



An observational cohort study to assess glycosylated hemoglobin screening for elective surgical patients

Étude de cohorte observationnelle pour évaluer le dépistage de l'hémoglobine glyquée chez les patients de chirurgie non urgente

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Abstract

Introduction Uncontrolled blood glucose is associated with a higher incidence of surgical site infections, greater utilization of resources, and increased mortality. Preoperative screening for diabetes in elective surgical patients is not routinely performed. The purpose of this study was to examine blood glucose control in a preoperative surgical population.

Methods Following ethics approval, adults presenting to the pre-surgical screening clinic in preparation for elective surgery were recruited. Data collection included a self-administered questionnaire on diabetic risk factors and blood glucose testing, including glycosylated hemoglobin (HbA1c). Descriptive analyses were conducted.

Results Seventy of the 402 participants (17.4%) had a previous diagnosis of diabetes (diabetics). Among those without a history of diabetes ($n = 332$ non-diabetics), 23.2% ($n = 77$) were considered very high risk for diabetes ($HbA1c = 6.0$ – 6.4%), and 3.9% ($n = 13$) had a provisional diagnosis of diabetes ($HbA1c \geq 6.5\%$). Fifty-six percent ($n = 39/70$) of diabetics had suboptimal glycemic control

($HbA1c > 7.0\%$), and 51.3% ($n = 20/39$) of this subgroup presumed their blood sugars were reasonably or very well controlled. Fifteen percent ($n = 2/13$) of patients with a provisional diagnosis of diabetes ($HbA1c \geq 6.5\%$) had an elevated random blood sugar (RBS) ($\geq 11.1 \text{ mmol}\cdot\text{L}^{-1}$), while 67% ($n = 8/12$) had an elevated fasting blood sugar (FBS) ($\geq 7.0 \text{ mmol}\cdot\text{L}^{-1}$). Forty-two percent ($n = 16/38$) of suboptimally controlled diabetics ($HbA1c > 7.0\%$) had an elevated RBS ($\geq 11.1 \text{ mmol}\cdot\text{L}^{-1}$), and 86% ($n = 31/36$) had an elevated FBS ($\geq 7.0 \text{ mmol}\cdot\text{L}^{-1}$).

Discussion Many elective surgical patients are at risk for unrecognized postoperative hyperglycemia and associated adverse outcomes. Random blood sugar testing has limited value and HbA1c may be a more appropriate test for the preoperative assessment of diabetic patients.

Résumé

Introduction La glycémie non contrôlée est associée à une incidence plus élevée d'infections du site chirurgical, à une utilisation plus importante des ressources et à une augmentation de la mortalité. Le dépistage préopératoire du diabète chez les patients de chirurgie non urgente n'est pas systématique. L'objectif de cette étude était d'examiner le contrôle glycémique chez une population chirurgicale en période préopératoire.

Méthode Après avoir obtenu l'accord du comité d'éthique, des adultes se rendant à la clinique de dépistage préchirurgical en préparation d'une chirurgie non urgente ont été recrutés. La collecte des données incluait un questionnaire auto-administré sur les facteurs de risque de diabète et un test de glycémie, y compris de l'hémoglobine glyquée (HbA1c). Des analyses descriptives ont été réalisées.

Résultats Un diagnostic de diabète avait déjà été posé pour soixante-dix des 402 participants (17,4 %)

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(diabétiques). Parmi les patients sans antécédents de diabète ($n = 332$, non-diabétiques), 23,2 % ($n = 77$) ont été évalués comme présentant un risque très élevé de diabète ($HbA1c = 6,0$ - $6,4$ %), et un diagnostic provisoire de diabète ($HbA1c \geq 6,5$ %) a été posé pour 3,9 % ($n = 13$) de ces patients. Le contrôle glycémique était sous-optimal chez 56 % ($n = 39/70$) des diabétiques ($HbA1c > 7,0$ %), et 51,3 % ($n = 20/39$) de ce sous-groupe prenaient pour acquis que leur glycémie était raisonnablement ou très bien contrôlée. Quinze pour cent ($n = 2/13$) des patients ayant reçu un diagnostic provisoire de diabète ($HbA1c \geq 6,5\%$) avaient une glycémie aléatoire élevée ($\geq 11,1 \text{ mmol}\cdot\text{L}^{-1}$), alors que 67 % ($n = 8/12$) avaient une glycémie à jeun élevée ($\geq 7,0 \text{ mmol}\cdot\text{L}^{-1}$). Quarante-deux pour cent ($n = 16/38$) des diabétiques mal contrôlés ($HbA1c > 7,0$ %) présentaient une glycémie aléatoire élevée ($\geq 11,1 \text{ mmol}\cdot\text{L}^{-1}$), et 86 % ($n = 31/36$) une glycémie à jeun élevée ($\geq 7,0 \text{ mmol}\cdot\text{L}^{-1}$).

