Predictors of Health Care Costs in Adults With Diabetes

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OBJECTIVE — The purpose of this study was to assess the impact of baseline A1c, cardiovascular disease, and depression on subsequent health care costs among adults with diabetes.

RESEARCH DESIGN AND METHODS — A prospective analysis was performed of data from a patient survey and medical record review merged with 3 years of medical claims. Costs were estimated using detailed data on resource use and Medicare payment methodologies. Generalized linear models were used to analyze costs related to clinical predictors after adjusting for demographic and socioeconomic factors.

RESULTS — In multivariate analysis of 1,694 adults with diabetes, 3-year costs in those with coronary heart disease (CHD) and hypertension were over 300% of those with diabetes only ($46,879 vs. $14,233; $P < 0.05$). Depression was associated with a 50% increase in costs ($31,967 vs. $21,609; $P < 0.05$). Relative to those with a baseline A1c of 6%, those with an A1c of 10% had 3-year costs that were 11% higher ($26,408 vs. $23,873; $P < 0.05$). Higher A1c predicted higher costs only for those with baseline A1c >7.5% ($P = 0.015$).

CONCLUSIONS — In adults with diabetes, CHD, hypertension, and depression spectrum disorders more strongly predicted future costs than the A1c level. Concurrent with aggressive efforts to control glucose, greater efforts to prevent or control CHD, hypertension, and depression are necessary to control health care costs in adults with diabetes.

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Adults with diabetes experience significantly higher health care costs than sex- and age-matched adults without diabetes (1–5). This increased use of resources is related to a broad range of factors including higher outpatient costs, higher pharmaceutical costs, higher rates of hospitalization, and longer hospital stays during admissions related to many diagnoses (6). Cardiovascular disease accounts for about 70% of deaths in adults with diabetes, and several studies show that cardiovascular disease is a major driver of costs in diabetes patients (7–10).

A substantial body of research on diabetes management has focused on glycemic control. Large randomized controlled trials have shown that aggressive management of A1c reduces the risk of microvascular complications in patients with type 1 and type 2 diabetes (11,12). In earlier work, we examined medical charges related to A1c and found that after controlling for demographics and cardiovascular disease, charges rose by ~30% as A1c increased from 6 to10%. In the same study subjects, after controlling for A1c, sex, and age, those with heart disease and hypertension had charges over 400% of those with diabetes alone. At the time, we concluded that cardiovascular disease was a stronger predictor of resource use in adults with diabetes than was the level of glycemic control (8).

Our previous analysis was conducted using data from 1992 to 1996, in an era when glycemic control was generally worse than it is now. In recent years, A1c levels have improved with the increased availability of more effective pharmacologic agents including new insulins, metformin, and thiazolidinediones, with marked A1c improvement noted in some care settings (13–16). Similarly, more effective pharmacologic strategies have been developed and disseminated for the primary and secondary prevention of cardiovascular disease, and studies have shown that the use of statins (17,18), fibrates (19), ACE inhibitors (20), and more aggressive control of hypertension (21,22) reduce cardiovascular morbidity and mortality in those with diabetes. Data show that A1c levels tend to rise with duration of diabetes (23), and the prevalence of depressive symptoms appears to be increased among those with diabetes (24) due to several factors (25–27). This study provides an analysis of recent data and uses a more extensive set of predictive factors that may impact the relationship of baseline A1c on costs including duration of diabetes, depression, income, and education level. We hypothesized that higher levels of baseline A1c, longer duration of diabetes, and presence of cardiovascular disease and depression would be associated with increased costs. We had no expectations regarding socioeconomic factors.

RESEARCH DESIGN AND METHODS

— This prospective study was conducted at HealthPartners, a Minnesota health plan with over 600,000 members. Persons with diabetes were identified from administrative databases using data from calendar year 1999. A diagnosis of diabetes was assigned to indi-

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Abbreviations: CHD, coronary heart disease; DRG, diagnostic related groups; RVU, relative value unit.

