determine the treatment pathway in advance depending on the anticipated duration of starvation. Avoid a variable rate intravenous insulin infusion if the starvation period is short (only one missed meal).
5. Prioritize patients with diabetes on the list. This reduces the starvation time and hence the likelihood of the patient requiring a variable rate intravenous insulin infusion.
6. Use 0.45% sodium chloride and 5% glucose with either 0.15 or 0.3% potassium chloride (as appropriate) as the substrate fluid of choice if a variable rate intravenous insulin infusion is required. It is recognized that this is not readily available at present but this guidance recommends that this becomes standard practice.
7. Capillary blood glucose (CBG) target ranges are controversial. Aim for capillary blood glucose between 6 and 10 mmol/l, but 4–12 mmol/l is acceptable. Avoid wide swings in capillary blood glucose.

8. Monitor capillary blood glucose regularly when the patient is under sedation. Hypoglycaemia sometimes manifests as drowsiness, which may be wrongly attributed to sedation.
9. Consider continuation of long-acting analogues (Glargine/Lantus[®], Detemir/Levemir[®]) alongside the variable rate intravenous insulin infusion during the perioperative period. This is generally recommended but local policies should be adhered to.
10. Prescribe and administer insulin according to National Patient Safety Agency guidance.
11. Involve the diabetes specialist team if blood glucose targets are not achieved and maintained.
12. Identify high-risk feet and provide pressure relief where necessary. Avoid use of anti-embolism stockings where contraindicated.
13. Ensure that preparation for discharge is ongoing.

Fluid management for patients requiring a variable rate intravenous insulin infusion

Aims of fluid management

- Provide glucose as substrate to prevent proteolysis, lipolysis and ketogenesis.
- Maintain blood glucose concentrations between 6 and 10 mmol/l where possible (acceptable range 4–12 mmol/l).
- Optimize intravascular volume status.
- Maintain serum electrolytes within the normal ranges.

Recommendations

There is limited evidence on which to base recommendations for optimal fluid and insulin management in the adult patient with diabetes undergoing surgery (see Controversial areas and Appendix 3 of this document). Until further data are available, the authors recommend the following:

- The substrate solution to be used alongside the variable rate intravenous insulin infusion should be based on serum electrolytes, measured daily and selected from:
 - 0.45% saline with 5% glucose and 0.15% potassium chloride;
 - 0.45% saline with 5% glucose and 0.3% potassium chloride.

Detailed guidance for setting up a variable rate intravenous insulin infusion is provided in Appendix 5 of the Supporting Information [42].

Fluid management for patients not requiring a variable rate intravenous insulin infusion

Aims of fluid management

- Provide intravenous fluid as required according to individual need until the patient has recommenced oral intake.
- Maintain serum electrolytes within the normal ranges.
- Avoid hyperchloraemic metabolic acidosis.

Recommendations

- Hartmann's solution should be used in preference to 0.9% saline [51].
- Glucose-containing solutions should be avoided unless the blood glucose is low.

Theatre and recovery

Aims

- Maintain good glycaemic control throughout.
- Maintain normal electrolyte concentrations.
- Optimize intra-operative cardiovascular and renal function.
- Provide multi-modal analgesia with appropriate anti-emetics to enable an early return to a normal diet and usual diabetes regimen.
- Avoid pressure damage to feet during surgery.

Action plan

1. Implement the World Health Organization surgical safety checklist bundle with target blood glucose 6–10 mmol/l (acceptable range 4–12 mmol/l).
2. Implement the agreed care plan.
3. Avoid unnecessary use of variable rate intravenous insulin infusion.
4. Check the capillary blood glucose level prior to induction of anaesthesia.
5. Monitor the capillary blood glucose level regularly during the procedure (at least hourly—more frequently if readings outside the target range).
6. Maintain the blood glucose in the range 6–10 mmol/l where this can be safely achieved. A range of 4–12 mmol/l is acceptable.
7. Correct a high blood glucose using additional subcutaneous insulin or by introducing a variable rate intravenous insulin infusion.
8. Prescribe fluid regimen as required.
9. Document the capillary blood glucose level, insulin infusion rate and substrate infusion on the anaesthetic record as recommended by the Royal College of Anaesthetists and Association of Anaesthetists of Great Britain and Ireland [52,53].
10. Consider the use of individualized goal-directed therapy [51].
11. Ensure arrangements are in place to admit high-risk patients to critical care if necessary.
12. Implement surgical and anaesthetic principles of the Enhanced Recovery Partnership Programme to promote early return to normal diet and usual diabetes management.
13. Use anaesthetic techniques to reduce the incidence of post-operative nausea and vomiting and promote early return to normal diet and usual diabetes management [54–56].

Post-operative care

Aims

- Ensure glycaemic control and fluid and electrolyte balance are maintained.
- Optimize pain control.
- Encourage an early return to normal eating and drinking, facilitating return to the usual diabetes regimen.
- Follow the principles of the Enhanced Recovery Partnership Programme.
- Avoid iatrogenic injury (drugs/diabetes management/infection/pressure damage).

Action plan

1. Staff skilled in diabetes management should supervise surgical wards routinely and regularly.
2. Allow patients to self manage their diabetes as soon as possible, where appropriate.
3. Provide written guidelines for the use of intravenous fluids and insulin.
4. Prescribe and administer insulin in line with National Patient Safety Agency guidance, in consultation with the patient wherever possible [15,41].
5. Aim for a capillary blood glucose level in the 6–10 mmol/l range where this can be achieved safely. A range of 4–12 mmol/l is acceptable.
6. Monitor electrolytes and fluid balance daily and prescribe appropriate fluids.
7. Treat post-operative nausea and vomiting to promote normal feeding.
8. Maintain meticulous infection control.
9. Inspect foot and pressure areas regularly [57].

