Effect of Preoperative Diabetes Management on Glycemic Control and Clinical Outcomes after Elective Surgery

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Objective: The aim of this study was to evaluate whether preoperative diabetes management can improve glycemic control and clinical outcomes after elective surgery.

Background: There is lack of data on the importance of diabetes treatment before elective surgery. Diabetes is often ignored before surgery and aggressively treated afterwards.

Methods: Patients with diabetes were identified and treated proactively before their scheduled surgeries. Data for all elective surgeries over 2 years before and 2 years after implementation of the program were collected.

Results: Out of 31,392 patients undergoing first surgery, 3909 had diabetes; 2072 before and 1835 after the program. Mean blood glucose on the day of surgery was 146.4 ± 51.9 mg/dL before and 139.9 ± 45.6 mg/dL after the program ($P = 0.0028$). Proportion of patients seen by the inpatient diabetes team increased. Mean blood glucose during hospital stay was 166.7 ± 42.9 mg/dL before and 158.3 ± 46.6 mg/dL after program ($P < 0.0001$). The proportion of patients with hypoglycemic episodes (<50 mg/dL) was 4.93% before and 2.48% after the program ($P < 0.0001$). Length of hospital stay (LOS) decreased among patients with diabetes (4.8 ± 5.3 to 4.6 ± 4.3 days; $P = 0.01$) and remained unchanged among patients without diabetes (4.0 ± 4.5 and 4.1 ± 4.8, respectively; $P = 0.42$). Changes in intravenous antibiotic use, patients discharged to home, renal insufficiency, myocardial infarction, stroke, and in-hospital mortality were similar among diabetic and nondiabetic groups.

Conclusions: Preoperative and inpatient diabetes management improves glycemic control on the day of surgery and postoperatively and decreases the incidence of hypoglycemia. These changes may eventually improve clinical outcomes. Although statistically significant, the decrease in LOS was of equivocal clinical significance in this study.

Keywords: elective surgery, length of hospital stay, postoperative outcomes, preoperative diabetes management

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Patients with diabetes mellitus have poor clinical outcomes after surgery as compared with those without diabetes.[1,2] Moreover, there is an association between perioperative blood glucose levels and surgical outcomes.[3,4] A recent interventional study showed a decrease in surgical complications, especially postoperative infections, by achieving good glycemic control in the postoperative period.[5] Therefore, good glycemic control during hospital stay has become a standard of care and many hospitals have established inpatient diabetes management teams. However, preoperative management of diabetes, before elective surgery, has not received much attention. In general, treatment of diabetes in the preoperative period is inadequate.[6,7]

Patients with poor glycemic control before surgery are likely to remain hyperglycemic during and after surgery as well.[8] Blood glucose levels >200 mg/dL can affect neutrophil phagocytic activity that may lead to an increased risk of infections and impaired wound healing.[9] Therefore, we hypothesized that better diabetes management before surgery will result in improved glycemic control and lower risk of surgical complications after surgery. This study was conducted to evaluate the effect of preoperative diabetes management on glycemic control and clinical outcomes after major elective surgery.

RESEARCH DESIGN AND METHODS

We established a new clinical program to systematically identify and manage adult patients with diabetes planned to undergo a major elective surgery. The program was implemented as a quality improvement initiative. All data for this study were obtained retrospectively. Waiver of informed consent for this study was approved by the Partners Health Human Research Committee. Data were obtained from the Research Patient Database Registry (RPDR). Research Patient Data Registry is a data warehouse that serves as a central clinical data repository for participating hospitals and clinics within the Partners HealthCare System, an integrated health care delivery network in Eastern Massachusetts that includes Massachusetts General Hospital and Brigham and Women's Hospital.