Discussion De nombreux patients devant subir une chirurgie non urgente courent un risque d'hyperglycémie postopératoire non identifiée et de complications associées. Les tests de glycémie aléatoire ont une valeur limitée et le test de la HbA1c pourrait être mieux adapté pour évaluer les patients diabétiques en période préopératoire.

The global prevalence of diabetes mellitus has become increasingly alarming. The number of those afflicted was estimated at 285 million in 2010 and is expected to grow to 439 million by 2030.¹ The vast majority of these cases are type 2 diabetes, and as many as 40% of patients with “pre-diabetes” and diabetes may be undiagnosed.²

For surgical patients, diabetes can be a significant concern. Perioperative hyperglycemia is associated with increased morbidity and mortality, impaired leukocyte function, and increased risk of infection and resource utilization.³⁻⁶ The association between surgical site infections and perioperative hyperglycemia is well established. High blood glucose levels lead to inflammation and reduced immune function, increasing susceptibility to bacterial infection.⁷⁻¹³ This may be further exacerbated by the fact that blood glucose has been shown to rise transiently during surgery in response to the stress of the surgical insult.^{7,14,15}

It has been suggested that all patients have blood glucose screening on admission to hospital due to the high incidence of unrecognized hyperglycemia among hospital inpatients.¹⁶ However, pre-surgical screening for diabetes mellitus is not routinely performed despite the high frequency of undiagnosed diabetes and resulting complications.^{15,16} Elevated fasting blood sugar levels

have been reported in 25% of noncardiac elective surgery patients with no history of diabetes,¹⁷ while 10.6% of patients with no history of diabetes undergoing cardiac surgery were found to have a preoperative glycosylated hemoglobin (HbA1c) in the diabetic range ($\geq 6.5\%$).¹⁸ Elevated preoperative HbA1c in elective cardiac surgery patients has also been shown to reduce five-year survival and increase the frequency of adverse events.^{19,20} With the high prevalence of undiagnosed diabetes, patients presenting for preoperative assessments are ideally suited for diabetes screening.

The Canadian Diabetes Association (CDA) and American Diabetes Association (ADA) have recommended the use of HbA1c to assess long-term glycemic control, providing an indication of glycemic control over the previous three to four months at the time of testing.^{21,22} In accordance with CDA guidelines, HbA1c $< 6.0\%$ is normal, while a range of 6.0-6.4% is very high risk for diabetes, known as “pre-diabetes”, and carries a 25-50% five-year risk of developing diabetes.^{21,22} Additionally, an international expert committee report suggests that patients with HbA1c $\geq 6.0\%$ should receive effective intervention.²³ A HbA1c $\geq 6.5\%$ is diagnostic of diabetes.^{21,22} Glycosylated hemoglobin testing is advantageous for pre-surgical patients because it is not affected by short-term glycemic fluctuations, does not require fasting, and can be taken at the same time as other bloodwork.²² In addition to recognizing previously undiagnosed cases of diabetes, pre-surgical screening with HbA1c may be a valuable predictor of postoperative adverse outcomes.¹⁸

The objectives of this study were to determine the incidence of elevated HbA1c in patients with no history of diabetes, the adequacy of recent glycemic control among diabetic patients, and the validity of random blood sugar (RBS) and fasting blood sugar (FBS) testing (using HbA1c as the gold standard) to identify patients with suboptimal glycemic control.

Methods

Patient selection

This observational cohort study was reviewed for ethical compliance by the Queen's University Health Sciences and Affiliated Teaching Hospitals Research Ethics Board. All patients ≥ 18 years of age scheduled for elective surgery with an on-site preoperative clinic assessment were eligible for the study. Healthy American Society of Anesthesiologists physical status I and II patients scheduled for minor surgical procedures were excluded as they are assessed via telephone interview. Recruitment occurred in the Hotel Dieu Hospital preoperative clinic in Kingston, Ontario during June and July

of 2012, and follow-up occurred in the preoperative assessment unit on the day of surgery where FBS was measured. Hotel Dieu Hospital is an ambulatory care hospital but also serves to prepare patients for inpatient surgery at the Kingston General Hospital. The catchment area covers a larger rural area (20,000 km² with over 500,000 residents). Participants were assigned a unique identifying number and all identifying information was removed from the data.