Discharge

Aims

- Ensure early discharge determined by pre-agreed clinical and social criteria.
- Ensure that factors likely to delay discharge are identified at the preoperative assessment so that any necessary arrangements are in place when the patient is medically fit for discharge.
- Ensure that plans are in place for safe management of diabetes post-discharge.

Action plan

1. In consultation with the patient, decide the clinical criteria that the patient must meet before discharge.
2. Set a date and/or time of discharge as early as possible. This should include weekends.
3. Identify whether the patient has simple or complex discharge planning needs and plan how they will be met.
4. Involve the diabetes specialist team if diabetes-related delays in discharge are anticipated.

5. Provide patient education to ensure safe management of diabetes on discharge.
6. Discharge should not be delayed solely because of poor glucose control. The ability of the patient or carer to manage the diabetes should be taken into consideration. Discuss with the diabetes specialist team if necessary.
7. Systems should be in place to ensure effective communication with community teams, particularly if changes to the patients' preoperative diabetes treatment have been made during the hospital stay.
8. Diabetes expertise should be available to support safe discharge and the team that normally looks after the patient's diabetes should be contactable by telephone.

Patient education

The diabetes inpatient specialist nurse, with the support of generalist nurses, can provide the patient education that is an essential part of discharge planning. Inpatient education can achieve earlier discharge and improved post-discharge outcomes [58]. The metabolic and endocrine effects of surgery may last for several days and patients and/or carers should be advised about blood glucose management during this period.

Emergency surgery

By definition there will be no opportunity for pre-admission planning. The blood glucose concentration should be closely monitored and, if it rises above 10 mmol/l, a variable rate intravenous insulin infusion should be commenced and continued until the patient is eating and drinking. It is recommended that if the patient is taking long-acting insulin analogues (e.g. Levemir or Glargine), these should be continued along with the variable rate intravenous insulin infusion.

The HbA_{1c} should be measured to assess the level of pre-admission blood glucose control as this may influence subsequent diabetes management.

Early involvement of the critical care and diabetes specialist teams is recommended in the management of any high-risk surgical patient.

Controversial areas

1. Glycaemic control

What is the evidence that tight glycaemic control improves the outcome of surgery?

In view of the dangers of hypo- and hyperglycaemia [5,59–64] it is reasonable to recommend that blood glucose should be maintained in the range 6–10 mmol/l [65] if this can be achieved safely. However, a range from 4 to 12 mmol/l is acceptable.

Is an elevated preoperative HbA_{1c} associated with adverse outcomes following a range of surgical procedures?

Elevated preoperative HbA_{1c} has been related to adverse outcomes following a variety of surgical procedures [66–69]. There is evidence that good control preoperatively, as measured by the HbA_{1c} level, is associated with improved outcomes after a range of non-cardiac surgical procedures [5,70].

What is the acceptable upper limit of HbA_{1c} for patients undergoing elective surgery?

There is insufficient evidence to recommend an upper limit of HbA_{1c} prior to elective surgery, and the risks associated with poor glycaemic control should be balanced against the necessity for surgery. An upper limit between 64 and 75 mmol/mol (8–9%) is acceptable, depending on individual circumstances. For many patients a lower target HbA_{1c} is achievable, but for those at high risk of hypoglycaemia a higher target may be appropriate.

The healthcare team who normally care for the patient with diabetes, whether in primary or secondary care, should advise on the individual target at the time of referral and this will help to avoid unnecessary postponement of surgery.

2. Fluid management in patients requiring a variable rate intravenous insulin infusion

Background

Fluid and electrolyte mismanagement is a recognized cause of morbidity and mortality in patients undergoing abdominal surgery [71–79]. Accurate fluid and electrolyte management is essential for patients with diabetes for whom the focus of fluid administration has previously tended to be provision of a substrate for insulin and prevention of ketogenesis, rather than maintenance of fluid and electrolyte balance.

Risk of hyponatraemia

Glucose/insulin infusions can achieve good glycaemic control but may lead to hyponatraemia. This is clinically insignificant in many patients, but hyponatraemia may lead to serious complications including death [80].

Aims of fluid therapy for the patient with diabetes

Major surgery or prolonged starvation (more than one missed meal) places the surgical patient with diabetes at increased risk of catabolism. In this situation the aims of fluid therapy are:

- prevention of gluconeogenesis, lipolysis, ketogenesis and proteolysis;
- maintenance of a blood glucose concentration between 6 and 10 mmol/l (4–12 mmol/l is acceptable);
- maintenance of euvolaemia [51];
- maintenance of serum electrolytes within the normal range.

The daily requirement of the healthy adult is 60–100 mmol of sodium, 40–80 mmol of potassium and 1.5–2.5 l of water [81].

In disease states these requirements may change and careful daily monitoring is needed, using clinical examination, fluid balance charts, daily measurement of serum electrolytes and regular weighing when possible [51].

Choice of perioperative fluid for patients requiring variable rate intravenous insulin infusion None of the UK fluid protocols currently available for the management of the adult perioperative patient with diabetes can combine maintenance of glycaemic control with normal electrolyte balance (See Appendix 3 of this document). This failure contributes to the excess morbidity and increased length of stay of these adult surgical patients.

As there are no randomized trials demonstrating the superiority of any specific fluid regimen, recommendations are based on the following criteria:

- least likely to cause harm as a result of electrolyte and fluid imbalance;
- provision of adequate substrate to prevent gluconeogenesis, lipolysis and ketogenesis;
- ease of use (reducing the risk of error);
- compliance with National Patient Safety Agency alerts 1 and 22 [82,83];
- minimum cannulae and pumps required.

