Windows of Opportunity to Improve Diabetes Care When Patients With Diabetes Are Hospitalized for Other Conditions

SHEILA H. ROMAN, MD, MPH[1,2]
MARK R. CHASSIN, MD, MPP, MPH[1]

OBJECTIVE — The overwhelming majority of hospitalizations for patients with diabetes occur for treatment of comorbid conditions. This study assessed broad-based interventions to improve diabetes care for patients hospitalized with cardiac conditions.

RESEARCH DESIGN AND METHODS — A pre-post quasi-experimental study design was used to evaluate the implementation of two quality improvement interventions: *1*) revision of the hospital's capillary blood glucose monitoring form into a color-coded process control chart and 2) a clinical path for type 2 diabetes as a secondary diagnosis. Interventions were implemented on the medical and surgical cardiac care units (not including the intensive care units on these services) of a tertiary academic medical center. A chart abstraction sample included 328 subjects with no exposure to the interventions and 336 subjects hospitalized after both interventions were implemented. Telephone surveys were conducted after discharge on 446 patients.

RESULTS — The frequency of patients with severe hyperglycemia (at least one glucose level >400 mg/dl) and prolonged hyperglycemia (at least three consecutive glucose levels >250 mg/dl) decreased from 12 and 17% preintervention to 6.6 and 10% postintervention ($P = 0.017$ and $P = 0.013$, respectively). We found that 9% of the patients preintervention and 5% of the patients postintervention ($P = 0.05$) had nosocomial infections. Patient-reported receipt of self-care instruction varied from 44 to 69% on nine survey items preintervention. Postintervention linear regression slopes for receipt of self-care instruction were all greater than preintervention slopes, but the differences did not achieve statistical significance. We found that 40% of the patients had important diabetes knowledge deficits.

CONCLUSIONS — Our broad-based interventions were associated with a decreased frequency of prolonged and severe hyperglycemia and a decreased frequency of nosocomial infections. We also identified opportunities to improve diabetes self-care instruction before discharge and to address important knowledge deficits of patients.

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Diabetes is a common, serious, and costly chronic disorder with a rapidly rising prevalence in the U.S. (1). Diabetes is associated with an excess of morbidity and mortality (2), and the health care costs for diabetes were estimated at $98 billion in 1997, with over half of the direct medical expenditures attributable to inpatient hospital care (3). The overwhelming majority of hospitalizations occur for comorbid conditions and not because the patients' diabetes requires acute treatment (4). As a consequence, diabetes management is rarely the focus of care during hospitalizations for patients with diabetes, and glucose control and other diabetes-related care processes are often inadequately addressed. Despite the frequency with which diabetic patients are hospitalized, there are no recognized standards of care for the inpatient management of diabetes. A small amount of literature (5–11) suggests that attention to glucose control and other diabetes care processes when patients are hospitalized for other conditions may improve clinical outcomes. In this study, we assessed the extent to which the introduction of broad-based interventions to facilitate and improve diabetes management in the hospital improved short-term diabetes-related care processes and outcomes for patients admitted with cardiac conditions.

RESEARCH DESIGN AND METHODS

Site of study

At Mount Sinai Medical Center, an 1,100-bed tertiary care academic medical center in New York City, >10% of patients hospitalized have a diagnosis code for diabetes, but in >90% of those patients, diabetes will not be the principal diagnosis. With the re-engineering of the hospital and clustering of patients with similar principal diagnoses into care centers, diabetes occurred as a secondary diagnosis with high frequency on certain units. On any given day, 25–40% of the patients on the hospital's medical and surgical cardiac care units (not including the intensive care units on these services) had diabetes. These units served as the sites for implementation of two diabetes quality improvement interventions.

Quality improvement interventions

The first quality improvement intervention was a revision of the hospital's capil-

From the Departments of [1]Health Policy and [2]Medicine, Mount Sinai School of Medicine, New York, New York.