Sample size

A convenience sample of 406 patients was established for enrolment, and a formal sample size estimate was not conducted due to the exploratory nature of this pilot study.

Data collection

Participants completed a paper questionnaire about comorbidities, diabetes risk factors, and demographic information (Appendix 1). The data collected were tailored around validated diabetic risk factors.²⁴⁻³⁰ Additional data, such as patient age, sex, admission status, body mass index, surgery type, medications, and blood pressure, were recorded from the nursing preoperative assessment form. Based on this collected information, patients were stratified into diabetic risk categories using a modified version of the validated Canadian Diabetes Risk Assessment Questionnaire (CANRISK)^{A, 31} (Appendix 2). The risk categories were adjusted to account for excluding waist circumference and fruit and vegetable consumption in the calculation. The original scale is out of 25 and our modified version is out of 21 to account for the four points allotted to waist circumference and diet. The CANRISK categories were similarly adjusted to account for the missing variables (Appendix 2). Diabetic patients were asked additional questions to evaluate method of glycemic control as well as their perceived level of glycemic control (Appendix 1). Self-perceived glycemic control was measured on a qualitative scale from “very poorly controlled” to “very well controlled”.

Glycosylated hemoglobin and RBS blood samples were collected during the visit to the preoperative assessment clinic. Fasting blood sugar was completed on the day of surgery. Test results for HbA1c, RBS, and day of surgery FBS were retrieved from the hospital electronic medical records system when they became available.

^A ANRISK is a point-based questionnaire prepared by the Public Health Agency of Canada. It estimates ten-year risk of type 2 diabetes by assessing for age, body mass index, waist circumference, physical activity, diet, hypertension, previous hyperglycemia, family history of diabetes, ethnicity, education, smoking, and gestational diabetes.

Outcome variables

The primary outcome variable was HbA1c category. Normal HbA1c was defined as < 6.0% and pre-diabetes was defined as HbA1c 6.0-6.4%.²¹ Provisional diagnosis of diabetes was defined as HbA1c ≥ 6.5%.²¹ Non-diabetic participants who had HbA1c ≥ 6.0% during the study had the results forwarded to their family physician for further follow-up. A RBS of ≥ 11.1 mmol·L⁻¹ and a FBS of ≥ 7.0 mmol·L⁻¹ were also considered provisionally diagnostic of diabetes.²¹ An optimal glycemic level for known diabetics was defined as a HbA1c of ≤ 7.0%, as lowering HbA1c to below this level has been shown to reduce vascular complications of diabetes.^{21,22} The term “non-diabetics” in our study refers to participants without any previous diagnosis of diabetes or any use of oral hypoglycemic agents or insulin prior to study test results.

Statistical analysis

Frequencies and percentages were calculated for categorical data, and mean and standard deviation were calculated for continuous data. Demographic, diabetic risk, and surgical characteristics were stratified by HbA1c categories: normal < 6.0%; very high risk for diabetes (pre-diabetes) 6.0-6.4%; diagnostic for diabetes ≥ 6.5%. Glycosylated hemoglobin categories were calculated for participants with and without a diagnosis of diabetes (< 6.0%, 6.0-6.4%, 6.5-7.0%, and suboptimal > 7.0%). Among participants with diabetes, self-perceived level of glycemic control was assessed. The modified CANRISK scores were calculated for participants without a diagnosis of diabetes and then stratified by HbA1c category. Random blood sugar and day of surgery FBS values stratified by HbA1c category were calculated for patients with and without diabetes. Data were entered into Microsoft Excel (version 14, Microsoft, Redmond, WA, USA), and statistical analysis was conducted using SPSS® (IBM Corp., IBM SPSS Statistics, version 21.0. Armonk, NY, USA).