Patients scheduled to be seen at the preoperative evaluation center before major elective surgeries that would likely result in hospitalization for >24 hours were prescreened for history of diabetes. HbA1c was ordered at the time of preoperative evaluation visit unless a result for HbA1c was available within the previous 3 months. Measurement of HbA1c was an indication that diabetes had been addressed as a problem at the preoperative evaluation visit. It was also used to identify patients with inadequate glucose control who will require the most aggressive treatment. However, the purpose of this program was to optimize treatment for all patients with diabetes irrespective of their HbA1c levels. Those with HbA1c ≥ 8% were referred to the diabetes management team. For patients with HbA1c <8%, a diabetes management protocol was followed by anesthesiologists with support/consultation available from the diabetes team if needed. Goal of treatment was to improve blood glucose levels by the day of surgery so that blood glucose level is <200 mg/dL on the morning of surgery. This target was chosen on the basis of available data [4] and agreed upon by all involved parties as the threshold blood

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glucose level that was a clear risk for surgical complications. HbA1c was not a target of treatment in this study due to lack of evidence that lowering HbA1c will decrease surgical complications. Surgery was not cancelled or delayed to improve diabetes control unless it was requested by the patient or the surgeon. Interventions were individually planned in a pragmatic manner, depending on the time available before surgery, clinical condition, patient knowledge and cooperation, as well as current diabetes treatment regimen. Individual plans developed by the team included, but were not limited to, the following: increasing the frequency of blood glucose testing (73% of patients), adjusting, adding or discontinuing oral medications (10% patients), titrating insulin, starting basal or bolus insulin, and changing the type of insulin used by the patient (27% patients). Patients were also advised about the medication changes to be made on the day of surgery and 1 day before surgery in anticipation of the fasting status on day of surgery. Out of all patients with diabetes, 21% (with HbA1c >8%) were managed directly by the diabetes team (half the patients were seen in person at the time of preoperative visits and half managed only over the phone); all others were followed by anesthesiologists with support from the diabetes team as needed.

Data for analysis included all adult patients (≥18 years old) seen in the preoperative center from January 1, 2011, to December 31, 2014, and admitted to hospital postoperatively within 30 days of their preoperative visit. The diagnosis of diabetes was based on ICD-9 code at the time of preoperative visit and during hospitalization. If a patient underwent more than 1 surgery during the specified time period, only the first surgery was taken into account. The preoperative diabetes management program was launched on February 1, 2013. Therefore, patients with diabetes seen at the preoperative center between January 1, 2011, and January 31, 2013, were considered the control group (group 1) and those seen in the preoperative center from February 1, 2013, to December 31, 2014, were considered to be the intervention group (group 2). Data from patients without known diabetes during the 2 respective periods were included in this analysis (group 3 and 4) to adjust for any temporal trends that may have affected our results.

Demographic data, diagnoses during admission for surgery, laboratory data, and length of hospital stay (LOS) were obtained from the RPDR. Insulin use at the time of admission was noted from the medication reconciliation list. We also collected data on admission to intensive care unit (ICU), intravenous antibiotic use after first day of hospitalization (that excluded prophylactic perioperative antibiotic administration), discharge disposition, death in the hospital, readmission to a Partners hospital within 30 days of discharge, renal failure or doubling of serum creatinine during the hospital stay, myocardial infarction, and stroke in the postoperative period. All point of care blood glucose values after admission were collected. We also collected data on consultation by the inpatient diabetes care team and inpatient anti-diabetic treatment. Charlson Comorbidity Index (CCI) was calculated from the ICD-9 codes.[10]

Statistical Analysis

Main analysis included the comparison between 2 diabetic groups. As an additional caution, we adjusted the clinical outcomes for temporal trends when suggested of such a possibility by data in the nondiabetic groups. Fasting blood glucose level on the day of surgery, before sending the patient to the operating room, was used an index of preoperative glycemic control. Mean point of care blood glucose level during the entire hospital stay was used as an index of inpatient glycemic control. Percentage of patients with any blood glucose <50 mg/dL was used as an index of hypoglycemia. Primary clinical outcome of this study was predetermined to be LOS based on our previous study that showed longer LOS in association with poor preoperative glycemic control.[6] LOS was calculated as the date of discharge minus date of admission without the hour of admission or discharge. Therefore, LOS for each individual patient was an integer. Minimum LOS for an individual patient was 1 day. Other major clinical outcomes included intravenous antibiotic use after day 1 (surrogate for in-hospital infection), discharge disposition, death in the hospital, readmission to hospital within 30 days of discharge, renal failure or doubling of serum creatinine during the hospital stay, myocardial infarction, and stroke in the postoperative period.