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

viduals who had either one inpatient or two outpatient encounters with diabetes-specific diagnoses from ICD-9 (250.xx, 357.2, 362.01, 362.02, 366.41) or who filled a prescription for anti-hyperglycemic medications (insulin, sulfonylurea, biguanide, thiazolidinedione, meglitinide, other secretogogue, or α-glucosidase inhibitor) in a 12-month period. Similarly, individuals were identified as having coronary heart disease (CHD) if they received at least one inpatient or two outpatient ICD-9 codes for CHD (410–414, 429.2, 428.0) or a relevant procedure code (CPT4 code between 33510 and 33545 or 36822 and ICD-9 codes between 36.0 and 36.29 or between 36.9 and 36.99) in a 12-month period. These identification methods have been previously validated. The diabetes identification method has estimated specificity of 0.99, sensitivity of 0.91, and positive predictive value of 0.94, and the CHD identification method has an estimated specificity of 0.99, sensitivity of 0.89, and positive predictive value of 0.79 (28).

Patients with diagnosed diabetes were randomly selected to receive a patient survey. A patient survey was sent to 4,780 adults with diabetes and returned by 2,832, for a response rate of 59.2%. The patient survey included over 140 questions examining multiple domains including history of chronic disease, health behaviors and self-management skills, and socioeconomic status. Of the 2,832 survey respondents who reported having diabetes, 2,117 (74.8%) gave written informed consent for a medical record review, which was completed for 2,077 (98.1%). We excluded 383 persons (18.4%) who did not have an A1c value recorded in the baseline period. Thus, the analysis sample included 1,694 persons with diabetes. Compared with those who were excluded, those in the analysis sample were equally likely to be female (47.0 vs. 46.1%; $P = 0.7$) but were older on average (62.6 vs. 57.8 years; $P < 0.001$) and were more likely to have CHD (24.0 vs. 19.9%; $P = 0.003$).

Diabetes and CHD were classified based on automated medical record data as described above. Hypertension, dyslipidemia, and depression spectrum disorders were classified based on self-report from the patient survey. Patients were asked, "Have you ever been told by a health professional that you have (high blood pressure or hypertension/high blood cholesterol/depression)?" Duration of diabetes was calculated using the answer to the question: "Approximately how old were you when you were first told you had diabetes?" Education and income were determined by self-report from the patient survey using standard survey items (29). We designated individuals who reported their highest educational attainment as less than high school as having a low education level. Individuals reporting household incomes as <$25,000 were designated as low income. Missing data from the survey-based measures were imputed using missing value multivariate regressions (30). A pharmacy coverage indicator was created from enrollment information to designate individuals with comprehensive pharmacy coverage under HealthPartners for the entire study period in which they were enrolled.

The dependent variable for this analysis was costs from the perspective of a health insurer. Claims and encounter data were obtained for study subjects for calendar years 1999–2002. Patients received care in 84 clinics within 18 medical groups that had contracts with HealthPartners to provide services to its members. Forty-three percent of study subjects were enrolled in a medical group with a fully capitated contract, 29% under a fee-for-service contract, and 28% under a contract that was partially capitated and partially fee-for-service. In order to avoid pricing bias resulting from use of fee-for-service claims versus encounter data (from capitated medical groups) and from varying fee schedules for fee-for-service claims, we determined to use a consistent method for pricing the service data at payment rates standard for Medicare.

Inpatient admissions were priced using diagnostic related groups (DRGs) and simulated outlier payments. Diagnostic and procedure data from the inpatient stay were combined with each patient's age and sex to calculate a DRG for the inpatient stay. DRGs were then priced at the national average Medicare rate for 2002. The DRG payment methodology allows for outlier payments for particularly expensive hospital stays. We simulated a DRG outlier payment by adding 60% of inpatient charges above the DRG charge threshold. Costs for 34 admissions (0.6%) were adjusted for outlier payments.

Costs for physician services in the hospital, outpatient hospital, and outpatient clinic settings as well as costs for all other outpatient services such as nursing services, laboratory services, and dialysis were priced using relative value units (RVUs). Each service was assigned an RVU based on the procedure code recorded. RVUs were then priced at $36.20, the national average Medicare allowable amount per RVU in 2002. We used analyses provided by the Department of Health and Human Services in a report to the President to determine the amount paid, on average, by large health plans aggressively negotiating drug prices for pharmaceuticals and supplies, which we estimate to be 68% of the average wholesale price (31). Stays at skilled nursing facilities were priced at $320 per day, the mean per diem payment during the study period.

