delivered with a mischievous grin. He will be mourned by Maureen to whom he was married for 52 years, and also by his two sons and two grandchildren. He will be remembered with affection and gratitude by all his friends and colleagues not only in the UK but also worldwide.

Graham Smith
Editor BJA 1987-1997
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Editor-in-Chief BJA 1997-2005

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Perioperative management of diabetes and the emerging role of anaesthetists as perioperative physicians

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Diabetes is the most common metabolic disorder and affects about 6–7% of the population and about 16% of the inpatient population.[1 2] Diabetes leads to accelerated atherosclerosis and patients are at higher risk of renal impairment, coronary vascular disease, peripheral vascular disease and cerebro-vascular disease. Subsequently, the surgical patient with diabetes is at higher risk of perioperative morbidity and mortality and subsequently longer length of hospital stays.[3–13] The reasons for this excess morbidity and mortality is multifactorial and includes increased risks of Hypoglycaemia and hyperglycaemia,[3–15] infective complications (both surgical site infections (SSIs) and systemic infections),[3–13] medical complications including acute kidney injury (AKI), acute coronary syndromes (ACS) and acute cerebro-vascular events,[3–13] hospital acquired diabetic ketoacidosis (DKA),[2 16] use of variable rate i.v. insulin infusion (VRIII),[2 14] misuse of insulin,[17 18] complex polypharmacy[2 14] and multiple co-morbidities including microvascular and macrovascular complications of the diabetes.[4 5]

On the basis of these concerns, NHS Diabetes commissioned the Joint British Diabetes Societies (JBDS) to produce guidance to optimise the management of the surgical patient with diabetes with the explicit aim of reducing the incidence of hypoglycaemia and hyperglycaemia, the risk of medical and infective complications, the risk of insulin and VRIII related harm and reducing the excess length of stay.[5]

The JBDS proposed the concept of the comprehensive care pathway for the management of the surgical patient with diabetes and utilised the enhanced recovery programme's concept of a multi-disciplinary pathway starting with the general practitioner (GP) and finishing at discharge (Fig. 1).[5] When the guidelines were first published in 2011 there were no prospective studies on which to base recommendations. It was necessary to reflect on current practice and reject policies that were clearly associated with harm. The main recommendations of the JBDS recommendations were:

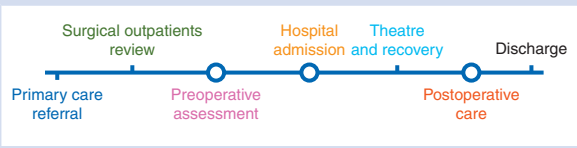

Fig 1 Comprehensive Care pathway for the elective surgical patient with diabetes.

- Promote day surgery and day of surgery admission when and where possible. This was based on the simple premise that if a patient is not in hospital it is less likely for iatrogenic harm to occur. It was also recognised that there was a widespread regional variation of care. Whilst some hospitals actively encouraged the elective surgical patient with diabetes to be managed in day surgery units (DSU), and managed these patients very well, many DSUs actively discouraged day surgery for any patient with diabetes.[19 20]
- Promote self-medication, if possible, as many patients are often more knowledgeable than ward medical and nursing staff about their own medical conditions, and have a vested interest to self -medicate properly.[21]
- Avoid the use of sliding scales/VRIII when and where possible, and that modification of the patient's usual diabetes medication was preferable. This modification should be agreed in the PAU clinic.
- Indications for the use of the VRIII include poor glycaemic control and anticipated prolonged starvation (defined as missing more than two meals).
- Every hospital should have guidelines to promote the safe use of the VRIII.
- To prevent iatrogenic hyponatraemia and hypokalaemia,[22] the maintenance fluid whilst on a VRIII should be 5% glucose

in 0.45% saline with either 0.15 or 0.3% potassium chloride based on daily electrolyte assessment.
- Promote the concept that ideal capillary blood glucose (CBG) should be 6–10 mmol litre^{-1}, and that an acceptable CBG is 4–12 mmol litre^{-1}.
- To prevent neuroglycopaenia in the unconscious state, the CBG should be measured hourly.
- Promote the concept that the elective patient should have an glycated haemoglobin (HbA1c) of <8.5% (69 mmol mol^{-1}) where practically possible.[5]

The authors of the JBDS guidelines recognise that there are no studies to demonstrate that actively lowering an elevated HbA1c improves outcome. However the following is acknowledged:

- Poor chronic preoperative glycaemic control as defined by elevated HbA1c is associated with a worse outcome.[9–13]
- Poor acute perioperative glycaemic control as defined by elevated perioperative CBGs are associated with a worse outcome.[3–8]
- Good long term preoperative glycaemic control allows in selected patients the diabetes to be safely managed without the VRIII (i.e. manipulation of normal diabetes medication), and thus promotes day surgery, and shorter length of hospital stays and shorter periods in which iatrogenic complications can occur.[23]
- The VRIII is associated with iatrogenic complications (including hypoglycaemia; hyperglycaemia; DKA; extended stay[2 14] hyponatraemia[22 24] and death[24–28]).
- Based on the above premises, a patient who has chronic poor glycaemic control (as defined as an elevated HbA1c) is more likely to suffer perioperative dysglycaemia and subsequently have a higher incidence of surgical site infection, systemic infections and other medical complications. Furthermore, they are more likely to be managed with a VRIII.
- Patients dislike and distrust the VRIII, and would prefer to avoid them if and when possible.
- Poor chronic glycaemic control as defined as an elevated HbA1c is associated with a worse outcome, and therefore allows identification of patients at higher risk of complications.[9–13] Thus an elevated HbA1c will help identify patients that require a higher level of care postoperatively.