Address correspondence and reprint requests to Sheila H. Roman, MD, MPH, Health Care Financing Administration, 7500 Security Blvd., Baltimore, MD 21244-1850. E-mail: sroman@hcfa.gov.

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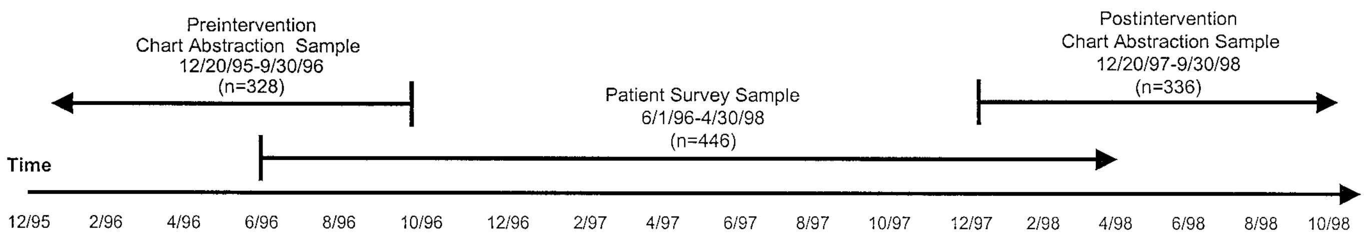
Abbreviations: BG, blood glucose; CBG, capillary BG; CBGM, CBG monitoring; DIGAMI, Diabetes and Insulin-Glucose Infusion in Acute Myocardial Infarction.

A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.



Timeline of Quality Improvement Interventions

12/20/95–9/30/96	Preintervention chart abstraction sample identified retrospectively
6/1/96	Postdischarge telephone survey begins
10/96–1/97	Pilot of revised CBGM form on medical unit of Cardiac Care Center
1/97–3/97	Pilot of revised CBGM form on surgical unit of Cardiac Care Center
6/97	Revised CBGM form approved for hospital-wide use
8/97	Revised CBGM form fully implemented on Cardiac Care Center study units
8/25/97	First patient placed on type 2 clinical path on surgical unit of Cardiac Care Center
10/03/97	First patient placed on type 2 clinical path on medical unit of Cardiac Care Center
12/97	Type 2 clinical path considered fully implemented on Cardiac Care Center units
12/20/97–9/30/98	Postintervention chart abstraction sample identified
4/30/98	Postdischarge telephone survey concludes

Figure 1—*Sample time frames.*

lary blood glucose monitoring (CBGM) form into a chart with color-coded columns for defined glucose ranges. Similar to a process-control chart, this format provided immediate visual input about trends in glucose control. Management algorithms corresponding to the color-coded columns gave guidance to the medical and nursing staff. The second quality improvement intervention was an interdisciplinary clinical path for management of type 2 diabetes as a secondary diagnosis. The path gave recommendations on when and how to initiate or adjust standing insulin or oral diabetic agent regimens based on glucose levels, and it provided staff with elements of patient self-care instructions to provide to patients before discharge.

Chart abstraction sample

The chart abstraction sample was identified from the hospital's administrative database and was consecutively sampled to identify ~300 unique subjects meeting inclusion criteria in each defined time frame. Subjects in the preintervention sample (n = 328) were hospitalized before any possible exposure to the quality improvement interventions, and the postintervention subjects (n = 336) were hospitalized after the quality improvement interventions were considered fully implemented (Fig. 1). Inclusion criteria included having a secondary diagnosis of diabetes, being discharged alive from the study units, and a minimum length of stay of 36 h or a maximum length of stay of 14 days.