Results

Four hundred and forty-four consecutive patients presenting to the pre-surgical screening clinic for an on-site preoperative assessment were approached to participate in the study and 406 (91%) consented. Glycosylated hemoglobin values were not available for four participants; therefore, the current analysis is based on 402 participants. Follow-up in the preoperative assessment unit ranged from seven to 30 days after their clinic visit,

Table 1 Patient characteristics stratified by HbA1c values

	No Diagnosis of Diabetes (<i>n</i> = 332)			Diagnosis of Diabetes (<i>n</i> = 70)	
	HbA1c < 6.0% (<i>n</i> = 242) (72.9%) Mean (SD)	HbA1c 6.0-6.4% (<i>n</i> = 77) (23.2%) Mean (SD)	HbA1c ≥ 6.5% (<i>n</i> = 13) (3.9%) Mean (SD)	HbA1c ≤ 7.0% (<i>n</i> = 31) (44.2%) Mean (SD)	HbA1c > 7.0% (<i>n</i> = 39) (55.7%) Mean (SD)
Age (yr)	57.0 (7.0)	67.1 (11.3)	68.5 (11.5)	68.1 (11.3)	62.0 (10.3)
BMI (kg·m ⁻²)	28.6 (6.3)	30.1 (6.4)	34.1 (10.6)	34.5 (8.2)	33.1 (8.2)
	<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)
Male	108 (44.6)	37 (48.1)	6 (46.2)	16 (51.6)	24 (61.5)
Caucasian	229 (94.6)	73 (94.8)	12 (92.3)	30 (96.8)	33 (84.6)
Smoker	48 (19.8)	13 (16.9)	1 (7.7)	3 (9.7)	12 (30.8)
Physically active ⁺	169 (69.8)	47 (61.0)	5 (38.5)	16 (51.6)	19 (48.7)
Inpatient	157 (65.1)	56 (72.7)	10 (76.9)	18 (58.1)	30 (76.9)
Oral corticosteroid use	4 (1.7)	2 (2.6)	1 (7.7)	1 (3.2)	1 (2.6)
Family History of DM	85 (35.1)	24 (31.2)	8 (61.5)	18 (58.1)	24 (61.5)
Surgical Procedure					
Cardiac	6 (2.5)	6 (7.9)	2 (15.4)	3 (9.7)	3 (7.7)
Vascular	5 (2.1)	7 (9.2)	0 (0)	2 (6.5)	3 (7.7)
General	41 (17.0)	6 (7.9)	2 (15.4)	4 (12.9)	7 (17.9)
Orthopedic	73 (30.3)	24 (31.6)	3 (23.1)	7 (22.6)	4 (10.3)
Gynecology	33 (13.7)	11 (14.5)	2 (15.4)	1 (3.2)	7 (17.9)
Urology	21 (8.7)	9 (11.8)	0 (0)	5 (16.1)	4 (10.3)
Ophthalmology	24 (10.0)	6 (7.9)	2 (15.4)	6 (19.4)	4 (10.3)
Other	38 (15.8)	10 (9.2)	2 (15.4)	3 (9.6)	7 (17.9)
Comorbidities					
Previous elevated FBS/IGT*	3 (1.2)	6 (7.8)	2 (15.4)	n.a.	n.a.
Hypertension	90 (37.2)	46 (59.7)	8 (61.5)	24 (77.4)	27 (69.2)
History of angina	10 (4.1)	12 (15.6)	3 (23.1)	5 (16.1)	6 (15.4)
History of MI	10 (4.1)	10 (13.0)	1 (7.7)	5 (16.1)	7 (17.9)
History of stroke	7 (2.9)	9 (11.7)	2 (15.4)	3 (9.7)	4 (10.3)
Peripheral vascular Disease	2 (0.8)	4 (5.2)	0 (0)	1 (3.2)	3 (7.7)
Renal Disease	5 (2.1)	7 (9.1)	0 (0)	4 (12.9)	1 (2.6)
Polycystic Ovarian Syndrome	1 (0.4)	0 (0)	0 (0)	0 (0)	1 (2.6)
History of Gestational DM	3 (1.2)	2 (2.6)	1 (7.7)	0 (0)	1 (2.6)

⁺ Physically active includes low, moderate, and high intensity activity. *Patients with a known diagnosis of diabetes were not included as having "History of elevated FBS/IGT". BMI = body mass index; DM = diabetes mellitus; FBS = fasting blood sugar; HbA1c = glycosylated hemoglobin; IGT = impaired glucose tolerance; MI = myocardial infarction; SD = standard deviation

and none of the participants were lost to follow-up. Patient characteristics are displayed in Table 1.