In this edition of the BJA, Jackson and colleagues[29] have reported a region-wide audit of the perioperative management of patients with diabetes undergoing elective surgery in the North West of England completed by NWARG (North West Research and Audit Group). This audit is one of the first major studies to originate from a trainee network. Eighty-five doctors and two audit clerks in 17 hospitals were involved in the audit, but of significant interest is that NWARG attracted no funding for this work. It illustrates the ability of trainee networks to gather large data rapidly, and creates the potential for collaborative projects between trainee networks and national guideline producing organizations. In addition it allowed local hospitals to benchmark themselves against regional practice and hence encourage change to local practices to improve compliance and so improve quality of care, in this case compliance with national diabetes guidance.

The report by Jackson and colleagues[29] demonstrates the potential impact of the new anaesthetic trainee research networks. The first one being formed in 2012 in the South West.[30] The Research and Audit Federation of Trainees (RAFT) is a supporting network for these regional groups whose number now approaches twenty organizations spread across the UK, and further information is available on the RAFT website.[31] RAFT is a key element in the National Institute of Academic Anaesthesia (NIAA) strategy to support anaesthetic trainees involved in research to improve patient care.[32] The aim is to increase the opportunities for all anaesthetic trainees to be involved in high impact research, which can be difficult outside of the major centres and with the rotational training programme necessary to deliver the entire curriculum. Research as defined in Annex G of the Curriculum for training in anaesthetics is a mandatory component of the curriculum.[33] In addition RAFT is represented at Council and Board level in the NIAA and the Health Services Research Centre (HSRC). RAFT, via its associated regional groups, link to the Quality Audit and Research Co-ordinators (QuARCs) found in most NHS hospitals.

Over the two-week period in October 2013 all patients undergoing elective surgery at participating hospitals during the weekdays were eligible for inclusion for the study by Jackson and colleagues. Pregnant, paediatric and non-elective patients were excluded to align with National guidance; 247 patients with diabetes were identified and included. Of the captured eligible patients in the audit, 87% were seen in the preoperative assessment clinic. A preoperative HbA1c was recorded in 71%. 20% (34/168) of patients who had had their HbA1c recorded had an HbA1c greater than 69 mmol mol^{-1}.

Jackson and colleagues found that a CBG was performed before induction of anaesthesia in 93% of patients. The CBG was in the acceptable range (4 to 12 mmol litre^{-1}) in 89% and ideal range (6 to 10 mmol litre^{-1}) in 61%. Three patients had CBG less than 4 mmol litre^{-1} and 22 patients had CBG greater than 12 mmol litre^{-1}. Intra-operative CBG were only available for 105/247 (43%) patients. During the operation, 50% of patients (53/105) were in the ideal range, 85% (89/105) were in the acceptable range. In recovery 73% (165/226) of patients had CBG recorded. Postoperative values were within the acceptable range in 91% (150/165) and in the ideal range for 55% (91/165) of patients.

The majority of patients returned to normal food and diet in a timely manner, with 57% (135/238) eating within one h of the end of surgery and a further 36% (86/238) planning. Only 7% (17/238) of patients did not eat the next meal, either because of a surgical decision or postoperative nausea or vomiting.

In the study by Jackson and colleagues only 8% (3/39) patients who had a VRIII, had the preferred fluid of 5% glucose in 0.45% saline with premixed potassium chloride to run concurrently. It is well recognized that the use of the VRIII is associated with hyponatremia because of insufficient saline in the substrate solution.[22] A recently published study has attributed the higher incidence of hyponatraemia and death in surgical patients with diabetes as a result of the practice of administering only dextrose containing fluids to the surgical patient with diabetes whilst on a VRIII.[24]

Jackson and colleagues have thus demonstrated that the guidance suggested by the JBDS in 2011 had not been adopted in their region by October 2013. Furthermore they have demonstrated that the non-adoption is associated with practice that is potentially harmful. One of the key recommendations of the JBDS guidelines was to keep the CBG in the ideal range of 6–10 mmol litre^{-1} in an effort to prevent hypo- and hyperglycaemia. Hypoglycaemia is defined as capillary blood glucose less than 4 mmol litre^{-1} (70 mg dl^{-1}) and in the patient with diabetes is caused by a relative excess of insulin or insulin secretins compared with carbohydrate intake. Hypoglycaemia is not a benign condition as demonstrated by the recent critical care studies in which intensive insulin therapy was used to aim for a CBG of 4–6 mmol litre^{-1}.[25–28] The treatment groups all had harm and

death associated with the tight glucose control and *post hoc* analysis of the Normoglycaemia in Intensive Care Evaluation - Survival Using Glucose Algorithm Regulation (NICE–SUGAR) Study has identified a CBG <4 mmol litre^{-1} as being an independent risk factor for death.[27]