Population characteristics are presented as number with percentage for categorical variables and mean ± standard deviation for continuous variables. Two group comparisons were analyzed using a Pearson Chi-square test for categorical variables. For continuous variables, a t test was used where normality was not rejected and Wilcoxon 2-sample test was used otherwise. To correct for changes unrelated to the diabetes program, we used zero-truncated negative binomial regression for LOS analysis where the effect is the incidence rate ratio.[11] Other binary outcomes were analyzed using logistic regression where the effect is the odds ratio. Both approaches included main effects of Patient Group (diabetes vs nondiabetes), Period (before program initiation vs after), and the Interaction. The goal of the analysis for each separate outcome was to test whether the diabetes management program was associated with changes in the outcome in diabetic patients that were greater than any changes seen in nondiabetic patients, while controlling for putative confounding variables (age, sex, race, ICU admission, CCI, gastrointestinal surgery, and cardiovascular surgery). This hypothesis was tested by the interaction between Group and Period; effects of the Program Initiation within each Group were derived from the full models. All statistical analyses were performed using SAS 9.4 (SAS Institute, Cary, NC).

RESULTS

During the study period, 31,392 patients underwent a first major elective surgery, out of which 3909 patients had a diagnosis of diabetes mellitus. Distribution of patients into the 4 groups is shown in Fig. 1.

Patient characteristics during the 2 respective periods are compared in Table 1. Proportion of patients with diabetes who had an HbA1c measurement at the time of preoperative visit increased from 31% during the control period to 69% during the intervention period. Of the patients with an HbA1c measurement, 21% were referred to the diabetes team due to HbA1c ≥8%. The average time between preoperative visit and day of surgery was 7.5 ± 5.8 days (range 0 to 29). Mean HbA1c was higher before program implementation. A higher percentage of patients were admitted to ICU after implementation of the program in both diabetic and nondiabetic groups. Before the program, 48% patients with diabetes were receiving insulin with or without noninsulin agents at the time of admission, and after program, 41% patients with diabetes were receiving insulin with or without noninsulin agents at the time of admission ($P = 0.0006$). Only insulin was used for glycemic control after surgery during the hospital stay.

Mean blood glucose on day of surgery was 146.4 ± 51.9 mg/dL before the program and 139.9 ± 45.6 mg/dL after the program ($P = 0.0028$). The proportion of patients with blood glucose >200 mg/dL was lower after the program (Table 1). After the program, 32.5% patients received a diabetes consult during their hospital stay as compared with 13.2% patients before the program. Mean blood glucose level during the hospital stay was 166.7 ± 42.9 mg/dL before the program and 158.3 ± 46.6 mg/dL after the program ($P < 0.0001$). The number of patients with 1 or more hypoglycemic episode (<50 mg/dL) was lower after the program (2.48%) than before the program (4.93%).

Clinical outcomes are summarized in Table 2. Among patients with diabetes, LOS changed from 4.78 ± 5.23 before the program to

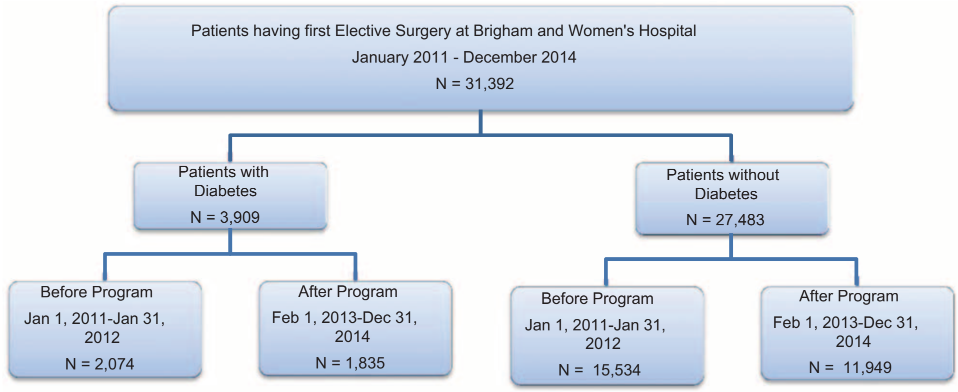

FIGURE 1. Distribution of patients included in analysis.