Glycosylated hemoglobin screening among non-diabetic and diabetic participants

Three hundred and thirty-two participants (82.6%) had no history of diabetes and 70 (17.4%) had a previous diagnosis of diabetes (Table 1). The distribution of HbA1c results for non-diabetics and diabetics is shown in the Figure. For

those with no previous diagnosis of diabetes presenting for pre-surgical screening, 23.2% (77/332) were at very high risk for developing diabetes (pre-diabetic), and 3.9% (13/332) had a provisional diagnosis of diabetes as defined by HbA1c testing. Fifty-six percent (39/70) of participants with diabetes were considered to have suboptimal glycemic control (HbA1c > 7.0%). Of these, 10.2% (4/39) were diet-controlled only, 35.9% (14/39) were on oral hypoglycemic agents, and 53.8% (21/39) were on insulin. Conversely, among diabetics with HbA1c ≤ 7.0%, 12.9% (4/31) were

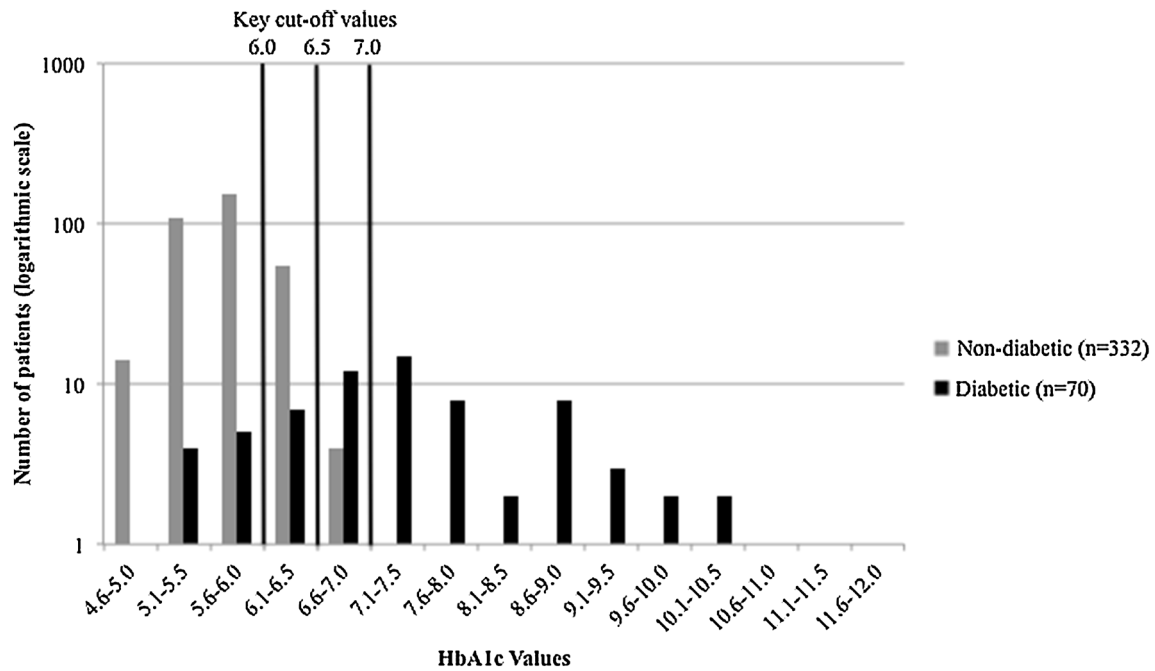


Figure Glycosylated hemoglobin values for patients with and without a previous diagnosis of diabetes

Table 2 Perceived levels of glycaemic control among diabetic patients vs prevalence of suboptimal glycaemic control

Perceived level of control	Optimal control (HbA1c ≤ 7.0%) (n = 31) n (%)	Suboptimal control (HbA1c > 7.0%) (n = 39) n (%)
Very poor	0 (0)	1 (2.6)
Poor	1 (3.2)	2 (5.1)
Sometimes	2 (6.5)	16 (41.0)
Reasonably well	10 (32.3)	15 (38.5)
Very well	18 (58.1)	5 (12.8)

HbA1c = glycosylated hemoglobin

Table 3 CANRISK category stratified by HbA1c levels among patients without a diagnosis of diabetes

CANRISK category	No diagnosis of diabetes		
	HbA1c < 6.0% (n = 241) n (%)	HbA1c 6.0-6.4% (n = 76) n (%)	HbA1c ≥ 6.5% (n = 13) n (%)
Low	74 (30.7)	7 (9.2)	1 (7.7)
Slight	123 (51.0)	37 (48.7)	2 (15.4)
Moderate	32 (13.3)	25 (32.9)	7 (53.8)
High	12 (5.0)	7 (9.2)	1 (7.7)
Very high	0 (0)	0 (0)	2 (15.3)

CANRISK = Canadian Diabetes Risk Assessment Questionnaire; HbA1c = glycosylated hemoglobin

diet-controlled only, 61.3% (19/31) were on oral hypoglycemic agents, and 25.8% (8/31) were on insulin.