Perioperative hyperglycaemia (as defined as CBG >10 mmol litre^{-1} (180 mg dl^{-1})) is associated with an increased risk of SSI, systemic infections and other medical complications of surgery including AKI and ACS. This association has been demonstrated in a number of surgical specialities.[3–7]

In the study by Jackson and colleagues many patients routinely needlessly fasted for 10 to 16 h, resulting in more than one missed meal. There was also clearly considerable room to improve prioritization of patients with diabetes on operating lists; only 51% of patients were listed first. Minimizing interruptions to food and medication routines reduces the need for VRIII, improves perioperative glycaemic control and improves patient satisfaction. Jackson and colleagues suggest that in 69% (27/39) the use of the VRIII may not have been indicated. Equally worryingly they identified at least 10% (25 patients from their cohort of 238) who missed two or more meals and potentially should have had a VRIII. The VRIII is an offshoot of the Alberti GIK (glucose insulin potassium)[34] regime and was never subjected to rigorous scientific studies before its widespread introduction. In theory, the VRIII has the potential for achieving excellent glycaemic control; however in reality the use of VRIII is associated with patient harm and death. Recent studies from the highly staffed critical care environment including the Van den Berghe studies; the efficacy of Volume Substitution and Insulin Therapy in Severe Sepsis (VISEP) and the NICE–SUGAR studies have demonstrated the use of the VRIII is associated with hypoglycaemia and death.[25–28] Repeated national UK audits have also demonstrated that on the general ward it is associated with harm, and patients on the VRIII are often either hypoglycaemic or hyperglycaemic.[2 14] This may be because of the fact that approximately one in 20 patients are having three or less CBG measurements per day. Furthermore issues with either delayed establishment of the VRIII or delayed administration of sub cutaneous insulin after discontinuation of the VRIII, have been identified, both potentially leading to DKA.[2 14] Thus, the advice is to avoid the use of the VRIII when and where possible. Despite these concerns, there is currently no other viable option for managing diabetes in the surgical patient who has a prolonged starvation period, and in these patients the use of the VRIII is justified with the aim of preventing the deleterious effects of hyperglycaemia and DKA in the patient with type 1 diabetes.[4 5]

Since the guidelines were published in 2011, several papers have been published that demonstrate the advantages of protocol-driven care for the surgical patient with diabetes. In one study (published only as an abstract), the authors audited the incidence of VRIII use and the manipulation of normal drugs use in the anaesthetic room before and after introduction of the national guidance to their District General Hospital, and the CBG in the anaesthetic room. Post introduction, they demonstrated significant reduction in VRIII use, and simultaneously the CBG was significantly more often in the acceptable range of 4–12 mmol litre^{-1}, and there was significantly less preoperative hypoglycaemia.[35] In a retrospective study, the authors demonstrated that their preoperative manipulation of insulins was safe and effective and was not associated with hypoglycaemia or significant hyperglycaemia.[36] In a prospective study, the authors demonstrated that basal insulins if reduced by 20% was a safe strategy to maintaining perioperative glycaemic control.[37] There have also been several papers published that demonstrate that perioperative manipulation of the subcutaneous insulin infusion (CSII) pump therapy is safe and effective.[38 39]

In 2015, the JBDS updated their guidelines[4] (which the Royal College of Anaesthetists (RCoA) endorsed again). There were minor modifications to the dosing regimens taking into account feedback and new publications in the literature. More importantly after the publication of the *post hoc* analysis of NICE Sugar,[27] which demonstrated a 'dose – response relationship' between the degree of hypoglycaemia and risk of death, the acceptable preoperative and intraoperative range has been narrowed to 6–12 mmol litre^{-1}, and values of <6 mmol litre^{-1} should now be regarded as imminent hypoglycaemia and treated.

With the surgical population becoming both older and having more co-morbidities, the RCoA recognizes the need to improve the management of the surgical patient with co-morbidity. Traditionally, the care of the patients undergoing major surgery has been tailored to the operation itself and the disease being treated by the procedure. However the majority of complications which occur after surgery are not as a result of technical failures by the surgical team, but are often foreseeable medical complications secondary to an underlying disease process. Subsequently the RCoA established the collaborative Perioperative Medicine programme in 2014.[40] The remit of the programme is to reduce variation and improve patient outcomes after surgery by having an integrated agenda and promoting a patient centred care pathway. This pathway is very similar to the pathway outlined in Fig. 1, but also identifies the fact that some patients never fully recover after major surgery. Thus, additionally, the Perioperative Medicine programme recognizes the fact that primary care services will need post discharge support and excellent communication from a team of hospital experts, who understand the impact of the major surgery on the individual patient and can help advise and co-ordinate ongoing medical issues that have arisen from the surgery. Guidelines for the Provision of Anaesthetic Services (GPAS) are being updated to promote the collaborative perioperative medicine programme.

