Potential Short-Term Economic Benefits of Improved Glycemic Control

A managed care perspective

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OBJECTIVE — There are limited data relating glycemic control to medical costs among patients with diabetes. The goal of this study was to examine the potential impact of improved glycemic control on selected short-term complications of diabetes and associated costs in a managed care setting.

RESEARCH DESIGN AND METHODS — Using a retrospective cohort design and automated databases from 1 January 1994 to 30 June 1998, adult members of the Fallon Clinic who were diagnosed with diabetes were identified and assigned to one of three study groups based on each patient's mean HbA_{1c} level: good control (<8%), fair control (8–10%), and poor control (>10%) groups. Inpatient (hospital or skilled nursing facility) admissions for selected acute (short-term) complications, represented by selected infections, hyperglycemia, hypoglycemia, and electrolyte disturbances, and the associated medical charges were evaluated across the three HbA_{1c} groups. Multivariate analyses were used to control for differences in several potential confounding factors among the study groups. All findings were expressed on a 3-year basis.

RESULTS — Of 2,394 patients with diabetes, ~10% (251) had at least one inpatient stay for a short-term complication, accounting for 447 admissions. Over 3 years, the adjusted rate of inpatient treatment ranged from 13 per 100 patients with good glycemic control to 16 per 100 patients with fair glycemic control and 31 per 100 patients with poor glycemic control ($P < 0.05$). The corresponding mean adjusted charges were approximately $970, $1,380, and $3,040, respectively. Among the 30% of the study population with long-term diabetic complications, the results were more marked; the adjusted admissions per 100 patients (mean charges) were estimated to be 30 ($2,610), 38 ($3,810), and 74 ($8,320) over 3 years for patients with an HbA_{1c} of <8, 8–10, and >10%, respectively.

CONCLUSIONS — In typical practice, better glycemic control is associated with a reduced rate of admission for selected short-term complications and, therefore, reduced medical charges for these complications over a 3-year period. The potential short-term economic benefits are important to consider when making decisions regarding the adoption and use of new interventions for the management of diabetes.

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Abbreviations: ICD-9-CM, *International Classification of Diseases, Ninth Revision, Clinical Modification.*

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

Findings from the Diabetes Control and Complications Trial show that the strict control of blood glucose through intensive therapy in patients with type 1 diabetes may reduce the development and progression of long-term complications (1). Likewise, similar benefits of tight glycemic control also appear to accrue in patients with type 2 diabetes (2,3). An economic model based on these clinical findings suggests that intensive life-long treatment strategies may be cost-effective, with a cost per quality-adjusted life-year gained of approximately $16,000 (4).

However, many of the benefits of tight glycemic control accrue over fairly long periods of time, because it takes many years for complications such as retinopathy, renal disease, and neuropathy to develop. Consequently, economic models and evaluations of the costs of diabetes have almost exclusively focused on long-term complications (4–8). Less is known about the potential economic effects of improved glycemic control on short-term complications.

A retrospective database analysis by Gilmer et al. (9), based on administrative and laboratory data from a managed care plan, showed that poorer glycemic control, as measured by HbA_{1c} levels, was associated with greater health care costs over a 3-year time period, particularly for patients with hypertension and/or heart disease. Although overall costs were increased, the specific components of the resource use associated with the worsening of glycemic control were not described. In addition, some costs, such as those for lower-extremity amputation, kidney disease, and heart disease, may not be affected by HbA_{1c} levels evaluated over short time intervals.

A more recent database study conducted at Kaiser Permanente of Northern California showed that patients with diabetes had an excess risk of hospitalization, relative to those without diabetes, for several acute complications, including hyperglycemia, hypoglycemia, and cellulitis (10). Moreover, excess hospitalizations were noted for several other potential short-term conditions, such as pneumonia, urinary tract infection, and electrolyte imbalance. To the

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best of our knowledge, there are no data relating the incidence of such short-term complications to the extent of glycemic control among patients with diabetes.

To further explore this issue, we undertook a retrospective database study that focused on the following questions of interest: *1*) How does the likelihood of inpatient admissions for selected short-term complications vary with the level of glycemic control? *2*) What are the cost consequences and the potential savings associated with better control? and *3*) Do these potential cost savings differ for patients with long-term complications of diabetes, such as ischemic heart disease, kidney disease, or retinopathy, versus those without these complications?