Perceived glycaemic control among diabetic participants

Of the suboptimally controlled diabetic participants, 38.5% (15/39) considered their blood sugar concentration to be reasonably well controlled, and 12.8% (n = 5/39) considered it to be very well controlled (Table 2). Sixty percent (n = 15/25) of participants who considered their glucose levels to be reasonably well controlled and 21.7% (n = 5/23) of participants who considered their glucose levels to be very well controlled had suboptimal glycaemic control (HbA1c > 7.0%).

Modified CANRISK scores for non-diabetic participants

The estimated ten-year risk of developing type 2 diabetes based on the modified CANRISK score stratified by HbA1c category is displayed in Table 3. Among non-diabetics at very high risk for developing diabetes (HbA1c 6.0-6.4%), 48.7% (37/76) fell into the “slightly elevated” risk group, and 32.9% (25/76) fell into the “moderate” risk group. Among non-diabetics with a provisional diagnosis of diabetes (HbA1c ≥ 6.5%), 53.8% (7/13) fell into the moderate risk category, while only 23.1% (3/13) were in the “high” or “very high” risk groups. Among patients with a HbA1c < 6.0%, 51% (123/241) were in the “slightly elevated” risk group, and 30.7% (74/241) were in the “low” risk group.

Table 4 Random and fasting blood sugar results among non-diabetic and diabetic participants stratified by HbA1c value

		RBS ≥ 11.1 mmol·L ⁻¹ n (%)	DOS FBS ≥ 7.0 mmol·L ⁻¹ n (%)
Non-diabetic	<6.0%	1/242 (0.4%)	16/200 (8%)
	6.0-6.4%	0/73 (0%)	7/64 (10.9%)
	$\geq 6.5\%$	2/13 (15.4%)	8/12 (66.7%)
	Total	3/328 (0.9%)	31/276 (11.2%)
Diabetic	$\leq 7.0\%$	1/31 (3.2%)	16/30 (53.3%)
	$>7.0\%$	16/38 (42.1%)	31/36 (86.1%)
	Total	17/69 (24.6%)	47/66 (71.2%)

DOS = day of surgery; FBS = fasting blood sugar. HbA1c = glycosylated hemoglobin; RBS = random blood sugar

Random blood sugar and day of surgery FBS screening among non-diabetics

Ninety-nine percent (328/332) of participants without a diagnosis of diabetes and with HbA1c results had RBS results available, and 83% (276/332) had FBS results available (Table 4). Only 15.4% (2/13) of non-diabetics with HbA1c $\geq 6.5\%$ had an elevated RBS (≥ 11.1 mmol·L⁻¹), while 66.7% (8/12) had an elevated FBS (≥ 7.0 mmol·L⁻¹) on the day of surgery.

Random blood sugar and day of surgery FBS screening among diabetics with suboptimal glycemetic control

Random blood sugar results were available for 99% (69/70) and FBS results were available for 94% (66/70) of diabetic participants with HbA1c results (Table 4). Only 42.1% (16/38) of diabetics with suboptimal glycemetic control (HbA1c $> 7.0\%$) had an elevated RBS (≥ 11.1 mmol·L⁻¹), while 86.1% (31/36) had an elevated FBS (≥ 7.0 mmol·L⁻¹) on the day of surgery. Based on our data and using HbA1c as our gold standard, RBS testing had a sensitivity of 42.1% and a specificity of 96.8% for identifying diabetic patients with poor glycemetic control. Fasting blood sugar had a sensitivity of 86.1% and a specificity of 46.7%.

Discussion

In this study conducted in the preoperative setting, we found that many patients not previously diagnosed with diabetes were at high risk for developing diabetes, and some patients had a HbA1c $\geq 6.5\%$, which is a provisional diagnosis of diabetes. In addition, the majority of patients diagnosed with diabetes had poorly controlled blood glucose levels.