Following the National Patient Safety Agency alert no. 22 [82], many paediatric surgical units now use 0.45% saline with 5% glucose with additional potassium chloride as their 'default' fluid running alongside a variable rate intravenous insulin infusion [75,84].

Until there are clinical studies to verify the safest solution for the adult surgical patient with diabetes on a variable rate intravenous insulin, the use of 0.45% saline with 5% glucose and 0.15% potassium chloride is advocated as the first choice solution, as in paediatric practice. The authors acknowledge the current limited commercial availability of this fluid, and the cost differential compared with conventionally used fluids in adults. Negotiations are taking place to address these issues and wider use of the recommended solutions will reduce cost and increase availability.

3. The continued use of glucose-lowering agents in the perioperative period

3.1. Long-acting insulin analogues

Many units advocate the continuation of long-acting insulin analogues alongside the variable rate intravenous insulin infusion. This has the advantage that no time is lost in re-establishing basal insulin once the variable rate intravenous insulin infusion is discontinued.

There is debate amongst diabetes teams as to whether the dose of long-acting insulin analogues should be reduced, depending on whether the patient has small frequent meals and snacks or not, and local policies should be agreed. If the dose of background insulin is correct, then blood glucose levels may

remain steady whilst not eating; however, many people may be on too much background insulin and only maintain their blood glucose levels by snacking regularly. It may be difficult to know, without the specialist team being involved, what any individual patient needs to do with their background insulin prior to fasting.

3.2. Metformin

Metformin is renally excreted. Renal failure may lead to high plasma concentrations which, if greater than 5 mcg/ml, are associated with an increased risk of lactic acidosis [85].

This guideline recommends that, for patients undergoing a short starvation period (one missed meal only), metformin can be continued unless patient is on a three-times-per-day regimen, when the middle dose should be omitted. In renal impairment metformin should be stopped when the preoperative fast begins and restarted post-operatively once the patient is eating again.

Prescribers must, however, be aware of the dangers of co-administration of potentially nephrotoxic agents, and patients discharged early after surgical intervention need to know when to seek medical help should they become unwell.

Radio-opaque contrast and metformin

Contrast-induced nephropathy is the development of renal impairment as a complication of radiological investigation using contrast media. Risk factors include advanced age, cardiac impairment and pre-existing renal impairment, particularly in patients with diabetes.

Guidance produced by the Royal College of Radiologists [86] recommended that there is no need to stop metformin after contrast has been administered in patients with a normal serum creatinine and/or eGFR of $> 50 \text{ ml min}^{-1} 1.73 \text{ m}^{-2}$. If the serum creatinine is above the reference range or the eGFR is below $50 \text{ ml min}^{-1} 1.73 \text{ m}^{-2}$, the need to stop the metformin should be discussed with the referring clinician.

Competing interests

NHS Diabetes paid for authors' travel expenses to attend guideline writing meetings.

Acknowledgements

These guidelines have been endorsed by the following organizations: Association of British Clinical Diabetologists; Association of Surgeons of Great Britain and Ireland; The British Association of Day Surgery; Diabetes Inpatient Specialist Nurse Group; Diabetes UK; Primary Care Diabetes Society; The Royal College of Anaesthetists; Society for Academic and Research Surgery; TREND UK. Abbreviated and adapted versions of this guideline have been published elsewhere for different specialities. The website is <http://www.asgbi.org.uk/en/>

publications/issues_in_professional_practice.cfm. Written permission for duplicate publication has been granted by the President of the Association of Surgeons of Great Britain and Ireland.

References

- 1 NHS Diabetes. *Findings from the National Diabetes Inpatient Audit (NaDIA) 2010*. 2011. Available at http://www.diabetes.nhs.uk/our_publications/reports_and_guidance/diabetes_information_and_data Last accessed 25 January 2012.
- 2 NHS Institute for Innovation and Improvement. *Think glucose. Inpatient care for people with diabetes*. 2010. Available at http://www.institute.nhs.uk/quality_and_value/think_glucose/welcome_to_the_website_for_thinkglucose.html Last accessed 25 January 2012.
- 3 Diabetes UK. *Improving Inpatient Diabetes Care – What Care Adults with Diabetes Should Expect When in Hospital*. 2009. Available at http://www.diabetes.org.uk/Documents/Position%20statements/Inpatient_position_statement_Updated_June_2009.doc Last accessed 25 January 2012.
- 4 Department of Health. *National Service Framework for Diabetes*. 2003. Available at http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/Browsable/DH_4096591 Last accessed 25 January 2012.
- 5 Frisch A, Chandra P, Smiley D, Peng L, Rizzo M, Gatcliffe C *et al*. Prevalence and clinical outcome of hyperglycemia in the perioperative period in noncardiac surgery. *Diabetes Care* 2010; **33**: 1783–1788.
- 6 Rayman G. *Inpatient Audit. Diabetes Update*. 2010. Available at http://www.diabetes.org.uk/upload/Professionals/publications/Comment_inpatient%20audit_new.pdf Last accessed 25 January 2012.
- 7 Hamblin PS, Topliss DJ, Chosich N, Lording DW, Stockigt JR. Deaths associated with diabetic ketoacidosis and hyperosmolar coma, 1973–1988. *Med J Aust* 1989; **151**: 441–442.
- 8 Cullinane M, Gray AJ, Hargraves CM, Lansdown M, Martin IC, Schubert M. Who Operates When? II. *The 2003 Report of the National Confidential Enquiry into Perioperative Deaths*. 2003. Available at <http://www.ncepod.org.uk/pdf/2003/03full.pdf> Last accessed 25 January 2012.
- 9 Cuthbertson BH, Amiri AR, Croal BL, Rajagopalan S, Brittenden J, Hillis GS. Utility of B-type natriuretic peptide in predicting medium-term mortality in patients undergoing major non-cardiac surgery. *Am J Cardiol* 2007; **100**: 1310–1313.
- 10 O'Brien MM, Gonzales R, Shroyer AL, Grunwald GK, Daley J, Henderson WG *et al*. Modest serum creatinine elevation affects adverse outcome after general surgery. *Kidney Int* 2010; **62**: 585–592.
- 11 Lee TH, Marcantonio ER, Mangione EJ, Polanczyk CA, Cook EF, Sugarbaker DJ *et al*. Derivation and prospective validation of a simple index for prediction of cardiac risk of major noncardiac surgery. *Circulation* 1999; **100**: 1043–1049.
- 12 Stamler J, Vaccaro O, Neaton JD, Wentworth D. Diabetes, other risk factors, and 12-year cardiovascular mortality for men screened in the Multiple Risk Factor Intervention Trial. *Diabetes Care* 1993; **16**: 434–444.
- 13 Veglio M, Chinaglia A, Cavallo-Perin P. QT interval, cardiovascular risk factors and risk of death in diabetes. *J Endocrinol Invest* 2004; **27**: 175–181.
- 14 Gordo A, Scuffham P, Shearer A, Oglesby A, Tobian JA. The health care costs of diabetic peripheral neuropathy in the US. *Diabetes Care* 2003; **26**: 1790–1795.
- 15 National Patient Safety Agency. *Insulin Safety. Reducing Harm Associated with the Unsafe Use of Insulin Products*. 2010. Available at <http://www.patientsafetyfirst.nhs.uk/Content.aspx?path=/interventions/relatedprogrammes/medicationsafety/insulin/> Last accessed 25 January 2012.