GPAS forms the basis of recommendations produced by the Royal College of Anaesthetists for anaesthetists with managerial responsibilities for service, and for other healthcare managers.[41] Subsequent to the Francis Enquiry, far reaching changes to the inspection process were introduced in 2013 by the Care Quality Commission (CQC). The CQC now inspects organizations using five domains underpinned by standard Key Lines of Enquiry (KLOEs). The organization must now be able to demonstrate that it is: safe; effective; caring; responsive and well led. In 2014, the RCoA mapped the standards that underpin Anaesthesia Clinical Services Accreditation (ACSA) to one or more of these five domains, thus integrating Guidelines for the Provision of Anaesthetic Services (GPAS) and ACSA with the requirements laid down by the CQC. The RCoA is again conducting the annual GPAS updating consultation, not only to advise on standards that should be adhered to, but also to ensure that that it will fulfil the standard criteria for accreditation by the National Institute for Health and Care Excellence (NICE). NICE accreditation requires a high level of evidence in recommendations, and this matches the desire of the College to promote evidence-based practice. In the future, departments that wish to be ACSA accredited, and pass CQC inspection will need to embrace GPAS.

Declaration of interest

N.L. was the lead anaesthetic author of the JBDS guidelines on Management of adults with diabetes undergoing surgery and elective procedures: improving standards.

N.P. was a contributor to the JBDS guidelines on Management of adults with diabetes undergoing surgery and elective procedures: improving standards and is on RCoA College Council.

M.M. is on RCoA College Council and is on editorial board of the BJA.

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How can we prevent opioid induced hyperalgesia in surgical patients?

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In this issue of the *British Journal of Anaesthesia*, Comelon and colleagues[1] report that gradual withdrawal of remifentanil infusion may prevent opioid-induced hyperalgesia in volunteers.

In this randomized, double-blinded, placebo-controlled, crossover study, nineteen volunteers were administered remifentanil for 30 min, with target infusion 2.5 ng ml^{-1} with abrupt or gradual withdrawal of remifentanil infusion. Pain was assessed with heat pain test and the cold pressor test at baseline, during infusion and 45–50 and 105–110 min after end of infusion. Forty-five min after the end of infusion there was remifentanil-induced hyperalgesia in the abrupt withdrawal session, with significantly higher pain scores compared with the gradual withdrawal and placebo sessions (both $P<0.01$), but no hyperalgesia after gradual withdrawal compared with placebo ($P=0.93$). In the cold pressor test, 50 min after the end of infusion there was hyperalgesia in both remifentanil sessions compared with placebo (gradual $P=0.01$, abrupt $P<0.01$). There were no differences between any of the remifentanil sessions compared with the placebo 105–110 min after end of infusion.

The study has a clear methodology and supports the beneficial impact of gradual withdrawal on the development of opioid-related hyperalgesia, when tested with the heat pain test. The absence of opioid-induced hyperalgesia prevention detectable in the cold pressure test paradigm, is not clearly explained and may be related to more negative skewness of pain rating. The clinical phenomenon is short lasting as no difference persists at 105–110 min after remifentanil administration. This is shorter than the impact observed on pain intensity and opioid use at 24 h in clinical studies.[2] This is probably related to the short duration of administration and therefore the limited cumulative dose of remifentanil administered to volunteers.

A recent review and meta-analysis on remifentanil and opioid-related hyperalgesia evaluated to what extent the phenomenon occurs clinically, as the literature appeared controversial. This review suggests that high intra-operative doses of remifentanil are associated with small but significant increases in acute pain, lasting 24 h after surgery and a higher postoperative morphine use, estimated to be 18 mg during the same 24 h period.[2] In this review, the additional morphine use was not associated with increased incidence of opioid related side-effects such as nausea, vomiting or sedation. These clinical data confirm that remifentanil opioid hyperalgesia is detectable in surgical patients but with a limited clinical significance. Interestingly, a subgroup analysis has suggested the protective role of propofol-based anaesthesia compared with inhalation anaesthesia agents against postoperative hyperalgesia.[2] In some situations, prevention of opioid-induced hyperalgesia may have even more clinical significance.[3] Genetic factors and preoperative use of opioid are two different preoperative factors, influencing potentially the benefit related to opioid-induced hyperalgesia prevention. A clinical study of 43 healthy volunteers, using a painful thermal stimulus, found that individuals homozygous for the met (158) polymorphism of the catechol O-methyl transferase gene, had greater hyperalgesia after remifentanil.[4] Another clinical situation is the potential preoperative use of opioid to treat preoperative pain. This chronic administration of

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Clinical Practice

CLINICAL PRACTICE

Perioperative management of diabetes in elective patients: a region-wide audit†

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Abstract

Background: Ten percent of elective surgical patients have diabetes. These patients demonstrate excess perioperative morbidity and mortality. National guidance on the management of adults with diabetes undergoing surgery was published in 2011. We present a region-wide audit of adherence to this guidance across the North Western Deanery.

Methods: Local teams prospectively collected data according to a locally approved protocol. Pregnant, paediatric and non-elective patients were excluded from this audit. Patient characteristics, type of surgery and aspects of perioperative management were collated and centrally analysed against audit criteria based upon national recommendations.