Our results are consistent with previous studies. In a study examining the prevalence of undiagnosed diabetes in 630 patients presenting for coronary artery bypass graft (CABG) surgery using HbA1c, 56.5% of patients were identified as pre-diabetic and 10.6% were identified as diabetic.¹⁸ Thirty percent of our 20 patients presenting for CABG surgery were considered pre-diabetic and 10% were diabetic. In another study of 493 patients presenting for elective noncardiac surgery, the prevalence of undiagnosed diabetes was examined using FBS screening. Results identified 19.3% of patients as having impaired fasting glucose and 6.5% as having a provisional diagnosis of diabetes.¹⁷ Ordinarily, these patients would not have blood glucose monitoring in the postoperative period; however, they would be at high risk for developing perioperative hyperglycemia and its associated complications, particularly with the added physiologic stress of surgery. Glycosylated hemoglobin is a readily available and simple screening test that can identify patients who may benefit from preoperative optimization of blood glucose levels and postoperative glucose monitoring. Early identification of these patients may help reduce postoperative complications associated with hyperglycemia, as high preoperative HbA1c has previously been shown to increase postoperative adverse events such as wound complications and cardiovascular events.^{19,32}

Our finding of poorly controlled blood glucose levels in the majority of diabetic patients presenting for surgery is also consistent with a previous study that reported most cardiac surgery patients with diabetes have suboptimal glycemetic control based on preoperative HbA1c testing.¹⁹ A significant advantage of HbA1c testing over RBS is the ability to provide feedback to diabetic patients about their glycemetic control over the previous several months rather than a snapshot during their preoperative assessment. This measure of long-term control is useful as patients' perceptions of their glycemetic control are often inaccurate.

We have illustrated that RBS testing has limited ability to identify diabetics with suboptimal glycemetic control given its low sensitivity. This can likely be attributed to some patients fasting for several hours prior to pre-surgical screening assessment or as a result of more diligent glycemetic control prior to a clinic visit.

Conversely, FBS testing on the morning of surgery had relatively higher sensitivity than RBS for identifying diabetic patients with poor glycemetic control, and a low specificity. Among non-diabetics in our study, FBS testing was able to identify a higher percentage of previously undiagnosed diabetic patients when compared with HbA1c screening. Given our small sample size, however, it is important to recognize the limitations of the validity of our calculated test sensitivities/specificities. Previous research has shown that a diagnostic threshold of a HbA1c $\geq 6.5\%$

classifies one-third fewer individuals as having diabetes compared with FBS testing.²² This difference may be widened further by hyperglycemia associated with pre-surgical stress. Nevertheless, an international expert committee argues that the greater clinical ease of HbA1c testing helps to identify a greater number of undiagnosed diabetic patients.²³ Furthermore, HbA1c testing does not require fasting or timed samples and there is limited effect from recent changes in activity or diet. Like RBS, HbA1c testing can be performed at the same time as other blood work and carries virtually no additional training, time, or patient risks. Screening also targets patients who may not otherwise present for glycemic testing through their family doctor.

Given enough time prior to surgery, an abnormally elevated HbA1c can prompt the optimization of a patient's diabetes as well as put the patient on the road to long-term diabetic management. This would include the involvement of the patient's family physician, diabetes education, lifestyle modification, and medical management. In certain high-risk surgical groups, such as patients undergoing coronary artery bypass procedures where morbidity is significantly increased in patients with elevated HbA1c, the patient may even benefit from delaying the surgery until glycemic control is established.¹⁹ In particular, diabetics presenting for cardiac surgery with poor glycemic control may benefit from tighter perioperative glycemic management, which has been shown to reduce wound infections and length of stay and improve survival.³³

It may not be cost effective to perform HbA1c screening on all patients scheduled for surgery as a significant proportion lack risk factors for diabetes. The yield for screening these patients would be very low; however, a cost-benefit analysis performed on HbA1c as a screening test for poor glycemic control is lacking. In our centre, the cost of HbA1c testing is approximately three times that of RBS.