RESEARCH AND DESIGN METHODS

— This study was based on a retrospective cohort design and used automated enrollment, medical and pharmacy claims, and clinical laboratory data files from the Fallon Clinic in Worcester, Massachusetts, a multispecialty group clinic with a predominantly managed care patient base. Most of the patients were members of the Fallon Community Health Plan, a health maintenance organization with over 200,000 enrollees.

The study population of interest consisted of adult plan members who had a diagnosis of diabetes between 1 January 1994 and 30 June 1998 and who also had multiple HbA_{1c} values available. These patients were assigned to study cohorts based on their mean levels of HbA_{1c} over this time period. Inpatient stays for specific short-term complications (events) occurring after the first HbA_{1c} test (the index date) through 30 June 1998 were identified and related to the average HbA_{1c} levels to explore variations in medical charges by the degree of glycemic control.

The principal measures of interest included *1*) the proportion of patients with one or more inpatient admissions for short-term complications, *2*) the mean number of such complications per patient, and *3*) the expected costs per patient for these events. Both unadjusted and adjusted analyses were undertaken for the entire study population and stratified according to whether patients had long-term complications of diabetes.

Only patients who met the following eligibility criteria were included in the study: *1*) age 35 years or older, *2*) a diagnosis of diabetes based on the *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM 250.xx) listed on at least two medical claims between 1 January 1994 and 30 June 1998, *3*) at least two HbA_{1c} values measured no more than 18 months apart during this period, and *4*) continuous enrollment in the plan from 1 January 1994 to 30 June 1998. Two claims indicating a diagnosis of diabetes were required to ensure that patients who were evaluated for diabetes, but not diagnosed, were not included in the study cohort. Multiple HbA_{1c} values were required to help ensure that patients were not being screened for diabetes periodically but were likely to have the diagnosis and to require monitoring of glycemic control.

Patients were assigned to study cohorts based on the mean of all HbA_{1c} values available during the study period as follows: good control (<8%), fair control (8–10%), and poor control (>10%).

Data sources

The patient enrollment file included age and sex, as well as a history of all the dates of enrollment and disenrollment from the plan. The inpatient claims file included the admission and discharge dates, a primary diagnosis (in ICD-9-CM format), up to two secondary diagnoses, and the procedures performed. Outpatient claims provided details on the date of service, the type of service, and the primary diagnosis (ICD-9-CM). The clinical laboratory file included all HbA_{1c} tests performed and analyzed by a single contract laboratory (CliniTech). The measurement of HbA_{1c} was stable throughout the study period.

Duration of follow-up

The duration of follow-up for each patient was defined as the number of days between the first HbA_{1c} test that occurred on or after 1 January 1994 and the cutoff date for the data files (30 June 1998). The statistical techniques used in this study adjusted for variable follow-up, and our findings were expressed on a 3-year basis.

Study measures

Inpatient admissions for short-term complications. We determined whether each study patient had at least one inpatient admission related to a short-term complication during the study period and the number of such events. These events were defined by an inpatient stay (hospital or skilled nursing facility) with a discharge diagnosis (primary or secondary) in any of the following four groups: *1*) hyperglycemia (ICD-9-CM codes 250.1x–250.3x), *2*) hypoglycemia (250.8x and 251.0x), *3*) selected infections (septicemia, 038.x; pneumonia, 480.x–486.x; kidney infections, cystitis, and urinary tract infections, 590.xx, 595.xx, and 599.0x; cellulitis, 680.xx–682.xx and 686.xx; and bacteremia, 790.7), and *4*) electrolyte imbalance (276.xx).

Cost of inpatient care for short-term complications. The total cost of inpatient care for short-term diabetes-related complications was estimated for each study patient by totaling the charges on each inpatient medical claim, as indicated on the billing data supplied by the health plan.

Assessment of comorbidities

The burden posed by comorbidities may differ among cohorts of patients defined by HbA_{1c} levels and may, thus, confound the relation between HbA_{1c} levels and rates of inpatient treatment for short-term complications. To adjust for this potential problem, we examined whether each patient had a long-term diabetes complication during the study period, defined as any inpatient discharge diagnosis (primary or secondary) that included neurological disease; cardiovascular, cerebrovascular, or peripheral vascular disease; amputation or ulceration; or renal and ophthalmic symptoms. In addition, cancer was included as a separate comorbidity, because its treatment may increase the risk of infection and other complications. We also assessed comorbidity using the Deyo et al. (11) adaptation of the Charlson Index for administrative claims data, excluding diabetes, i.e., the diagnosis of interest in our study population (11,12). Because our findings were nearly identical to those based on chronic diabetic complications and cancer, they are not reported herein.