Results: 247 patients with diabetes were identified. HbA1c was recorded in 71% of patients preoperatively; 9% of patients with an abnormal HbA1c were not known by, or referred to, the diabetes team. 17% of patients were admitted the evening preceding surgery. The mean fasting time was 12:20(4) h. Variable rate i.v. insulin infusions (VRIII) were not used when indicated in 11%. Only 8% of patients received the recommended substrate fluid, along with the VRIII (5% glucose in 0.45% saline). Intra-operative capillary blood glucose (CBG) was measured hourly in 56% of patients. Intra-operative CBG was within the acceptable range (4–12 mmol.L^{-1}) in 85% of patients. 73% of patients had a CBG measurement performed in recovery. The WHO checklist was used in 95% of patients.

Conclusions: National perioperative guidelines were not adhered to in a substantial proportion of patients with diabetes undergoing elective surgery. This study represents a template for future trainee networks.

Key words: anaesthesia; clinical audit; diabetes mellitus; perioperative care; surgical procedures, elective

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Editor's key points

- Diabetes is a common problem among surgical patients.
- Optimal perioperative management probably limits the increased perioperative morbidity and mortality associated with diabetes.
- The authors, part of a regional trainee network, audited compliance with current UK guidelines in 17 hospitals.
- Compliance with the guidelines was poor.

At least ten percent of patients undergoing elective surgery have diabetes.[1 2] These patients have complex medical needs and experience increased morbidity and mortality.[1] In a retrospective cohort study of 11 633 patients undergoing elective colorectal and bariatric surgery, perioperative hyperglycaemia was associated with a significantly increased risk of postoperative infection, re-operative interventions and death, whilst patients with preoperative hyperglycaemia who were commenced on insulin, had no significant increase in these complications.[3] In a meta-analysis of observational studies in patients with diabetes undergoing total hip replacement, there was an approximately two fold increase in the risk of established surgical site infection, urinary infection and lower respiratory tract infections.[4] National guidance, commissioned by NHS Diabetes and authored by the Joint British Diabetes Societies Inpatient Group, was published in 2011.[2] It adopts a comprehensive, multi-disciplinary approach, with the aim of improving management and outcomes in this high-risk cohort.

While many aspects of diabetes care are nationally audited each year, perioperative care has received less attention. In one study of 69 patients with diabetes undergoing both emergency and elective surgery, conducted before publication of the national guidelines, only 56.5% of patients were managed according to the local protocol for perioperative glycaemic control.[5] A recent retrospective review of 50 patients with diabetes undergoing knee arthroplasty, showed a lack of optimization of blood glucose control in relation to preoperative glycated haemoglobin (HbA1c) and perioperative blood glucose monitoring.[6]

We therefore undertook a prospective region-wide audit of the perioperative management of patients with diabetes undergoing elective surgery in the North West of England, over a two-week period. We believe the results of this audit will allow hospital trusts to benchmark local against regional practice and identify both deficiencies in current practice and lack of adherence to national guidance. This is the first region-wide project conducted by our group, North West Research and Audit Group (NWRAG); a secondary outcome is to validate the concept of trainee-led, region-wide projects in anaesthesia across our region.

Methods

The protocol and data collection sheets were registered with and approved by the local audit department at each participating hospital. Each anaesthetic department provided verbal consent to allow an assessment of their practice. The audit was advertised through local and regional e-mail lists, social media and posters in order to recruit local investigators (LI) and raise awareness amongst all anaesthetists in the region. Audit protocol and criteria were provided by e-mail on request.

All patients undergoing elective surgery at participating hospitals during the weekdays from 7th to 18th October 2013 were eligible for inclusion. Pregnant, paediatric and non-elective patients were excluded, as the national guidance is primarily intended for non-pregnant adults undergoing elective surgery.

The writing group reviewed the 22 principal recommendations in the national guidance. Recommendations that were measurable and related to individual patient care during the immediate perioperative period were chosen (Table 1). Additionally the following sub-recommendations were chosen: all patients should undergo preoperative assessment, a capillary blood glucose (CBG) should be checked before induction of anaesthesia and patients should be encouraged to return to normal eating and drinking at the earliest opportunity. The data collection sheet (Supplementary material, Appendix S1) was designed to include patient characteristics (age, sex, ASA status, surgical specialty, principal mode of anaesthesia, type of diabetes and disposal) and fields to assess the implementation of the chosen recommendations.

All theatre lists with potentially eligible patients were screened and discussed with the anaesthetizing anaesthetist. Theatres dedicated to trauma, emergency, paediatric and obstetric surgery were not screened. The LI made an initial visit at the beginning of each operation and collected patient characteristics and information regarding perioperative diabetes care on an anonymized paper form. The form was left with the anaesthetizing anaesthetist, who was asked to complete the form. The LI then re-visited the patient in the recovery area and completed

Table 1 Audited recommendations and data collected. VRIII, variable rate i.v. insulin infusion; AA, anaesthetizing anaesthetist; KCl, potassium chloride; CBG, Capillary blood glucose; WHO, world health organization

Recommendation
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
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.
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 VRIII wherever possible.
K17 - Patients expected to miss more than one meal should have a VRIII.
K18 - The recommended first choice substrate solution for a VRIII is 0.45% sodium chloride with 5% glucose and either 0.15% KCl or 0.3% KCl.
K20 - CBG concentrations should be monitored and recorded at least hourly during the procedure and in the immediate postoperative period.
K23 - The WHO surgical safety checklist bundle should be implemented. The target blood glucose should be 6–10 mmol.L^{-1} (acceptable range 4–12 mmol.L^{-1}).

any remaining data fields. All data was stored and transported securely. Each hospital team developed and piloted a local data collection plan to optimize capture.