Total costs were calculated as the sum of costs from claims or encounters generated from the day of the first A1c measurement until the first of the date of disenrollment, death, or the study end date, which was 31 December 2002. Sixty-five individuals (3.3%) died during the study period, and 1,368 (81%) remained enrolled throughout the study period. Three-year cost was calculated as total cost divided by the number of days enrolled from the first A1c measurement until disenrollment, death, or the end of the study multiplied by 1,095.75 (3×365.25).

Generalized linear regression was used to estimate the relationship between 3-year costs and baseline A1c level, CHD, hypertension, dyslipidemia, and depression while controlling for demographics (age and sex), duration of diabetes, pharmacy coverage, income, and education (8). A1c was analyzed as two covariates: one for A1c levels >7.5% and another for A1c levels <7.5%. Costs were specified as having a γ distribution, and the link function was logistic. Thus, the estimated regression coefficients are on the log scale, and their direction and magnitude provide an indication of their effect: positive (negative) values indicate increased (decreased) costs, with the cost multiplier being approximately the exponential of the regression coefficient. Observations were weighted by each individual's duration in the study. Standardized estimates of costs by the level of baseline A1c were calculated by estimating the average cost across all individuals as if they had that level of baseline A1c (baseline A1c was used for

Table 1—*Study sample characteristics* (n = *1,694*)

Variable	
Demographic	
Female sex	796 (47.0)
Age (years)	62.6 ± 12.8
A1c	7.5 ± 1.5
Duration of diabetes	12.0 ± 12.7
Comorbid chronic disease	
CHD	407 (24.0)
Hypertension	1,111 (65.6)
Lipids	1,052 (62.1)
Depression	413 (24.4)
Socioeconomic	
Low income	325 (19.2)
Low education	115 (6.8)
Enrollment	
Years enrolled	2.6 ± 0.4
Pharmacy coverage	1,326 (78.3)
Health care costs	
3-year costs	23,948 ± 31,003
3-year costs (25th percentile)	7,577
3-year costs (50th percentile)	14,535
3-year costs (75th percentile)	30,033

Data are mean, means ± SD, or *n* (%).

the analysis regardless of subsequent A1c values). Costs related to cardiovascular disease and depression were calculated similarly. Costs by A1c stratified by cardiovascular disease and depression were calculated as the average predicted cost across people with the specific condition standardized to the particular A1c value.

RESULTS — Population characteristics are summarized in Table 1. The study sample was 47% female with a mean age of 63 years. Mean A1c was 7.5%, and mean duration of diabetes was 12 years. There were high rates of cardiovascular disease: 24% were identified as having CHD and 66% reported having hypertension. The rate of reporting dyslipidemia was 62%, while 24% self-reported depressive symptoms, 19% were in low-income households, and 7% had less than a high school education. Mean enrollment from the first A1c until the end of observation was 2.6 years, and 78% had pharmacy coverage throughout the study period. Mean 3-year health care cost was $23,948 (SD $31,003). Median cost was $14,535 (interquartile range $7,577–$30,033).

Table 2 shows results from the regression analysis. The main variable of interest, A1c level, was significantly associated with cost when A1c was >7.5% (P = 0.015) but insignificant for A1c values <7.5% (the reference group, A1c = 7.5%, had both A1c covariates set to zero). CHD ($P < 0.001$), hypertension ($P < 0.001$), and depression ($P < 0.001$) were also associated with increased cost. Dyslipidemia and duration of diabetes were not significantly associated with cost. Those with pharmacy coverage under HealthPartners cost more than those without coverage, although there were not significant differences in nonpharmacy costs ($P = 0.16$).

Costs by level of A1c as well as presence of CHD and hypertension are shown in Table 3. Higher baseline A1c levels are associated with greater costs among persons with higher initial levels of A1c. Those with CHD, hypertension, and depressive symptoms also had greater costs.