4.62 ± 4.28 after the program. In the regression model predicting LOS, the interaction between diagnostic group (diabetes vs nondiabetes) and intervention (before vs after) was significant ($P = 0.01$) indicating the effect of intervention. Results from the model show that in the diabetic group, the intervention significantly reduced LOS ($P = 0.02$) but not in the nondiabetic group ($P = 0.69$), confirming the effect of our program. The covariates that were significant in this model included age, sex, race, type of surgery, ICU admission, and CCI (Supplementary Table 1). Data analysis after removing patients who died in the hospital did not change the results.

Intravenous antibiotic use decreased significantly overall ($P \leq 0.001$) and to a similar extent in both groups. Readmission rates decreased nonsignificantly in diabetic group ($P = 0.23$) and significantly in the nondiabetic group ($P = 0.0002$); however, the group effects were not significant ($P = 0.66$). Proportion of patients discharged to home did not change significantly in either group. In-hospital mortality, incidence of renal insufficiency, myocardial infarction, and stroke did not change significantly in either group. Also, for these binary outcome models, the covariates age, sex, race, type of surgery, ICU admission, and CCI were significant to a

TABLE 1. Patient Characteristics and Glucose Control

	DM 2011–2012	DM 2013–2014	*P*	Non-DM 2011–2012	Non-DM 2013–2014	*P*
Age, years	64.3 ± 13.2	64.5 ± 12.8	0.97	59.7 ± 15.2	58.5 ± 15.3	<0.001
Sex, N (%)						
Male	994 (48)	907 (49)	0.097	6243 (40)	5144 (43)	<0.001
Female	1080 (52)	928 (51)		9290 (60)	6804 (57)	
Race, N (%)						
White	1551 (75)	1411 (77)	0.055	13,185 (85)	10,205 (85)	0.393
Black	220 (11)	179 (10)		862 (6)	572 (5)	
Other	303 (15)	245 (13)		1489 (10)	1172 (10)	
Type of surgery, N (%)						
Cardiovascular	300 (15)	249 (17)	0.42	1374 (9)	1226 (11)	<0.001
Noncardiovascular						
Gastrointestinal Surgery	432 (21)	393 (21)		2301 (15)	1591 (13)	
Gynecology	111 (5)	76 (4)		1659 (11)	802 (7)	
Neurosurgery	175 (8)	155 (8)		1318 (9)	1421 (12)	
Oncology	141 (7)	155 (8)		1353 (9)	999 (8)	
Orthopedics	353 (17)	321 (17)		3355 (22)	2576 (22)	
Thoracic	244 (12)	211 (11)		1926 (12)	1517 (13)	
Urology	116 (6)	122 (7)		939 (6)	783 (7)	
Other	202 (10)	153 (8)		1309 (8)	1034 (9)	
Patients with A1c, N (%)	642 (31)	1267 (69)	<0.001	N/A	N/A	
Mean A1c, %	7.3 ± 1.4	7.1 ± 1.3	0.01			
Mean Creatinine, mg/dL	1.2 ± 1.2	1.2 ± 1.1	0.24	0.92 ± 0.7	0.92 ± 0.6	0.88
ICU during admission, N (%)	138 (7)	157 (9)	0.025	895 (6)	942 (8)	<0.001
CCI score	1.99 ± 2.6	2.05 ± 2.6	0.30	1.77 ± 2.6	1.79 ± 2.6	0.57
Patients receiving insulin at the time of admission, N (%)	604 (48.1)	706 (41.2)	0.0006	N/A	N/A	
Mean Admission blood glucose on day of surgery, mg/dL	146.4 ± 51.9	139.9 ± 45.6	0.0028	N/A	N/A	
Patients with admission blood glucose >200 mg/dL, N (%)	213 (12.53)	142 (9.16)	0.0021	N/A	N/A	
Patients seen by inpatient DMS, N (%)	274 (13.2)	597 (32.5)	<0.0001	N/A	N/A	
Mean blood glucose after day of surgery, mg/dL	166.7 ± 42.9	158.3 ± 40.6	<0.0001	N/A	N/A	
Patients with any blood glucose <50 mg/dL during hospitalization, N (%)	77 (4.93)	36 (2.48)	0.0004	N/A	N/A	

Percentages may differ because complete data were not available for all variables.
DM indicates diabetic group; DMS, diabetes management service; non-DM, nondiabetic group.