- 16 Jhanji S, Thomas B, Ely A, Watson D, Hinds CJ, Pearce RM. Mortality and utilisation of critical care resources amongst high-risk surgical patients in a large NHS trust. *Anaesthesia* 2008; **63**: 695–700.
- 17 Pearce RM, Harrison DA, James P, Watson D, Hinds C, Rhodes A *et al*. Identification and characterisation of the high-risk surgical population in the UK. *Crit Care* 2006; **10**: R10.
- 18 Levetan CS, Passaro M, Jablonski K, Kass M, Ratner RE. Unrecognized diabetes among hospitalized patients. *Diabetes Care* 1998; **21**: 246–249.
- 19 Moghissi ES, Korytkowski MT, Dinardo MM, Hellman R, Hirsch IB, Inzucchi S *et al*. American Association of Clinical Endocrinologists and American Diabetes Association consensus statement on inpatient glycemic control. *Diabetes Care* 2009; **32**: 1119–1131.
- 20 Sampson MJ, Brennan C, Dhatriya K, Jones C, Walden E. A national survey of inpatient diabetes services in the UK. *Diabet Med* 2007; **24**: 643–649.
- 21 Desborough JP. The stress response to trauma and surgery. *Br J Anaesth* 2000; **85**: 109–117.
- 22 Alberti KG, Thomas DJ. The management of diabetes during surgery. *Br J Anaesth* 1979; **51**: 693–710.
- 23 Thomas DJ, Platt HS, Alberti KG. Insulin-dependent diabetes during the peri-operative period. An assessment of continuous glucose–insulin–potassium infusion, and traditional treatment. *Anaesthesia* 1984; **39**: 629–637.
- 24 Furnary AP, Zerr KJ, Grunkemeier GL, Starr A. Continuous intravenous insulin infusion reduces the incidence of deep sternal wound infection in diabetic patients after cardiac surgical procedures. *Ann Thorac Surg* 1999; **67**: 352–362.
- 25 Department of Health. *National Service Framework for Diabetes: Care of People with Diabetes during Admission to Hospital*. 2007. Available at http://www.dh.gov.uk/en/Publicationsandstatistics/Publications/PublicationsPolicyAndGuidance/Browsable/DH_4903302 Last accessed 25 January 2012.
- 26 Flanagan D, Moore E, Baker S, Wright D, Lynch P. Diabetes care in hospital—the impact of a dedicated inpatient care team. *Diabet Med* 2008; **25**: 147–151.
- 27 Sampson MJ, Crowle T, Dhatriya K, Dozio N, Greenwood RH, Heyburn PJ *et al*. Trends in bed occupancy for inpatients with diabetes before and after the introduction of a diabetes inpatient specialist nurse service. *Diabet Med* 2006; **23**: 1008–1015.
- 28 Davies M, Dixon S, Currie CJ, Davis RE, Peters JR. Evaluation of a hospital diabetes specialist nursing service: a randomized controlled trial. *Diabet Med* 2001; **18**: 301–307.
- 29 Cavan DA, Hamilton P, Everett J, Kerr D. Reducing hospital inpatient length of stay for patients with diabetes. *Diabet Med* 2001; **18**: 162–164.
- 30 Winterstein AG, Hatton RC, Gonzalez-Rothi R, Johns TE, Segal R. Identifying clinically significant preventable adverse drug events through a hospital's database of adverse drug reaction reports. *Am J Health-Syst Pharm* 2002; **59**: 1742–1749.
- 31 Cohen LS, Sedhom L, Salifu M, Friedman EA. Inpatient diabetes management: examining morning practice in an acute care setting. *Diabetes Educ* 2007; **33**: 483–492.
- 32 Hellman R. A systems approach to reducing errors in insulin therapy in the inpatient setting. *Endocr Pract* 2004; **10**: 100–108.
- 33 National Patient Safety Agency. *Patient Safety Observatory Report 4: Safety in Doses*. 2010. Available at <http://www.nrls.npsa.nhs.uk/resources/patient-safety-topics/medication-safety/?entryid45=59822&q=0%2%acsafty+in+doses%2%ac> Last accessed 25 January 2012.
- 34 Institute for Safe Medication Practices (USA). *ISMP's List of High-Alert Medications*. 2008. Available at <http://www.ismp.org/Tools/highalertmedications.pdf> Last accessed 25 January 2012.
- 35 National Patient Safety Agency. *Safety in Doses: Improving the Use of Medicines in the NHS*. 2009. Available at <http://www.nrls.npsa.nhs.uk/resources/patient-safety-topics/medication-safety/?entryid45=61625&q=0%2%acsafty+in+doses%2%ac> Last accessed 25 January 2012.
- 36 Department of Health. *The 'Never Events' List 2011/12. Policy Framework for Use in the NHS*. 2011. Available at http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/documents/digitalasset/dh_124580.pdf Last accessed 25 January 2012.
- 37 National Patient Safety Agency. *Safer Administration of Insulin*. 2010. Available at <http://www.npsa.nhs.uk/corporate/news/the-national-patient-safety-agency-npsa-has-today-issued-guidance-for-all-nhs-organisations-across-england-and-wales-aimed-at-re/> Last accessed 25 January 2012.
- 38 NHS Diabetes. *The Safe Use of Intravenous Insulin Infusions*. 2011. Available at http://nhsdiabetes.healthcare.co.uk/nhs_diabetes_england.aspx Last accessed 25 January 2012.
- 39 Diabetes UK. *Collation of Inpatient Experiences 2007*. 2007. Available at <http://www.diabetes.org.uk/Documents/Professionals/Surveys/Collation%20of%20Inpatient%20Experiences%20Finalfinal.doc> Last accessed 25 January 2012.
- 40 The Diabetes Team UHoLNT. *Surgery and Procedures in Patients with Diabetes*. 2007. Available at <http://www.leicestershirediabetes.org.uk/documents/UHL%20Surgery%20and%20Procedures%20in%20Patients%20with%20Diabetes%20Jan%202007.pdf> Last accessed 25 January 2012.
- 41 Fowler D, Rayman G, NHS Diabetes. *Safe and Effective Use of Insulin in Hospitalised Patients*. 2010. Available at http://www.diabetes.nhs.uk/our_publications/reports_and_guidance/inpatient_and_emergency/ Last accessed 25 January 2012.
- 42 Dhatriya K, Flanagan D, Hilton L, Kilvert A, Levy N, Rayman G *et al*. *Management of Adults with Diabetes Undergoing Surgery and Elective Procedures: Improving Standards*. London: Joint British Diabetes Societies Inpatient Care Group for NHS Diabetes, 2011. Available at http://www.diabetes.nhs.uk/our_publications/reports_and_guidance/inpatient_and_emergency/ Last accessed 25 January 2012.
- 43 Department of Health. *Enhanced Recovery*. 2011. Available at <http://www.dh.gov.uk/en/Healthcare/Electivecare/Enhancedrecovery/index.htm> Last accessed 25 January 2012.
- 44 Department of Health. *Delivering Enhanced Recovery. Helping Patients to get Better Sooner after Surgery*. 2010. Available at http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/@dh/@en/@ps/documents/digitalasset/dh_115156.pdf Last accessed 25 January 2012.
- 45 Lassen K, Soop M, Nygren J, Cox PB, Hendry PO, Spies C *et al*. Consensus review of optimal perioperative care in colorectal surgery: Enhanced Recovery After Surgery (ERAS) group recommendations. *Arch Surg* 2009; **144**: 961–969.
- 46 Varadhan KK, Neal KR, Dejong CH, Fearon KC, Ljungqvist O, Lobo DN. The enhanced recovery after surgery (ERAS) pathway for patients undergoing major elective open colorectal surgery: a meta-analysis of randomized controlled trials. *Clin Nutr* 2010; **29**: 434–440.
- 47 Kaczynski J, May J, Pogoda I, Caldwell G. Management of patients with diabetes mellitus referred for elective surgery from primary care: the challenge of the 18 weeks pathway. *J Periop Pract* 2010; **20**: 411–413.
- 48 British Association of Day Surgery. *BADS Directory of Procedures*, 3rd edn. London: British Association of Day Surgery, 2009.
- 49 Flanagan D, Ellis J, Baggot A, Grimsehl K, English P. Diabetes management of elective hospital admissions. *Diabet Med* 2010; **27**: 1289–1294.
- 50 National Institute for Health and Clinical Excellence. *Venous Thromboembolism – Reducing the Risk*. 2010. Available at <http://guidance.nice.org.uk/CG92> Last accessed 25 January 2012.