Patient survey sample

The patient survey sample was prospectively identified from medical record numbers in the study unit–based CBGM meters (Fig. 1). Patients were surveyed by telephone in English or Spanish within 2–3 weeks of their hospital discharge. Patients discharged before the day on which the first patient was placed on the type 2 clinical path were considered preintervention (n = 289), and patients discharged after that date were categorized as postintervention (n = 157) (Fig. 1). Of the 875 patients identified as eligible for the patient survey, 156 (18%) could not be contacted because of wrong telephone numbers, disconnected telephones, repeated busy signals, repeated no answers, or no telephone. An additional 145 (20%) denied having diabetes when contacted. A total of 23 patients (3%) were excluded because of sample selection discrepancies. Of the remaining 551 patients, 446 (81%) completed the full telephone survey. Chart reviews were conducted for a subsample of 72 charts of 90 patients denying diabetes when contacted in the preintervention period. Of these patients, 19 (26%) had a diagnosis of diabetes documented at the time of hospital admission. An additional 31 patients (43%) had plasma glucose levels >200 mg/dl during their hospitalization and may have had undiagnosed diabetes. The remaining 22 patients had no evidence of diabetes (12).

Data collection instruments

A computerized chart abstraction instrument was developed, tested for reliability and validity, and used to collect demographic information, case mix (using the Charlson Index [13]) data, glucose data from the unit-based CBGM meters, laboratory glucose data <60 or >400 mg/dl, and information on the presence of nosocomial infections, defined as an infection that was acquired during the hospitalization and not present at the time of the hospitalization. One registered nurse serving as chart abstractor reviewed charts for both time frames using the same instrument. The survey instrument was a composite of items obtained from internal research and from both Picker Institute and previously validated surveys adapted for use in this study (14–16). The survey assessed knowledge about hypo- and hyperglycemia as well as receipt of in-

Table 1—*Characteristics of patients in chart abstraction sample*

	Preintervention	Postintervention	*P*
n	328	336	
Age (years)*	66 ± 12	66 ± 11.2	NS
Sex*			NS
Male	55	52	
Race*			0.001
Caucasian	45	33	
Hispanic	27	25	
African-American	14	12	
Asian	3	5	
Other	4	12	
Unknown	7	14	
Comorbidities (Charlson Index)			NS
1	23	26	
2	35	31	
3	21	18	
4	12	14	
5	5	7	
6	4	4	

Data are means ± SD or %, unless otherwise indicated. *Obtained from administrative data.

structions for diabetes self-care and management before discharge.

Analysis of data

We used *t* tests and χ^2 tests, as appropriate, for comparisons of pre- and postintervention data. Linear regression was used to analyze changes over time in selected data from the patient survey. All analyses were based on the assumption of independence for all variables.

RESULTS

Chart abstraction data

Patient characteristics. Table 1 shows the demographic and clinical characteristics of patients in the chart abstraction sample. There were no significant differences in the age or sex distribution for the subjects abstracted before and after implementation of the interventions. Whereas higher frequencies of "unknown" and "other" codes for race were noted for postintervention subjects, we are unaware of any significant shift in the hospital's patient demographics during this study, and race is known to be inaccurately coded in administrative data. The distribution of patient comorbidities, as determined by the Charlson Index (13), was similar for the pre- and postintervention subjects.

Glucose control. Mean first glucose levels (means ± SD) after admission were similar (204 ± 94 and 188 ± 87 mg/dl pre- and postintervention, respectively). HbA_{1c} levels on admission were infrequently obtained (8 and 21%), and mean HbA_{1c} levels were similar (9.0 ± 2 vs. 8.6 ± 1.8%). The frequency of patients with glucose levels in defined ranges were compared pre- and postintervention. Postintervention, the frequency of patients with prolonged hyperglycemia (at least three consecutive blood glucose [BG] levels >250 mg/dl) and severe hyperglycemia (at least one BG >400 mg/dl) decreased significantly; for prolonged hyperglycemia, frequency values were 17 vs. 10% pre- and postintervention, respectively ($P = 0.013$), and for severe hyperglycemia, those values were 12 vs. 6.6% ($P = 0.017$). The frequency of patients having at least one BG <60 mg/dl was not significantly changed postintervention (8 vs. 11%). A total of 24 and 29% of patients pre- and postintervention, respectively, maintained all of their BG levels in the 80–250 mg/dl range (NS). Lengths of hospital stay were shorter for patients who maintained their BG levels in the 80–250 mg/dl range (6.1 vs. 5.8 days), than for patients with BG levels outside of that range (7.7 vs. 7.0 days). Patients were more likely to receive a standing diabetes regimen during their hospitalization postintervention (78 vs. 92%, $P = 0.001$).