Our data collection method was anticipated to produce incomplete data sets. Where the information for a specific data point was unavailable to the investigator because it had not been performed (such as a preoperative capillary blood glucose), the data collection sheet included a 'data unavailable field'. Where a data field was completely blank, it was assumed that the LI did not fill in the form completely. For each data type, means were derived using the total number of patients where complete data for that field was available.

From the raw data, the following calculations were made: BMI (weight divided by height squared); fasting time (anaesthesia start time minus time of last meal); whether the patient had at least one CBG measurement per h (procedure length minus one divided by number of CBG readings undertaken intra-operatively). Data are presented as percentage of total cohort or mean, standard deviation or median alongside interquartile range, where appropriate.

Results

Over the study period, 247 patients with diabetes were identified and included. The patients' clinical characteristics are summarized in Table 2 and the operative procedures undertaken are detailed in Table 3. Over a two-week period 85 doctors and two audit clerks in 17 hospitals were involved in the audit. As detailed in the methods section, some data fields were incomplete and therefore the denominators are the total number of patients for whom data were available.

87% (214/245) of patients were seen in the preoperative assessment clinic. A preoperative HbA1c was recorded in 71% (168/238) of patients. The mean HbA1c was 58.0(16.9) mmol. mol^{-1} [7.5 (3.7%)]. 20% (34/168) of patients who had had their

Table 2 Characteristics of study subjects. Values are given as mean (sc) or *n* (%)

	All Patients
n	247 (100%)
Age (yr)	64.4 (20–91)
BMI (Kg M^{-2})	31.1 (6.6)
Gender	
Male	134 (54%)
Female	113 (46%)
ASA class	
I	0 (0%)
II	125 (51%)
III	117 (47%)
IV	5 (2%)
Diabetes mellitus	
Type 1	32 (13%)
Type 2	215 (87%)
Primary mode of anaesthesia	
Sedation	8 (3%)
General	169 (68%)
Regional	30 (12%)
Neuraxial	40 (16%)
Discharge from recovery to	
Day case unit	104 (42%)
Ward	130 (53%)
Level 1–3	13 (5%)

Table 3 Operations by surgical specialty

Operations by surgical specialty	Number
Orthopaedic surgery	**76**
Total knee replacement	18
Total hip replacement	8
Arthroscopic shoulder surgery	8
Arthroscopic knee surgery	7
Cubital tunnel decompression	6
Revision total hip replacement	4
Shoulder arthroplasty	2
Dupytren's contracture surgery	2
Carpal tunnel decompression	2
Other	19
General surgery	**53**
Laparoscopic cholecystectomy	13
Hernia repair, inguinal	6
Hernia repair, other	8
Bowel resection, laparoscopic or open	7
EUA rectum / with or without other procedure	4
Reversal of ileostomy	3
Mastectomy and sentinel lymph node biopsy	3
Other breast procedure	4
Hepatic resection, laparoscopic or open	2
Other	3
Urology	**40**
Cystoscopy/ with or without biopsy	14
Transurethral resection of bladder tumour	6
Nephrectomy, laparoscopic or open	5
Transurethral resection of the prostate	5
Circumcision	3
Ureteroscopy and treatment of renal calculi	3
Other	4
Gynaecology	**20**
Hysteroscopy / with or without other procedure	10
Gynaecological laparotomy	4
Repair anterior vaginal prolapse	2
Vulval biopsy and excision lesion	2
Other	2
ENT	**16**
Endoscopy/with or without biopsy	**6**
Septoplasty	**2**
Resection of thyroid gland	**2**
Other	**6**
Ophthalmology	**12**
Phacoemulsification and intraocular lens implantation	9
Other	3
Vascular	**11**
Amputation toe	4
Carotid endarterectomy	3
Other	4
Maxillofacial	**7**
Dental extractions	4
Other	3
Other	**12**
Pain	**3**
Neurosurgery	**2**
Cardiology	**2**
Cardiothoracic surgery	**2**
Plastic surgery	**2**
Transplant and endocrine surgery	**1**

HbA1c recorded had an HbA1c greater than 69 mmol.mol^{-1} (8.5%); these operations continued as planned. 23% (52/230) of patients were already under the care of a diabetes specialist team, a further nine patients were referred as part of the pre-operative assessment process. 9% (14/164) of patients had an HbA1c greater than 69 mmol.mol^{-1} (8.5%) and were not under specialist diabetes care.