Table 2—*Multivariate regression analysis of 3-year cost* (n = *1,694*)

Variable	Coefficient	SE	Z-stat	*P*	95% CI
Female	0.0802	0.0900	0.89	0.373	−0.0963 to 0.2567
Age 62 years	0.0174	0.0031	5.57	0.000	0.0113–0.0235
(Age 62 years) ^2	−0.0003	0.0001	−2.22	0.026	−0.0006 to 0.0000
Female × (age 62 years)	−0.0097	0.0041	−2.37	0.018	−0.0177 to −0.0017
[Female × (age 62 years)]^2	0.0003	0.0002	1.29	0.196	−0.0002 to 0.0008
A1c 7.5% and A1c >7.5%	0.0534	0.0220	2.43	0.015	0.0103–0.0966
A1c 7.5% and A1c <7.5%	−0.0218	0.0431	−0.51	0.613	−0.1063 to 0.0627
Duration of diabetes (12 years)	0.0019	0.0027	0.71	0.478	−0.0034 to 0.0072
CHD	0.7639	0.0646	11.83	0.000	0.6374–0.8905
Hypertension	0.2233	0.0471	4.74	0.000	0.1310–0.3156
Lipids	0.0951	0.0597	1.59	0.111	−0.0219 to 0.2122
Depression	0.3043	0.0709	4.29	0.000	0.1654–0.4432
Pharmacy coverage	0.3995	0.0714	5.59	0.000	0.2594–0.5395
Low income	0.1196	0.0699	1.71	0.087	−0.0175 to 0.2566
Low education	−0.0265	0.0917	−0.29	0.773	−0.2062 to 0.1532
Constant	9.1013	0.0985	92.37	0.000	8.9081–9.2944

The dependent variable is an estimate of 3 years of health care costs. The generalized linear regression uses a γ distribution with a log-link function and a covariance matrix that is robust to heterscedasticity and allows for clustering of variance by primary care clinic. Observations are weighted by length of enrollment.

Table 3—*Standardized cost differentials for 1% changes in A1c for 1,694 adults with diabetes over a 3-year period*

Patient classification	Changes in A1c levels				Overall*†
	10 to 9%*	9 to 8%*	8 to 7%	7 to 6%	
Diabetes with heart disease and hypertension	2,675 ± 1,164	2,536 ± 1,048	726 ± 953	−1,001 ± 2,000	46,879 ± 2,388
Diabetes with heart disease	2,078 ± 900	1,970 ± 811	564 ± 745	−778 ± 1,547	36,577 ± 2,410
Diabetes with hypertension	1,130 ± 498	1,071 ± 449	306 ± 400	−423 ± 849	19,805 ± 859
Diabetes without heart disease or hypertension	805 ± 353	763 ± 318	218 ± 287	−301 ± 603	14,233 ± 548
Diabetes with depression	1,818 ± 793	1,723 ± 714	493 ± 643	−680 ± 1,365	31,967 ± 1,961
Diabetes without depression	1,231 ± 539	1,167 ± 485	334 ± 439	−461 ± 921	21,609 ± 641
Overall	1,374 ± 599	1,303 ± 539	373 ± 488	−514 ± 1,029	

Data are means ± SE. *$P < 0.05$. †For statistical comparison, patients with heart disease and/or hypertension are compared with patients without heart disease or hypertension; patients with depression are compared with patients without depression.

Overall, the cost differential between those with A1cs of 6 and 10% was $2,536 ($23,873 vs. $26,408; $P < 0.05$). This differential was greatest for those with diabetes, hypertension, and CHD ($4,935) and least for those without hypertension or CHD ($1,486). Total costs were greater for individuals with CHD and hypertension ($46,897) compared with those without hypertension or CHD ($14,233) ($P < 0.05$). Individuals reporting depression cost $10,358 more than those without depression ($31,967 vs. $21,609; $P < 0.05$).

CONCLUSIONS — These results indicate that CHD, hypertension, depression, and A1c levels all are significant independent predictors of health care costs in adults with diabetes after controlling for age, sex, duration of diabetes, educational level, and income. This study provides confirmation and valuable extension to previous work on clinical predictors of costs in adults with diabetes (1,3,6,8,32,33).