Statistical analyses

We estimated the proportion of patients with at least one inpatient stay for a short-term complication on both an unadjusted and adjusted basis using individual-level data. For the latter, we estimated the probability of inpatient treatment during follow-up using a binomial regression analysis based on a logistic function, controlling for each patient's follow-up time (expressed in the logarithm of years and censored for the inpatient admissions). The independent variables included the HbA_{1c} group (<8, 8–10, or >10%), age, sex, presence of a long-term diabetes complication, and presence of a cancer diagnosis. A predicted 3-year probability of inpatient treatment was calculated from the logistic function for each patient in each of the HbA_{1c} groups.

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An average 3-year risk was then derived for each HbA_{1c} group.

We also calculated the mean number of admissions for short-term complications on both an unadjusted and adjusted basis. The latter used a Poisson regression, which was well suited for the relatively rare events (13). Each patient's follow-up time (expressed in the logarithm of years but not censored for inpatient admissions) was controlled for in the analysis. The independent variables included the HbA_{1c} group, age, sex, presence of a long-term diabetes complication, and presence of a cancer diagnosis. A predicted 3-year probability was calculated from the Poisson model for each patient in each of the HbA_{1c} groups, and an average 3-year risk was then derived for each HbA_{1c} group. Inpatient stays were evaluated for all patients and stratified by the presence of a long-term diabetic complication.

Finally, we estimated the average cost of inpatient care for short-term complications using least-squares regression, adjusting for the factors listed above. However, no statistical testing was performed on medical charges, because actual costs were unavailable and charges are not easy to generalize from one setting to another. The analyses of data were conducted using SAS Version 7.0 for Windows NT (SAS Institute, Cary, NC).

RESULTS

Patient characteristics

We identified a total of 9,156 plan members who were diagnosed with diabetes between 1 January 1994 and 30 June 1998. A total of 3,475 of these people were excluded because they were not continuously enrolled for the entire study period. In addition, 3,089 people were excluded because they either did not have any HbA_{1c} values or did not have at least two values measured no more than 18 months apart. This left a total of 2,394 diabetic plan members who met our study eligibility criteria and were included in the analysis. The average age of these patients was 63 years, and ~55% were men. Approximately 30% had a long-term diabetes complication, and 2.5% had a cancer diagnosis (Table 1). Over 80% of the population filled prescriptions for diabetes medications during the study.

There were important differences across the three study cohorts defined by average HbA_{1c} levels. For example, patients with poor glycemic control were more likely to have long-term diabetic complications than those with good or fair control. Similarly, the duration of follow-up in the study was longer among patients in the two groups with the highest HbA_{1c} levels. Patients experiencing poorer glycemic control may have had diabetes for a longer amount of time and may have been suffering from long-term complications. These patients, therefore, may have been more closely monitored by their physicians. Finally, the likelihood of treatment with diabetes medications was the greatest in the two groups with the highest HbA_{1c} levels.

Table 1—*Characteristics of the study population by HbA_{1c} category*

Characteristics	HbA_{1c} category (%)			Total
	<8	8–10	>10	
n	725	1,424	245	2,394
Age (years)				
35–49	20.7	23.8	39.6	24.5
50–59	21.9	24.4	25.7	23.8
60–70	40.0	38.8	27.8	38.0
>70	17.4	13.1	6.9	13.7
Mean ± SD	64.8 ± 11.4	63.4 ± 11.4	59.0 ± 11.4	63.4 ± 11.4
Men	57.4	54.4	52.7	55.1
Presence of long-term complications*	28.6	31.9	32.7	31.0
Presence of cancer	3.0	2.2	2.5	2.5
Use of antidiabetic drug therapy	59.3	91.4	96.7	82.2
Duration of follow-up (months)	34.3	42.5	44.0	40.2

Data are % unless otherwise indicated. *Long-term complications include *1*) neurological symptoms; *2*) cardiovascular, cerebrovascular, or peripheral vascular disease; *3*) amputation/ulceration, and *4*) renal and ophthalmic symptoms.

Relation between glycemic control and inpatient admissions

Of the 2,394 patients with diabetes, a total of 251 (~10%) were admitted for the treatment of short-term complications, accounting for a total of 447 inpatient stays. For these admissions, 59% of the qualifying diagnoses were for infections, 21% were for hyperglycemia or hypoglycemia, and 20% were for electrolyte disturbances. There were a total of 4,562 admissions during the study period for any reason.