- 51 Powell-Tuck J, Gosling P, Lobo DN, Allison SP, Carlson GL, Gore M *et al.* *British Consensus Guidelines on Intravenous Fluid Therapy for Adult Surgical Patients (GIFTASUP)*. 2009. Available at http://www.bapen.org.uk/pdfs/bapen_pubs/giftasup.pdf Last accessed 25 January 2012.
- 52 Royal College of Anaesthetists, Association of Anaesthetists of Great Britain and Ireland. *Good Practice Guide. A Guide for Departments of Anaesthesia, Critical Care and Pain Management*. 2006. Available at [http://www.rcoa.ac.uk/docs/goodpractice\(oct2006\).pdf](http://www.rcoa.ac.uk/docs/goodpractice(oct2006).pdf) Last accessed 25 January 2012.
- 53 NHS Evidence – Women’s Health Specialist Collection. *The CEMACH/OAA Diabetes Project: A National Audit of Anaesthetic Records and Care for Women with Type 1 or Type 2 Diabetes Undergoing Caesarean Section*. London: Centre for Maternal and Child Enquiries, 2010. Available at http://www.oaa-anae.ac.uk/assets/_managed/editor/File/Reports/CMACE_OAA_diabetes_report_2010.pdf Last accessed 25 January 2012.
- 54 Pierre S, Corno G, Benais H, Apfel CC. A risk score-dependent anti-emetic approach effectively reduces post-operative nausea and vomiting – a continuous quality improvement initiative. *Can J Anaesth* 2004; **51**: 320–325.
- 55 Gold BS, Kitz DS, Lecky JH, Neuhaus JM. Unanticipated admission to the hospital following ambulatory surgery. *J Am Med Assoc* 1989; **262**: 3008–3010.
- 56 Apfel CC, Korttila K, Abdalla M *et al.* A factorial trial of six interventions for the prevention of postoperative nausea and vomiting. *N Eng J Med* 2004; **350**: 2441–2451.
- 57 NHS Diabetes, Diabetes UK. *Putting Feet First. Commissioning Specialist Services for the Management and Prevention of Diabetic Foot Disease in Hospitals*. Available at http://www.diabetes.org.uk/Documents/Reports/Putting_Feet_First_010709.pdf Last accessed 25 January 2012.
- 58 Nettles AT. Patient education in the hospital. *Diabetes Spectr* 2005; **18**: 44–48.
- 59 The NICE-SUGAR Study Investigators. Intensive versus conventional glucose control in critically ill patients. *N Eng J Med* 2009; **360**: 1283–1297.
- 60 Gandhi GY, Nuttall GA, Abel MD *et al.* Intraoperative hyperglycemia and perioperative outcomes in cardiac surgery patients. *Mayo Clin Proc* 2005; **80**: 862–866.
- 61 Lipshutz AK, Gropper MA. Perioperative glycemic control: an evidence-based review. *Anesthesiology* 2009; **110**: 408–421.
- 62 Gandhi GY, Nuttall GA, Abel MD *et al.* Intensive intraoperative insulin therapy versus conventional glucose management during cardiac surgery: a randomized trial. *Ann Intern Med* 2007; **146**: 233–243.
- 63 Vriesendorp TM, Morelis QJ, DeVries JH, Legemate DA, Hoekstra JB. Early post-operative glucose levels are an independent risk factor for infection after peripheral vascular surgery. A retrospective study. *Eur J Vasc Endovasc Surg* 2004; **28**: 520–525.
- 64 Bilotta F, Spinelli A, Giovannini F *et al.* The effect of intensive insulin therapy on infection rate, vasospasm, neurologic outcome, and mortality in neurointensive care unit after intracranial aneurysm clipping in patients with acute subarachnoid hemorrhage: a randomized prospective pilot trial. *J Neurosurg Anesthesiol* 2010; **19**: 156–160.
- 65 Martinez MA, Williams KA, Pronovost PJ. Thinking like a pancreas: perioperative glycemic control. *Anesth Analg* 2007; **104**: 4–6.
- 66 Walid MS, Newman BF, Yelverton JC *et al.* Prevalence of previously unknown elevation of glycosylated hemoglobin in spine surgery patients and impact on length of stay and total cost. *J Hosp Med* 2010; **5**: E10–E14.
- 67 O’Sullivan CJ, Hynes N, Mahendran B *et al.* Haemoglobin A1c (HbA1c) in non-diabetic and diabetic vascular patients. Is HbA1c an independent risk factor and predictor of adverse outcome? *Eur J Vasc Endovasc Surg* 2006; **32**: 188–197.