Congruent with previous findings, A1c continues to be a significant predictor of costs, although cardiovascular disease continues to be an even stronger predictor. In previous work, those with diabetes plus CHD and hypertension had costs 400% above those with diabetes alone. The somewhat smaller effect of cardiovascular disease in this study compared with our previous study may have resulted from our method of estimating costs (rather than charges) or could be related to improved control of A1c and major cardiovascular risk factors compared with the early 1990s. For example, mean A1c values have declined from 8.3% in our previous study to 7.5% in this study. Studies have also documented increased rates of aspirin use and improved blood pressure and lipid control over this period of time in this study population (14). Specifically, aspirin use increased from about 30% in 1995 to about 60% in 2001, while mean LDL in those with diabetes fell from about 134 mg/dl in 1995 to 106 mg/dl in 2001. Trends toward better blood pressure control have also been observed, with a drop in mean systolic blood pressure of ~1 mm/year from 1999 to 2002 in the study population (34). While A1c level remains a significant predictor of future total costs, the cost differential related to level of A1c was less dramatic than what was noted in our previous study. Moreover, when A1c was <7.5%, it was not a significant predictor of future costs. This last observation is especially interesting in light of suggestions from the American Association of Clinical Endocrinologists that an A1c <6.5% may be appropriate for some patients (35).

A number of limitations must be considered in interpreting these data. First, the generalizability of our results is limited by the geographic and demographic characteristics of the study population. This limitation is mainly related to ethnicity: HealthPartners members (and Minnesota residents) are less likely to be Latino, African American, or Asian, compared with a nationally representative population of patients with diabetes. Second, there may be unmeasured variables that are related to both clinical predictors and costs. However, this study is stronger in this regard than most previous work on the topic because we measured and controlled for demographic and socioeconomic factors as well as duration of diabetes and several important chronic conditions. Finally, the results are interpretable only at the level of groups of patients. For an individual patient, clinical care should be customized to maximize benefits with consideration of factors such as age, presence of cardiovascular disease, physiological response, readiness to change, and availability of pharmacy benefits (36,37).

While this study demonstrates that CHD, hypertension, depression, and A1c level are predictors of future costs in adults with diabetes, these data do not prove that their treatment will reduce costs. Other studies address the cost-effectiveness of intensive management of hypertension, dyslipidemia, and hyperglycemia in adults with diabetes. Analyses by the Centers for Disease Control and Prevention suggest that intensive management of glycemic control and dyslipidemia is generally less cost-effective than intensive hypertension control, which is cost-saving (38). Improved A1c, blood pressure, and lipids are consistently associated with better clinical outcomes in multiple clinical trials (17,39,40). Although clinical trial data suggest that aggressive management of hypertension and dyslipidemia significantly reduces major cardiovascular events (18,20,41,42), clinical trials have not yet shown a reduction in cardiovascular events from aggressive management of A1c (12). Clinical trials also suggest that resources devoted to more intensive A1c control (e.g., a move in A1c from 8 to <7%) return less on the investment than resources devoted to more intensive blood pressure control (a drop of 10

mmHg from 156 to 146 mmHg) (43) or more aggressive lipid control (44). In an observational study, only those with A1c >10% who reduced A1c substantially had lower subsequent costs relative to those who did not improve, while changes in A1c level for the large majority of the diabetes population did not affect their subsequent costs (32).

Until recently, most health plans and medical groups that attempt to improve diabetes care have focused primarily on improving A1c (45). This strategy makes clinical and economic sense when median A1c is high (A1c >8%). However, once median A1c improves to <8%, considerable evidence suggests that other factors (primary and secondary prevention of CHD, control of blood pressure, control of lipids, smoking cessation) may provide more clinical benefits at less cost on a population basis (36,46). The significance of these data and the need for greater focus on CHD prevention and control have received insufficient attention.

Despite the limitations of this study, the results are interesting and valuable in that they confirm the importance of A1c as a predictor of costs while placing this observation in a broader perspective. Although A1c remains an important clinical predictor of costs, several other clinical predictors including CHD, hypertension, and depressive symptoms are equal or more important predictors of cost. While continuing to aggressively control A1c, clinicians should place greater emphasis on prevention or control of CHD, hypertension, and depressive symptoms.

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