TABLE 2. Clinical Outcomes

	DM 2011–2012 N = 2074	DM 2013–2014 N = 1835	*P*	Incidence Rate Ratio (95% CI)	Non-DM 2011–2012 N = 15534	Non-DM 2013–2014 N = 11949	*P*	Incidence Rate Ratio (95% CI)	*P* for Interaction*
Length of hospital stay, d	4.78 ± 5.23	4.62 ± 4.28	0.02	0.95 (0.91–0.99)	3.98 ± 4.49	4.11 ± 4.78	0.69	1.00 (0.99–1.02)	0.01
				Odds Ratio (95% CI)				Odds Ratio (95% CI)	
Intravenous antibiotic use after 24 h of admission, N (%)	491 (23.7)	370 (20.2)	0.001	0.76 (0.65–0.89)	2836 (18.3)	1969 (16.5)	<0.0001	0.83 (0.78–0.89)	0.34
Readmission within 30 days†, N (%)	296 (14.3)	236 (12.9)	0.23	0.89 (0.74–1.08)	1422 (9.2)	956 (8.0)	0.0002	0.85 (0.77–0.92)	0.66
Discharge to home, N (%)	1679 (81.0)	1465 (79.8)	0.38	0.93 (0.78–1.10)	13638 (87.8)	10,469 (87.8)	0.11	0.94 (0.86–1.01)	0.72
Death in the hospital, N (%)	6 (0.29)	7 (0.38)	0.77	1.18 (0.39–3.59)	24 (0.15)	31 (0.26)	0.27	1.38 (0.78–2.42)	0.79
Renal failure or doubling of serum creatinine	33 (1.81)	26 (1.59)	0.39	0.79 (0.46–1.35)	114 (0.94)	95 (0.97)	0.44	0.89 (0.67–1.19)	0.69
Acute MI in the hospital	121 (5.8)	97 (5.3)	0.59	0.91 (0.65–1.28)	639 (4.1)	532 (4.4)	0.10	0.88 (0.76–1.02)	0.87
Stroke in the hospital	57 (2.7)	42 (2.3)	0.46	0.85 (0.55–1.32)	163 (1.0)	123 (1.0)	0.52	0.92 (0.72–1.18)	0.77

DM indicates diabetic group; non-DM, nondiabetic group.
*The interaction compares the effect of the intervention for DM versus non-DM.
†Excludes 68 patients who died in the hospital.

variable degree (Supplementary Table 1, http://links.lww.com/SLA/B246). Adding other types of surgery to the models did not change the results.

DISCUSSION

This study shows that early treatment of diabetes, starting at the time of preoperative evaluation, results in improved glycemic control perioperatively. It decreases the incidence of inpatient hypoglycemia and may be associated with a shorter LOS. These data were generated in a real-world clinical practice setting, while treating patients in a pragmatic manner. Poorly controlled diabetic patients were referred to a diabetes care team, while all others were treated by the anesthesia team as is the common practice. However, while diabetes as a problem was often missed before implementation of the program as suggested by only 31% patients having an HbA1c test, more attention was paid to diabetes after the program as suggested by 69% patients having an HbA1c test.

The benefits seen in this study were rather small and showed significance only for the LOS. However, with an estimated 1000 patients with diabetes undergoing elective surgery at a major hospital, this could amount to savings of about 200 hospital days per year. Even with the most conservative cost estimates of $2000 for each hospital day,[12] this amounts to $400,000 savings per year for the hospital. It is important to note that the benefits seen in this study were achieved with only a minimal intervention that is feasible at most institutions and incurs minimal cost because it can be easily incorporated into routine practice. Our glycemic goals were liberal and no surgery was delayed or cancelled for the purpose of diabetes control. Our intervention was directed more toward making a culture change in the preoperative center based on existing evidence[4] rather than testing a new hypothesis. One of the thoughts behind implementing this program was to improve inpatient glycemic control. Our program led to a significant increase in the number of inpatient diabetes consults that was associated with improvement in glycemic control and lower incidence of hypoglycemia during the hospital stay, changes that are known to be associated with improved clinical outcomes. Surprisingly, a smaller proportion of patients were getting insulin at the time of admission after the program than before the program. Despite that, glycemic control improved at the time of admission after the program. We speculate that compliance with insulin as well as with noninsulin agents may have improved after our program.