- 68 Gustafsson UO, Thorell A, Soop M, Ljungqvist O, Nygren J. Haemoglobin A1c as a predictor of postoperative hyperglycaemia and complications after major colorectal surgery. *Br J Surg* 2009; **96**: 1358–1364.
- 69 Halkos ME, Lattouf OM, Puskas JD *et al.* Elevated preoperative hemoglobin A1c level is associated with reduced long-term survival after coronary artery bypass surgery. *Ann Thorac Surg* 2008; **86**: 1431–1437.
- 70 Dronge AS, Perkal MF, Kancir S *et al.* Long-term glycemic control and postoperative infectious complications. *Arch Surg* 2006; **141**: 375–380.
- 71 Eldridge AJ, Sear JW. Peri-operative management of diabetic patients. Any changes for the better since 1985? *Anaesthesia* 1996; **51**: 45–51.
- 72 Hall GM. Management of diabetes during surgery: 30 years of the Alberti regimen. *Br J Anaesth* 2009; **103**: 789–791.
- 73 Walsh SR, Walsh CJ. Intravenous fluid-associated morbidity in postoperative patients. *Ann R Coll Surg Engl* 2005; **87**: 126–130.
- 74 Lobo DN, Dube MG, Neal KR *et al.* Problems with solutions: drowning in the brine of an inadequate knowledge base. *Clin Nutr* 2001; **20**: 125–130.
- 75 Lobo DN, Dube MG, Neal KR, Allison SP, Rowlands BJ. Peri-operative fluid and electrolyte management: a survey of consultant surgeons in the UK. *Ann R Coll Surg Engl* 2002; **84**: 156–160.
- 76 Varadhan KK, Lobo DN. A meta-analysis of randomised controlled trials of intravenous fluid therapy in major elective open abdominal surgery: getting the balance right. *Proc Nutr Soc* 2010; **69**: 488–498.
- 77 Walsh SR, Cook EJ, Bentley R *et al.* Perioperative fluid management: prospective audit. *Int J Clin Pract* 2008; **62**: 492–497.
- 78 Callum KG, Gray AJ, Hoile RW *et al.* *Extremes of Age: The 1999 Report of the National Confidential Enquiry into Perioperative Deaths*. 1999. Available at <http://www.ncepod.org.uk/pdf/1999/99full.pdf> Last accessed 25 January 2012.
- 79 Dagogo-Jack S, Alberti K. Management of diabetes mellitus in surgical patients. *Diabetes Spectr* 2002; **15**: 44–48.
- 80 Achinger SG, Moritz ML, Ayus JC. Dysnatremias: why are patients still dying? *South Med J* 2006; **99**: 353–362.
- 81 Panel on Dietary Reference Values of the Committee on Medical Aspects of Food Policy. *Dietary Reference Values for Food Energy and Nutrients for the UK*. London: HMSO, 1991.
- 82 National Patient Safety Agency. *Reducing the Risk of Hyponatremia When Administering Intravenous Infusions to Children*. 2007. Available at <http://www.nrls.npsa.nhs.uk/resources/?EntryId45=59809> Last accessed 25 January 2012.
- 83 National Patient Safety Agency. *Potassium Solutions: Risks to Patients from Errors Occurring during Intravenous Administration*. 2002. Available at <http://www.nrls.npsa.nhs.uk/resources/?entryid45=59882> Last accessed 25 January 2012.
- 84 North Central London (NCL) Paediatric Diabetes Network. *Clinical Guideline: Diabetic Children Undergoing Surgery*. 2007. Available at http://www.gosh.nhs.uk/clinical_information/clinical_guidelines/cm_g guideline_00000 Last accessed 25 January 2012.
- 85 The Electronic Medicines Compendium. *Metformin: Summary of Product Characteristics*. 2010. Available at <http://www.medicines.org.uk/EMC/medicine/23786/SPC/Metformin+500mg+tablets/> Last accessed 25 January 2012.
- 86 Royal College of Radiologists. *Metformin: Updated Guidance for Use in Diabetics with Renal Impairment*. 2009. Available at http://www.rcn.org.uk/_data/assets/pdf_file/0011/258743/BFCR097_Metformin.pdf Last accessed 25 January 2012.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Online document. Management of adults with diabetes undergoing surgery and elective procedures: improving standards. Full position statement.