We collected data which had previously been shown to correlate with an increased risk of diabetes in order to identify patients who could benefit from diabetes screening. Nevertheless, it is difficult to draw conclusions from our modified CANRISK questionnaire. Only one-quarter of the patients with a provisional diagnosis of diabetes based on HbA1c testing were classified in the "high" or "very high" risk groups using our questionnaire. There are several reasons for a poor correlation between our HbA1c diagnostic results and our modified CANRISK assessment, including an insufficient number of study participants (as the study was not powered for this secondary analysis), the use of a modified CANRISK

questionnaire rather than the original validated questionnaire, and the use of a patient-administered questionnaire. Further research is needed to develop a simple screening questionnaire similar to the CANRISK questionnaire for use in the preoperative setting to guide HbA1c screening.

There are several limitations of this study. A small number of patients were given a new diagnosis of diabetes based on our screening, thus, we were not able to determine which elements of a screening questionnaire would be most useful. The reliance on a patient questionnaire as well as a chart review for demographic data, risk assessment, and medical history requires patients to interpret questions accurately and healthcare professionals to enter complete and accurate documentation in the patient record. Lastly, the population in the catchment area from which the study sample was drawn is known to be older than the provincial average due to the high number of retirees; therefore, a larger multicentre study is required to validate an HbA1c screening protocol among elective surgical patients in the general population.

Although it is clear there is a substantial cohort of patients at very high risk for diabetes as well as with undiagnosed diabetes, future research is needed to determine guidelines for more focused screening. Research is also needed to assess potential mortality and morbidity and cost benefits that may be achieved through pre-surgical HbA1c screening.

In conclusion, there are numerous elective surgical patients with no diabetic history who are at very high risk for diabetes or have a provisional diagnosis of diabetes. These patients are at considerable risk for unrecognized postoperative hyperglycemia and associated adverse outcomes. Among patients with a history of diabetes, the majority have suboptimal glycemic control. Relative to HbA1c, RBS testing in pre-surgical screening has limited sensitivity in identifying patients with poor glycemic control. These results suggest that HbA1c testing may be easily implemented and more appropriate than RBS testing for the preoperative assessment of diabetic and non-diabetic patients alike. Future study is needed to determine if HbA1c testing is a cost-effective screening tool for patients with no history of diabetes.

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Conflicts of interest None declared.

Appendix 1 Patient Questionnaire

Prevalence of Hyperglycemia in Patients Presenting to Pre-Surgical Screening: Patient Questionnaire

Have you been diagnosed with any of the following medical conditions?

Please check all that apply

- Diabetes type 1
- Diabetes type 2
- Abnormal glucose tolerance or fasting blood sugar (pre-diabetes)
- Gestational diabetes (diabetes during pregnancy)
- High blood pressure
- Angina
- Heart attack
- Stroke / TIA (mini-stroke)
- Congestive heart failure
- Peripheral vascular disease
- Kidney disease
- Polycystic ovarian syndrome

What is your ethnicity?

- Caucasian African Asian Hispanic Caribbean Aboriginal other

Do you have a family history of diabetes? YES NO

Are you currently a smoker? YES NO

Are you an ex-smoker? YES NO

How would you describe your exercise habits?

- No exercise
- Infrequent exercise
- Weekly low intensity exercise (e.g. walking)
- Weekly moderate intensity exercise (e.g. dancing)
- Weekly strenuous exercise (e.g. running)

Please answer the following questions if you have been diagnosed with diabetes:

How long ago were you diagnosed with diabetes? _____ years

How do you control your blood sugar (select all that apply)?

- Diet Oral medication Insulin

How frequently do you check your blood sugars?

- 2- 4 times per day Once per day Weekly Monthly Never

How well do you feel your blood sugar is controlled?

- Very poorly controlled Poorly controlled Sometimes controlled
 Reasonably well controlled Very well controlled

Appendix 2 Modified CANRISK questionnaire

Variable	Points
Age	
40-44	0
45-54	2
55-64	3
65+	4
BMI	
<25	0
25-30	1
>30	3
Physically active*	
yes	0
no	2
Hypertension	
yes	2
no	0
Previous impaired fasting glucose OR previous impaired glucose tolerance testing OR previous gestational diabetes	
yes	5
no	0
History of diabetes within immediate family	
yes	5
no	0

*Physically active was defined as minimum weekly low intensity exercise (such as walking)

Lower than 6 low risk: 1 in 100 will develop diabetes

6 - 8 slightly elevated risk: 1 in 25 will develop diabetes

9 - 11 moderate risk: 1 in 6 will develop diabetes

12 - 16 high risk: 1 in 3 will develop diabetes

over 16 very high: 1 in 2 will develop diabetes

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