Previous data show that patients with diabetes have longer hospital stay than nondiabetic patients and LOS correlates with diabetes control.[1,3,13–15] Hyperglycemia, hypoglycemia, and increased glycemic variability have each been independently associated with an increased risk of mortality in hospitalized patients.[16] Most of these data relate to blood glucose levels after admission to hospital.[1,17] Much of the data on relation between hyperglycemia and clinical outcomes was generated in cardiac surgery patients.[18–23] However, diabetes can affect the primary disease process in cardiovascular disease, and therefore, one cannot be confident about the independent effects of diabetes on surgery outcomes. Data in noncardiovascular surgeries are limited but show an association between glucose levels and outcomes such as infection rates, wound healing, renal failure, and thromboembolic episodes after surgery.[1,24,25] A randomized controlled trial by Van den Berghe and colleagues showed remarkable benefits of maintaining normal glucose levels in surgical ICU[26]. However, initial enthusiasm about this study was eventually dampened by studies showing lack of similar benefits in other ICU situations[27,28]. Recent study by Umpierrez et al[5] showed benefits of perioperative glycemic control in the non-ICU setting. Thus, diabetes control is clearly an important part of the postoperative care to decrease the risk of infection. Our study provides evidence that preoperative diabetes management may add to the benefits by further improving perioperative glycemic control. Our intervention led to earlier and more frequent referral to inpatient diabetes service and thus, improved the overall perioperative care. As a result of more frequent evaluation by the inpatient diabetes service, mean blood glucose levels during the hospital stay improved and risk of hypoglycemia decreased. We think that the improvement in postoperative glycemic control with or without preoperative control would have improved the clinical outcomes. However, increased involvement of the inpatient diabetes care team resulted from our preoperative intervention. The program may also have led to more timely discharge planning and early discharge from the hospital, explaining the decrease in LOS.

There have been previous attempts to streamline management of diabetes preoperatively. A consortium of British Diabetes Societies issued guidelines in 2012 suggesting that attempts should be made to achieve an HbA1c below 8.5% preoperatively.[29] Some orthopedic surgeons have been targeting for an HbA1c <7% before joint replacement surgery based on limited data.[14,30] However, the management of diabetes preoperatively is mostly arbitrary and often ignored, as suggested by our previous study and other studies.[6,31,32] This may have been due to lack of evidence that preoperative management of diabetes adds to the benefits of adequate glycemic control during the hospital stay. Our study provides the first data showing that preoperative management of diabetes is worthwhile.

One limitation of our study is that we did not evaluate different goals of glycemic control in this study. Moreover, HbA1c was not the goal of treatment in this study. Aiming for lower HbA1c would have involved delaying surgery, and without proven benefits at this time, it could not be implemented as a quality of care. We believe that future studies are needed to evaluate whether lower blood glucose levels and HbA1c control before surgery improves clinical outcomes. Another limitation is the nonrandomized design and retrospective nature of data collection in this study. We included all patients undergoing elective surgery during the specified period to avoid any selection bias. It is likely that there were unobserved differences in patient mix and in the standards of care before versus after intervention. We used data from patients without known diabetes to control for secular trends, patient type, and process-related factors over the years of observation. Therefore, process-related factors are unlikely to be affecting our main results. Nevertheless, it is still possible that there was a change in procedures or factors that were specifically directed to patients with diabetes and this change could affect our results.

In conclusion, preoperative management of diabetes before elective surgery, in addition to inpatient diabetes management, improves glucose control on the day of surgery and during hospitalization and leads to a slight decrease in LOS. Although further studies are conducted to establish the level of ideal diabetes control before elective surgery, preoperative counseling to improve glycemic control before the day of surgery should be recommended.

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