17% (42/243) of patients were admitted the evening preceding surgery. In the opinion of the anaesthetizing anaesthetist, 12/42 patients were admitted solely for optimizing glycaemic control. This small group of patients tended towards a higher preoperative HbA1c, than the study population as a whole [71.6(13.7)] mmol.mol^{-1} [8.7(3.4%)] compared with 58.0(16.9) mmol.mol^{-1} [7.5(3.7%)]. Pre-anaesthesia CBG was within the acceptable range in 75% of these patients. The mean age and range was 56.8(00.00) yr and distribution of ASA grades (41% ASA II, 58% ASA III) were similar to the study population as a whole. The reason for overnight admission before surgery was not recorded in the remaining 30 patients.

Data for the time of the last meal and start of anaesthesia was available in 222 patients and the mean fasting time was 12:20(4:00) h. 51% (124/244) of patients were undergoing surgery first on the operating list. Variable rate i.v. insulin infusion (VRIII) (previously 'sliding scale insulin') is intended to achieve and maintain normoglycaemia. It is recommended for patients missing at least two meals and in those with decompensated diabetes. In our study, VRIII was used in 39 patients; 27 of whom had a short starvation time. A VRIII was not used in 25 patients missing two or more meals; four, 13, and eight of these patients routinely use insulin, tablets or diet only to control their blood sugars, respectively. 0.45% sodium chloride and 5% glucose with either 0.15% or 0.3% potassium chloride is the substrate recommended by the national guidance to be used alongside a VRIII. The recommended substrate was used in only 3/39 patients prescribed a VRIII.

The WHO checklist was omitted in 5% (12/246) of patients. A CBG measurement was performed before induction of anaesthesia in 93% (226/243) of patients. CBG was in the acceptable range (4 to 12 mmol.L^{-1}) and ideal range (6 to 10 mmol.L^{-1}) in 89% (201) and 61% (137), respectively. Three patients had CBG less than 4 mmol.L^{-1} (range 3.4–3.9 mmol.L^{-1}) and 22 patients had CBG greater than 12 mmol.L^{-1} (mean 13.7 mmol.L^{-1}, range 12.1–16.9 mmol.L^{-1}).

The median length of operation was 1:15 h (interquartile range 0:40 to 2:15 h, n=225). Intra-operative CBG measurements were only available for 105/247 (43%) patients. During the operation, 50% of patients (53/105) were in the ideal range, 85% (89/105) were in the acceptable range. The lowest recorded intraoperative CBG was 2.7 mmol.L^{-1} and the highest was 20.1 mmol.L^{-1}.

In recovery 73% (165/226) of patients had CBG recorded. Postoperative values were within the acceptable range in 91% (150/165) and in the ideal range for 55% (91/165) of patients. Recorded CBG values in recovery ranged from 2.4 to 21.3 mmol.L^{-1}.

The majority of patients returned to normal food and diet in a timely manner, with 57% (135/238) eating within one h of the end of surgery and a further 36% (86/238) planning to eat the next meal. Only 7% (17/238) of patients did not eat the next meal, either because of a surgical decision or postoperative nausea or vomiting.

Discussion

To our knowledge, this is the largest published prospective audit of perioperative diabetes management. We have demonstrated that national perioperative recommendations for the management of patients with diabetes have been poorly implemented across the North West of England, which is in keeping with other published work.[5 6]

High preoperative HbA1c concentrations have been shown in several studies to be associated with increased postoperative complications.[7–11] However a recent systematic review found no definitive relationship between preoperative HbA1c and postoperative outcomes.[12] The authors of that review raised concerns regarding the quality of available studies; these were often retrospective, of small sample size and included patients from a wide range of surgical specialties. The concentration at which preoperative HbA1c was considered 'high' varied; many studies utilized the American Diabetes Association cut-off of 53 mmol.mol^{-1} (7%), which is derived from a non-surgical population.[13] One large retrospective study of 1775 patients undergoing major non-cardiac surgery found that an HbA1c greater than 64 mmol.mol^{-1} (8%) was associated with increased hospital length of stay.[14] The target of 69 mmol.mol^{-1} (8.5%) in current UK guidelines is pragmatic; it reflects the lack of evidence to support more aggressive preoperative glycaemic control and should be safely achievable in the majority of patients. A well-conducted large prospective study examining the association between preoperative HbA1c and postoperative outcome is required.

Despite the uncertainty it is nonetheless concerning that 28% of patients in our study did not have a preoperative HbA1c recorded. Most of the 'high-risk patients', as identified by a high HbA1c, were already under specialist care. Delaying elective surgery to optimize glycaemic control may reduce postoperative complications and is recommended by guidelines. There are a number of potential barriers to delaying surgery; these include the urgency of surgery, organizational factors, such as a lack of local protocols for referring patients from preoperative assessment clinic, and lack of awareness and understanding of current recommendations.