Nosocomial infections. Nosocomial infections decreased during the postintervention period. A total of 28 patients (9%) had 28 nosocomial infections documented preintervention (1 line sepsis, 15 urinary tract, 1 catheter site, 6 pneumonia, and 5 intravenous site/other) compared with 16 patients (5%) having 17 infections postintervention (2 sternal wound, 5 urinary tract, 4 catheter site, 1 pneumonia, and 5 intravenous site/other) ($P = 0.05$).

Patient survey data

Characteristics of patients surveyed. There were no significant differences in terms of age, sex, race, educational level achieved, duration of diabetes, or diabetes treatment regimens between patients surveyed before and after introduction of the type 2 clinical path (Table 2). Nearly half of the patients reported known duration of diabetes for >10 years, and the vast majority reported taking medications for their diabetes. The educational level achieved varied widely, and >25% of patients did not consider English their first language. There were similar percentages of patients who reported that they did not perform home glucose monitoring (17 vs. 18%) pre- and postintervention, and values for previous attendance of a diabetes education program were also similar (27 vs. 29%).

Table 2—*Characteristics of patients in survey sample*

	Preclincal path	Postclinical path	*P*
n	289	157	
Age (years)*	63 ± 11	64 ± 12	NS
Sex*			NS
Male	59	55	
Race*			NS
Caucasian	38	39	
Hispanic	21	14	
African-American	18	16	
Asian	3	4	
Others	8	9	
Unknown	12	18	
Duration of diabetes			NS
> 10 years	45	45	
1–10 years	47	46	
< 1 year	4	6	
New onset	4	3	
Diabetes regimens			NS
OAs	52	51	
Insulin-using	32	31	
Insulin + OA	6	9	
Diet alone	10	9	
Educational level			NS
Elementary	11	13	
High school	51	43	
Beyond high school	38	44	
English primary language			NS
Yes	71	78	

Data are means ± SD or %. The preclinical path was from June 1996 to 24 August 1997, and the postclinical path was from 25 August 1997 to April 1998. *Obtained from administrative data base. OA, oral agent.

Diabetes self-care information and instruction. Patients were asked nine questions about diabetes self-care information and instructions they received in the hospital. Before the introduction of the type 2 clinical path, 69% of the patients reported receiving dietary information about their diabetes, 68% reported receiving instructions for monitoring their BG, and 60% reported receiving written dietary instructions. Only 54% of the patients reported receiving an explanation of their diabetes treatment plan before discharge. Of the insulin-using patients, 60% said they had received instructions on insulin injection technique, and 47% reported receiving instructions on drawing up and mixing insulin. Of the patients taking oral agents, 58% reported receiving instructions about the action and timing of their pills in relation to meals. When asked whether someone on the hospital staff had told them what diabetes danger signals to watch out for after discharge, only 44% said they had received advice. We were unable to compare pre- and postintervention survey data by averaging responses in each time period because the preintervention period did not provide a uniformly stable baseline. When we plotted responses for each question by month and performed linear regression analysis to estimate slopes for these trend lines, we found that the preintervention slopes were negative in the preintervention period in six of nine cases. In all cases, the postintervention slopes were positive and greater than the preintervention slopes, but none of the differences between the pre- and postintervention slopes were different from zero at the level of 5% to establish statistical significance.