We found a statistically significant positive relation between the HbA_{1c} group and the likelihood of inpatient admissions for short-term complications on both an unadjusted and adjusted basis (both $P <$ 0.01, based on a test for trend). The latter analysis, which controlled for the differences among the study cohorts in age, sex, presence of cancer, and presence of long-term diabetes-related complications, showed that the proportion of patients admitted for a short-term complication over 3 years increased from 8.5% among patients with good control to 17.8% among those with poor control (Table 2). This statistically significant increase in the likelihood of inpatient treatment was also found in both patient subgroups (those who did not have long-term diabetic complications and those who did); the absolute increase in risk was larger for those with long-term complications.

The average number of admissions for short-term complications followed a similar pattern. On an adjusted basis, the average number of admissions over 3 years was 2.5 times greater among patients with poor glycemic control versus those with good control (i.e., 13 inpatient stays per 100 patients vs. 31 per 100, respectively). Although the increase in the number of inpatient stays across the three HbA_{1c} groups is modest for patients without long-term diabetic complications, the number of inpatient stays is substantially higher among those with such complications, ranging from 30 to 74 per 100 persons. Correspondingly, the average adjusted charges for inpatient treatment for patients with good control was approximately $970 over a period of 3 years compared with $1,380 and $3,040 for those with fair or poor glycemic control, respectively (Table 3). Among the patients with chronic diabetic complications, the results were more marked.

CONCLUSIONS — To explore the potential economic benefits of improved glycemic control, we conducted a retrospec-

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Table 2—*Inpatient stays for short-term complications over a 3-year period*

HbA_{1c} category (%)	All patients		Patients without long-term diabetic complications		Patients with long-term diabetic complications	
	Unadjusted	Adjusted*	Unadjusted	Adjusted†	Unadjusted	Adjusted†
Proportion of patients with one or more inpatient stays for short-term complications						
<8	7.3	8.5	2.5	3.1	19.3	21.2
8–10	11.0	10.7	3.5	3.5	27.1	25.5
>10	16.7	17.8	7.9	8.3	35.0	38.3
Average number of inpatient stays for short-term complications per 100 study patients						
<8	12.4	12.8	3.9	4.6	33.8	30.3
8–10	19.0	15.6	4.3	4.2	50.2	37.9
>10	35.5	30.6	9.1	9.3	90.0	74.2

*Proportion of patients admitted was estimated using binomial regression, while the expected number of admissions was estimated using Poisson regression. Both controlled for age, sex, cancer, chronic diabetic complications, and duration of follow-up, and adjusted to 3 years. The relation between HbA_{1c} category and inpatient stays was significant at $P < 0.01$. †Proportion of patients admitted was estimated using binomial regression, while the expected number of admissions was estimated using Poisson regression. Both controlled for age, sex, cancer, and duration of follow-up, and adjusted to 3 years. The relation between HbA_{1c} category and inpatient stays was significant at $P < 0.01$.

tive study using enrollment, medical claims, and clinical laboratory data for ~2,500 adults with diabetes enrolled in the Fallon Clinic health plan within a recent 4-year period. We found that the likelihood of inpatient admission for selected short-term complications and the average number of such stays increased significantly with higher levels of HbA_{1c}. On an adjusted basis, patients with poor glycemic control had more than double the number of inpatient admissions over a 3-year period than those with good glycemic control 31 vs. 13 per 100 patients, respectively; $P < 0.01$). The largest absolute difference in admission rates occurred in patients who had long-term diabetic complications (30 per 100 patients with good control vs. 74 per 100 patients with poor control; $P < 0.01$). Corresponding average adjusted charges were also lowest among patients with good control and highest among those with poor control.

Our finding that HbA_{1c} levels positively correlate to medical charges in clinical practice was consistent with the study by Gilmer et al. (9), although their data were somewhat older and included all costs regardless of diagnosis. To the best of our knowledge, our study is the first to relate short-term complications to levels of glycemic control. The results from this investigation may be helpful in understanding the potential economic implications of short-term interventions designed to improve glycemic control, such as disease management programs and newer drug therapies.

We acknowledge several limitations of our study. First, although our analyses suggest that a correlation exists between selected short-term complications and the extent of glycemic control, it does not demonstrate that these events could have been avoided. Only intervention studies can establish whether lowering HbA_{1c} levels reduces the costs for acute diabetic complications. Second, the precise diagnoses that could vary with the level of glycemic control on a short-term basis are subject to judgment. In our study, we chose to focus on hyperglycemia, hypoglycemia, and cellulitis, which were all classified as short-term (acute) complications of diabetes in a recent database study by Selby et al. (10). We also included several additional conditions that diabetic patients experience more frequently than nondiabetic patients, including other infections and electrolyte imbalance (10). Further work is required to identify which diagnoses are correlated to glycemic control on a short-term basis.