Please note: Wiley-Blackwell are not responsible for the content or functionality of any supporting materials supplied by the authors. Any queries (other than for missing material) should be directed to the corresponding author for the article.

Appendix 1

Guideline for perioperative adjustment of insulin (short starvation period—no more than one missed meal)

Insulins	Day prior to admission	Day of surgery	
		Patient for morning surgery	Patient for afternoon surgery
Once daily (evening) (e.g. Lantus [®] or Levemir [®] , Insulatard [®] Humulin I [®] Insuman [®])	No dose change*	Check blood glucose on admission	Check blood glucose on admission
Once daily (morning) (Lantus [®] or Levemir [®] Insulatard [®] Humulin I [®] Insuman [®])	No dose change	No dose change*. Check blood glucose on admission	No dose change*. Check blood glucose on admission
Twice daily (e.g. Novomix 30 [®] , Humulin M3 [®] Humalog Mix 25 [®] , Humalog Mix 50 [®] , Insuman [®] Comb 25, Insuman [®] Comb 50 twice daily Levemir [®] or Lantus [®])	No dose change	Halve the usual morning dose. Check blood glucose on admission. Leave the evening meal dose unchanged	Halve the usual morning dose. Check blood glucose on admission. Leave the evening meal dose unchanged
Twice daily—separate injections of short-acting (e.g. animal neutral, Novorapid [®] Humulin S [®]) Apidra [®] and intermediate acting (e.g. animal isophane Insulatard [®] HumulinI [®] Insuman [®])	No dose change	Calculate the total dose of both morning insulins and give half the total dose as intermediate acting only in the morning. Do not give any short-acting insulin in the morning. Check blood glucose on admission. Leave the evening meal dose unchanged	Calculate the total dose of both morning insulins and give half the total dose as intermediate acting only in the morning. Do not give any short-acting insulin in the morning. Check blood glucose on admission. Leave the evening meal dose unchanged
Three, 4 or 5 injections daily	No dose change	Basal bolus regimens: omit the morning and lunchtime short-acting insulins. Keep the basal unchanged*. Premixed morning insulin: halve the morning dose and omit lunchtime dose. Check blood glucose on admission	Take usual morning insulin dose(s). Omit lunchtime dose. Check blood glucose on admission

*Some units would advocate reduction of usual dose of long-acting analogue by one third. This reduction should be considered for any patient who 'grazes' during the day (see Controversial areas).

Warn the patient that their blood glucose control may be erratic for a few days after the procedure.

Appendix 2

Guideline for perioperative adjustment of non-insulin medication (short starvation period—no more than one missed meal)

Tablets	Day prior to admission	Day of surgery	
		Patient for morning surgery	Patient for afternoon surgery
Acarbose	Take as normal	Omit morning dose if 'nil by mouth'	Give morning dose if eating
Meglitinide (repaglinide or nateglinide)	Take as normal	Omit morning dose if 'nil by mouth'	Give morning dose if eating
Metformin (procedure not requiring use of contrast media*)	Take as normal	Take as normal	Take as normal
Sulphonylurea (e.g. Glibenclamide, Gliclazide, Glipizide, Glimeperide.)	Take as normal	Once daily morning omit Twice daily omit morning	Once daily morning omit Twice daily omit morning and afternoon
Pioglitazone	Take as normal	Take as normal	Take as normal
DPP-IV inhibitor (e.g. Sitagliptin, Vildagliptin, Saxagliptin)	Take as normal	Omit on day of surgery	Omit on day of surgery
GLP-1 analogue (e.g. Exenatide, Liraglutide)	Take as normal	Omit on day of surgery	Omit on day of surgery

*If contrast medium is to be used and eGFR less than $50 \text{ ml min}^{-1} 1.73 \text{ m}^{-2}$, metformin should be omitted on the day of the procedure and for the following 48 h.