Knowledge about diabetes. Although there was no patient education program or intervention provided on the units, questions about target BG ranges and causes of hyperglycemia and hypoglycemia were also assessed in the patient survey. We found that 60% of patients knew their target BG range preintervention compared with 62% postintervention. When asked to indicate which of several patient actions would lead to high blood sugars, 39 and 34% of patients pre- and postintervention, respectively, either chose a wrong answer or said they did not know. For causes of hypoglycemia, 47 and 43% chose a wrong answer or did not know. Despite these data demonstrating basic and important deficits of diabetes knowledge in 40% of the patients surveyed, 72 and 74% of patients pre- and postintervention, respectively, rated their confidence level in managing their diabetes treatment plan as very confident.

CONCLUSIONS — Diabetes is an important and commonly associated secondary diagnosis for hospitalized patients. However, few studies have examined the quality of diabetes care received when patients are hospitalized for other conditions (8,9), and there are only recommendations (17) and no widely recognized standards of care for diabetes in this setting. The approach has been to maintain glucose levels in ranges found to prevent hypoglycemia, excess catabolism, ketoacidosis, and hyperosmolarity (17,18) and then leave most other diabetes care processes to the ambulatory setting. Because on any given day in a hospital there are large numbers of patients with diabetes as a comorbidity, we assessed broad-based quality improvement interventions designed to help routine hospital staff focus on diabetes care received by hospitalized patients. Specifically, we assessed whether these interventions would improve diabetes-related clinical processes and short-term outcomes. Other studies have been narrowly focused on patients with a principal diagnosis of diabetes who were admitted for metabolic control (19,20); these studies measured the impact of a diabetes team or endocrinologist on hospital length of stay as the primary outcome (10,19,20) while providing little information about clinical outcomes. Our interventions were associated with a decreased frequency of severe and prolonged hyperglycemia and a decreased frequency of nosocomial infections. We also observed that patients frequently reported lack of self-care instructions for diabetes before discharge and that they commonly had easily identifiable diabetes knowledge deficits. These data demonstrate that there are multiple opportunities to improve diabetes care when patients with diabetes are hospitalized for other conditions.

Other noninterventional studies found inadequate glucose control for hospitalized patients with diabetes as a comorbid condition. One study examined the use of sliding scale insulin and found that 23% of the medical patients had at least one capillary BG (CBG) CBG $\leq$60 mg/dl, and 40% had at least one CBG $\geq$300 mg/dl (21). In a second study ~50% of coronary artery surgery patients had perioperative BG levels >230 mg/dl (8). Using a combination of laboratory and CBGM results, we documented that 29% of the patients in our chart abstraction sample had prolonged hyperglycemia (at least three consecutive BG levels >250 mg/dl) or severe hyperglycemia (at least one BG >400 mg/dl). This frequency decreased significantly postintervention to 16.6% without a statistically significant increase in hypoglycemia. Although our clinical path recommended a target BG range of 100–200 mg/dl, only 24 and 29% of the patient sample pre- and postintervention, respectively, had BG levels maintained within this range. These data suggest that our interventions successfully focused staff attention on treatment and prevention of the highest glucose levels. However, the frequencies of patients with glucose levels in ranges still having potential for adverse consequences (e.g., diabetic ketoacidosis, other fluid and electrolyte abnormalities [22–23], infection [24], or hypoglycemia [25–27]) remained relatively high.

Our observation that the frequency of patients with nosocomial infections decreased in the postintervention period supports an increasing body of literature demonstrating that glucose control during episodes of hospitalization for other conditions is associated with decreased infectious complications. Recent nonrandomized prospective studies have shown that early postoperative hyperglycemia was a predictor for sternal wound infections after cardiac surgical procedures (6,7) and nosocomial infections after various surgical procedures (5,8). As yet, there are no randomized trials of intensive versus usual glucose management in surgical settings.