Furthermore, short-term complications were identified based on selected ICD-9-CM codes that appeared as primary or secondary diagnoses on inpatient bills. In the database used for this study, it was not possible to distinguish acute hospital stays from admissions to skilled nursing facilities. There are also inherent inaccuracies associated with the use of ICD-9-CM diagnosis codes, which may have led us to misestimate the number of events. To address these issues, we conducted a chart review based on samples of two groups of inpatient stays from two randomly selected patient samples. The first group consisted of 69 inpatient stays (~15% of the observed number of events) with a diagnosis of a short-term diabetic complication noted on medical claims for 50 study patients. Of these 69 inpatient stays, 58 (85%) involved admission to an acute-care hospital. The diagnosis data from the discharge summaries, which were completed only for hospital stays, showed that a qualifying discharge diagnosis (i.e., for a short-term event) was listed on 64 (93%) of these admissions. For the second group of inpatient admissions with discharge summaries (n = 29, drawn from 20 patients), which

Table 3—*Average charges per patient for short-term complications*

HbA_{1c} category	All patients		Patients without long-term diabetic complications		Patients with long-term diabetic complications	
	Unadjusted	Adjusted*	Unadjusted	Adjusted†	Unadjusted	Adjusted†
<8	810	970	220	240	2,280	2,610
8–10	1,390	1,380	280	270	3,790	3,810
>10	2,660	3,040	470	580	7,190	8,320

Data are U.S. dollars. *Estimated using ordinary least-squares regression, controlling for age, sex, cancer, chronic diabetic complications, and duration of follow-up, and adjusted to 3 years; †estimated using ordinary least-squares regression, controlling for age, sex, cancer, and duration of follow-up, and adjusted to 3 years.

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did not have a short-term complication noted in the billing data, 12 stays (41%) were found on examination to have a qualifying diagnosis. Therefore, the results of the chart review indicate that we may have underestimated the number of inpatient stays for acute diabetic complications, which suggests that our results may be conservative.

It is possible that some of the inpatient stays we identified as events were not the sole cause for admission or that they could, perhaps, have been incidental findings for patients who were admitted principally for other medical problems. Determining the reasons for admission based on ICD-9-CM discharge diagnoses is fraught with difficulties (14,15). Moreover, to the best of our knowledge, there are no accepted methodologies for apportioning costs among multiple diagnoses. The emphasis that we placed on acute complications may help limit but not eliminate this problem.

Because the frequency of inpatient admissions probably increases with the severity and duration of diabetes, each of which may also be correlated with HbA_{1c} levels, it is possible that our findings are due to residual confounding by these two factors. In this study, we attempted to adjust for the severity of diabetes among the study cohorts by controlling for age, sex, several chronic diabetic complications, and follow-up time. The latter two factors are especially important because they may be a reasonable proxy for the duration of diabetes. Nonetheless, to the extent that we were unsuccessful in these efforts at statistical control, we may have overstated the reduction in costs that may be associated with better glycemic control.

We assessed the occurrence of short-term diabetes-related complications any time after the first observed HbA_{1c} value, because the precise temporal relation between these two factors is uncertain. Moreover, patients were assigned to groups based on their average HbA_{1c} level during follow-up because glycemic control was quite variable and a predefined starting date was not available, given that patients were not required to be newly diagnosed. Randomized studies may be required to better understand the temporal relation between glycemic control, as evaluated by HbA_{1c}, and the occurrence of diabetic complications.

Finally, our findings regarding costs may not be generalizable to all patients with diabetes. Treatment patterns for this disease may differ according to individual physician practice styles, health plan guidelines, and geographical regions. In addition, data on resource costs were not available to us, but rather our analyses relied on charges. It is known that charges often exceed resource costs, but the magnitude of this mark-up differs from one institution to another. However, by reporting our findings in terms of admission rates, other researchers may use our findings in conjunction with their own cost data.

Despite these limitations, this exploratory analysis suggests that in typical practice, better glycemic control is associated with lower inpatient admissions and costs during a 3-year time period. These potential short-term savings in cost are important to consider when making decisions regarding the adoption and use of new interventions for the management of diabetes.

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