DPP-IV, dipeptidyl peptidase 4; GLP-1, glucagon-like peptide 1.

Appendix 3*

Advantages and disadvantages of intravenous solutions

	Advantages	Disadvantages
0.45% saline with 5% glucose with 0.15% potassium chloride at 83–125 ml/h with a continuous variable rate intravenous insulin infusion	<ul style="list-style-type: none"> • Constant supply of substrate • Meets daily sodium and potassium requirements • Safety profile of regimen demonstrated in the paediatric population with diabetes 	<ul style="list-style-type: none"> • Not widely available • Hypotonic solution <i>in vivo</i> with reference to plasma and may still predispose to hyponatraemia • May exceed daily requirements of sodium
0.9% saline with 5% glucose with 0.15% potassium chloride at 83–125 ml/h with a continuous variable rate intravenous insulin infusion	<ul style="list-style-type: none"> • Constant supply of substrate • Meets sodium and potassium requirements • Safety profile of regimen demonstrated in the paediatric population with diabetes 	<ul style="list-style-type: none"> • Not widely available • Will exceed daily sodium chloride requirement and predispose to oedema and hyperchloraemic metabolic acidosis
0.18% saline with 4% glucose with 0.15% potassium chloride at 83–125 ml/h with a continuous variable rate intravenous insulin infusion	<ul style="list-style-type: none"> • Constant supply of substrate • Meets daily sodium and potassium requirements • Widely available 	<ul style="list-style-type: none"> • Associated with hyponatraemia. Use in children has been curtailed by the National Patient Safety Agency • Hypotonic solution <i>in vivo</i> with reference to plasma
5–10% glucose with 0.15% potassium chloride at 125 ml/h with a continuous variable rate intravenous insulin infusion	<ul style="list-style-type: none"> • Constant supply of substrate • Widely available 	<ul style="list-style-type: none"> • Does not provide any sodium • Associated with hyponatraemia

Appendix 3* (Continued)

	Advantages	Disadvantages
5–10% glucose with 0.15% potassium chloride at 125 ml/h with additional 0.9% saline at a variable rate to correct the hyponatraemia and a continuous variable rate intravenous insulin infusion	<ul style="list-style-type: none"> • Constant supply of substrate • Widely available 	<ul style="list-style-type: none"> • Requires three infusion pumps (one for the glucose, one for the saline and one for the insulin) • May need multiple venous access leading to difficulties in obtaining blood samples and venous access • May lead to fluid overload
10% glucose with 0.15% potassium chloride at 60 ml/h with additional 0.9% saline at 60 ml/h with a continuous variable rate intravenous insulin infusion	<ul style="list-style-type: none"> • Constant supply of substrate • Widely available 	<ul style="list-style-type: none"> • Needs three infusion pumps (one for the glucose, one for the saline and one for the insulin) • May need multiple venous access leading to difficulties obtaining blood samples and venous access
10% glucose with 0.15% potassium chloride at 100 ml/h if capillary blood glucose less than 15 mmol/l with a continuous variable rate intravenous insulin infusion		<ul style="list-style-type: none"> • Erratic supply of substrate • Unpredictable administration of sodium • Increased nursing workload and difficulties in maintaining accurate fluid balance charts with constant changes of fluid bags according to capillary blood glucose
0.9% saline with 0.15% potassium chloride at 100 ml/h if capillary blood glucose more than 15 mmol/l with a continuous variable rate intravenous insulin infusion		
500 ml 10% glucose and 0.15% potassium chloride with 5 units insulin if capillary blood glucose less than 6 mmol/l	<ul style="list-style-type: none"> • Intrinsically safe as substrate and insulin are co-administered • Evidence to support its use 	<ul style="list-style-type: none"> • Increased nursing workload and difficulties in maintaining accurate fluid balance charts with constant changes of fluid bags according to capillary blood glucose
500 ml 10% glucose and 0.15% potassium chloride with 10 units insulin if capillary blood glucose 6–10 mmol/l		<ul style="list-style-type: none"> • Hyponatraemia is a recognized complication
500 ml 10% glucose and 0.15% potassium chloride with 15 units insulin if capillary blood glucose 10–20 mmol/l		<ul style="list-style-type: none"> • May lead to fluid overload with the co-administration of additional 0.9% saline
500 ml 10% glucose and 0.15% potassium chloride with 20 units insulin if capillary blood glucose more than 20 mmol/l		
All administered at 100–125 ml/h and with additional 0.9% saline to treat established hyponatraemia		

*Appendix 6 in main guideline document (see Supporting Information).

The rate of fluid infusion suggested should be for as long as the patient is fasted. Once they are ready to eat and drink, the intravenous fluid infusion can be stopped.

The cost of 0.45% saline with 5% glucose with 0.15% potassium chloride is significantly higher than either 0.9% physiological saline solution or 5% glucose solution. At the time of writing, there have been circuitous discussions between the bulk purchasers in the National Health Service (NHS) and the fluid manufacturers. The manufacturers suggest that the cost of the fluid will go down as demand goes up. However, the NHS purchasers say they will only buy more when the costs come down.

0.45% saline with 5% glucose with 0.15% potassium chloride is widely available, but because it is currently only recommended for use in the paediatric population [82], it is currently most widely stocked in those areas.