The Royal College of Nursing perioperative fasting guidelines recommend fasting times of six h for solids and two h for clear fluids in healthy adults.[15] The national guidance for perioperative management of adults with diabetes recommends minimizing starvation by organizing operative lists and avoiding modification of usual diabetes medication, when no more than one meal is missed. In our cohort, mean fasting time for solids was 12 h. Worryingly, many patients routinely fasted 10 to 16 h, resulting in more than one missed meal and the use of VRIII. There was also clearly considerable room to improve prioritization of patients with diabetes on operating lists; only 51% of patients were listed first. Minimizing interruptions to food and medication routines reduces the need for VRIII, improves perioperative glycaemic control and improves patient satisfaction.[16] Our data suggest management of fasting could be improved. While airway management mandates an awareness of absolute fasting time, optimal diabetes management and patient satisfaction requires a paradigm shift towards assessing and predicting the number of missed meals.

Some studies suggest that acute changes in blood glucose lead to oxidative stress, which contributes to macrovascular disease.[17 18] Other theoretical benefits of normoglycaemia include reduced endothelial dysfunction and improved immune function. The treatment of in-patient hyperglycaemia (defined as blood glucose greater than 12 mmol.L^{-1}) has been questioned recently, predominantly because of a lack of proven benefit, potential for significant hypoglycaemia and poor junior medical staff confidence in managing glycaemic control.[19] Nonetheless, studies have shown that even mild hyperglycaemia is associated with poor postoperative outcomes.[1] Our results demonstrate that most patients remained within the acceptable, though not the ideal, CBG range intra-operatively. We cannot comment on the

consequences of poor perioperative glycaemic control, as we did not collect outcome data.

The national guidance aims to reduce the use of VRIII where and when possible as a result of the frequent complications associated with this intervention. However, VRIII is sometimes necessary when other attempts to achieve glycaemic control have not been successful. Reduction in VRIII use can be achieved by identifying patients with good glycaemic control, minimizing fast times and adjusting usual anti-hyperglycaemic medication; this requires planning. In spite of a short predicted fasting time, 11% of patients receive a VRIII; it is unclear whether there were other indications for VRIII, such as poor long-term glycaemic control, or failure of alternative strategies to achieve glycaemic control. Nonetheless, given the long fasting time in our cohort, it is likely that a significant number of patients who were predicted to have a short fasting time, actually missed more than one meal. This might have contributed to the large proportion of patients with an intra-operative CBG outside the ideal range.

The national guidance is authored by diabetologists, anaesthetists and a diabetic specialist nurse, with input from surgical and patient safety representatives.[2] It has been endorsed by a number of medical and nursing groups including the Royal College of Anaesthetists and the Association of Surgeons of Great Britain and Ireland. The recommendations are based on the best available evidence, summarized in a non-systematic review by the guideline authors. Some recommendations are not measurable; this impacted upon which recommendations we chose to audit. Future editions must give greater consideration as to how well the guidelines are implemented to effect a change in practice; our findings highlight major deficiencies in adhering to these guidelines. This is particularly important given the increasing prevalence of diabetes, driven largely by the worldwide epidemic of type 2 diabetes, and the fact that patients with diabetes are more likely to undergo surgery than patients without diabetes.[1 20]

Regional trainee-led networks offer the opportunity to collect large data sets and to characterize the care given to specific patient sub-groups. Within surgical sub-specialties randomized controlled trials and national surveys of practice have been successfully published in high profile journals.[21 22] This project represents one of the first attempts by a group of anaesthetists in training to transfer this approach to perioperative medicine. Through this project, we provide a proof of concept within our own region. Future projects following this model would benefit from working in partnership with the guideline authors. Because our network covers approximately 10% of the acute NHS footprint, a successful project would be of considerable national interest.

Our audit was designed to be pragmatic and clinicians were not blinded to the presence of auditors; they assisted with data collection. This approach was chosen, as we wished to ensure all relevant patients were identified and all forms completed. Nonetheless, not all data forms were complete and it is likely we missed some eligible patients during the data collection period. This is a potential source of bias for our results and indeed it is possible that implementation of the recommendations is better or worse than we report. We did not collect reliable denominator data to calculate the incidence of diabetes in our elective surgical population.

Our audit differs from the traditional audit cycle and might be better described as a clinical survey. We do not make explicit recommendations and have not 'closed the audit loop'. Instead, each trust submitting data to this project have had the opportunity to review their results against the aggregate average of the region and consider local changes to practice. We chose this approach because we felt, as a group of trainees, it was unrealistic to implement a set of recommendations across a large region.

In conclusion, we have demonstrated that the national guidance for the management of patients with diabetes during the perioperative period, has been poorly implemented in adult patients undergoing elective surgery in our region. Our audit approach was pragmatic, providing a useful characterization of current practice from which future guidance might be developed. Trainee-led collaborative studies across multiple sites are an evolving concept in British anaesthesia and this study provides an early proof of concept for other groups to build upon.

Authors' contributions

Study design/planning: M.J.J., H.Y., R.M.
Study conduct: M.J.J., C.P., F.W., G.B., A.M.
Data analysis: M.J.J.
Writing paper: M.J.J., C.P., F.W., G.B., A.M., F.W.
Revising paper: all authors

Supplementary material

Supplementary material is available at *British Journal of Anaesthesia* online.

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Declaration of interest

M.J.J. and C.P. are the Vice-chair and Chair of NWRAG, respectively. F.W. and A.M. sit on the NWRAG executive committee. G.B. is acts as link person between NWRAG and the North West School of Anaesthesia.

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