The Diabetes and Insulin-Glucose Infusion in Acute Myocardial Infarction (DIGAMI) study was a randomized controlled study of the effect of intensive insulin treatment on mortality and morbidity in patients hospitalized with diabetes and acute myocardial infarction (10,11). The DIGAMI study consisted of insulin-glucose infusion administered acutely followed by intensive subcutaneous insulin management for at least 3 months, and it showed a significant effect on mortality at 1 year (10) that was still present at 3.5 years (11), but it showed no effect on immediate survival. Long-term mortality was predicted by the severity of the glucose state at the time of hospital admission (28). These data suggest that intensification of ambulatory diabetes control resulting from a patient's randomization to the intensive in-hospital treatment arm was a factor, and they provide support for identifying those patients in need of intensification of their diabetes control by measuring HbA_{1c} levels when patients are hospitalized for other conditions. Although a nonrandom sample of patients had HbA_{1c} levels measured at the time of hospitalization in our study, both pre- and postintervention mean levels were above 8%, a level at which intensification of diabetes therapy is recommended (29). Recent cost-effectiveness analysis of data from the DIGAMI study showed a gain in life-years at an acceptable level of increased cost for the intensive insulin patients (30), and those increased costs were largely incurred from longer hospitalizations for institution of multidose insulin.

Lack of diabetes self-care instructions before discharge was commonly reported by patients in this study. Although we observed a reversal of negative trends in six of nine self-care items and increased the rate of positive responses in all subjects postintervention, none of the changes reached conventional levels of statistical significance. The short duration of postintervention data collection, an unstable baseline of practice, relatively small numbers of observations, and large variations associated with the regression slope estimates may have hampered our ability to demonstrate a definitive impact. We found that 45% of the patients surveyed reported they had diabetes for >10 years, yet ~40% did not know their recommended target BG range and had important readily identifiable knowledge deficits. These data suggest that hospitalizations for other conditions offer important episodes of care for hospital staff to identify deficits in diabetes knowledge and self-care and to stratify patients so that these deficiencies can be addressed.

There are some important limitations to the quasi-experimental design of our study. First, only associative relationships—not causal ones—can be made between our interventions and the observed outcomes. Second, the rapidly changing health care environment may have interfered with our ability to detect changes caused by temporal changes in practice that were beyond our control and that affected hospital practice during the time frame of the study. Third, because this was a "real-world" study, our data were practice-generated and not generated by investigators using a strictly enforced and adhered-to protocol. Fourth, this study took place at a single institution, and thus we were unable to prospectively compare our outcomes with a control setting uncontaminated by exposure to the interventions implemented. Finally, the results could have been influenced by regression to the mean. For example, patients with a diagnosis of diabetes who denied having diabetes when contacted were excluded from the survey. This could have resulted in better results for patient knowledge and frequency of self-care instruction than that which might have otherwise been seen had these patients not been excluded. Despite these limitations, we believe that our findings are important and generalizable. Similar findings were reported by the University HealthSystem Consortium in a multi-institutional study of inpatient diabetes management of patients admitted for acute myocardial infarction, coronary artery bypass graft, and pneumonia at 24 sites (31). They found that 24% of the patients maintained BG levels between 60 and 250 mg/dl during their hospitalization and that rates of patient-reported self-care instruction were 36–64%, with variation across institutions.

In conclusion, there were 3,375,000 hospitalizations with diabetes as a secondary diagnosis, accounting for 9.5% of all discharges in the 1997 National Inpatient Sample (4). Thus, there is a large potential to impact short- and long-term outcomes of care for people with diabetes when they are hospitalized for other conditions. Broad-based interventions and standards of care directed at routine hospital staff will be required. We have demonstrated the feasibility of a broad-based effectiveness trial, and we have shown that outcomes can be improved. Future multicenter randomized studies of effectiveness should be considered. This will require participation of multiple stakeholders to develop and test hospital-based strategies that will improve glycemic control, identify self-care and knowledge deficits, evaluate the status of preventive screening, diagnose diabetes, and communicate results along the continuum of care.

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