Impact of Office Systems and Improvement Strategies on Costs of Care for Adults With Diabetes

TODD P. GILMER, PHD[1]
PATRICK J. O'CONNOR, MD, MPH[2]
WILLIAM A. RUSH, PHD[2]
A. LAUREN CRAIN, PHD[2]
ROBIN R. WHITEBIRD, PHD[2]
ANNE M. HANSON, BA[2]
LEIF I. SOLBERG, MD[2]

OBJECTIVE — To assess the impact of organizational features and improvement strategies of primary care clinics on health care costs of adults with diabetes.

RESEARCH DESIGN AND METHODS — This study included a prospective cohort study of 1,628 adults with diabetes in a large, health care organization receiving care in 84 clinics within 18 medical groups. Data from surveys of patients, clinic medical directors and managers, and medical record reviews were merged with 3 years of medical claims. Costs were estimated using health plan data on resource use and common Medicare payment methodologies. Generalized linear regression models were used to analyze costs related to clinic characteristics, adjusting for individual patient comorbidity, demographic, and socioeconomic factors.

RESULTS — Clinics with regular clinician meetings to discuss patient care problems and clinics that used diabetes registries to prioritize patients based on cardiovascular risk were associated with lower 3-year costs: −$3,962 ($P = 0.002$) and −$2,916 ($P = 0.019$), respectively. The use of databases to monitor lab results was associated with higher costs ($2,439, $P = 0.038$). Quality improvement strategies focused on resource use related to diabetes care (−$2,883, $P = 0.017$) or heart disease care (−$3,228, $P = 0.014$) were associated with lowered costs, whereas quality improvement strategies that emphasized pharmacy use for patients with heart disease ($3,059, $P = 0.029$) or depression ($2,962, $P = 0.038$) were associated with increased costs.

CONCLUSIONS — Several organizational features of primary care offices were significant predictors of future health care costs for adults with diabetes. The mechanism by which such factors affect costs of care and the relationship of costs to clinical outcomes merits further evaluation.

Diabetes Care 29:1242–1248, 2006

Large-scale clinical trials in adults with diabetes have demonstrated consistent benefits in morbidity and mortality for patients who achieve evidence-based levels of HbA_{1c} (A1C), blood pressure, and LDL cholesterol (1–4). However, achieving these clinical goals in routine practice settings remains a challenge. Wagner and colleagues (5–8) have advocated the use of a coherent chronic care model to improve care, and there is accumulating evidence that patient activation and the use of selected office systems to support chronic disease care is related to improved quality of care. Very little attention has been given to the impact of these office systems and improvement strategies on the cost of diabetes care. Continuing increases in medical expenditures, combined with research indicating a tenuous relationship between higher costs of care and higher quality of care, underscore the importance of considering both quality and costs when developing care improvement strategies (9,10). It has frequently been assumed that improved diabetes care in the outpatient setting will lead to overall reductions in costs through reduced rates of hospitalizations for diabetes complications such as heart attacks, strokes, infections, and renal failure (11). However, many innovations designed to improve the quality of care may contribute to increased costs, especially since underuse of services is a major component of low quality of care (12). In this study, we hypothesize that some office system and improvement strategies will significantly increase future health care costs of patients with diabetes, while others may significantly decrease them after control of patient characteristics such as age, sex, education, income, insurance coverage, duration of diabetes, and cooccurring chronic diseases.

RESEARCH DESIGN AND METHODS

This prospective study was conducted at HealthPartners, a Minnesota health plan with over 600,000 members. People with diabetes were identified from administrative databases using data from calendar year 1999. A diagnosis of diabetes was assigned to individuals who had either one or more inpatient or two or more outpatient encounters with diabetes-specific diagnoses from the ICD-9 (250.xx, 357.2, 362.01, 362.02, or 366.41) or who filled a prescription for antihyperglycemic medications (insulin, sulfonylurea, biguanide, thiazolidenedione, meglitamide, other secretogogue, or α-glucosidase inhibitor) in a 12-month period. Similarly, people were identified as having chronic heart disease (CHD) if they received at least one inpatient or two outpatient ICD-9 codes for CHD (410–414, 429.2, or 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

From the [1]Department of Family and Preventive Medicine, University of California, San Diego, California; and the [2]HealthPartners Research Foundation, Bloomington, Minnesota.

Address correspondence and reprint requests to Todd P. Gilmer, PhD, Associate Professor, Department of Family and Preventive Medicine, University of California, San Diego, 9500 Gilman Dr., La Jolla, CA 92093-0622. E-mail: tgilmer@ucsd.edu.

Received for publication 26 September 2005 and accepted in revised form 20 February 2006.

Abbreviations: CHD, chronic heart disease; DRG, diagnostic related group; EMR, electronic medical record; RVU, relative value unit.

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

DOI: 10.2337/dc05-1811

period. These identification methods have been previously validated. The diabetes identification method has an estimated specificity of 0.99, a sensitivity of 0.91, and a positive predictive value of 0.94, and the CHD identification method has an estimated specificity of 0.99, a sensitivity of 0.89, and a positive predictive value of 0.79 (13).

Surveys and data collection

Additional information for this study was derived from surveys of patients, clinic managers, and clinic medical directors, which were administered in 1999 as part of the Agency for Health Care Research and Quality–funded study "QUEST for Health." Eighteen (86%) of 21 eligible medical groups and 84 of 86 (98%) eligible clinics within these groups were initially recruited for the study, and all maintained involvement throughout the 3-year study period. Within participating clinics, 4,674 of 7,600 (61.5%) eligible adult patients with specific chronic diseases provided survey data. Of 2,832 patients with diabetes who responded to the survey, 2,117 (74.8%) gave written informed consent for a medical record review, which was completed for 2,077 (98.1%) people. We excluded 383 people (18.4%) who did not have an A1C value (a control covariate) recorded in the baseline period. There were 270 (16.6%) people who received care in clinics where the clinic manager failed to return the survey and 446 (27.4%) people who received care in clinics where the clinic medical director failed to return the survey. As the combined exclusions would result in a dataset underpowered to address the study questions, we created two datasets, one for each survey. Thus, the analysis sample for questions derived from the clinic manager survey included 1,424 people with diabetes, and the analysis sample for questions derived from the clinic medical director survey included 1,228 people. Compared with those who were excluded due to nonreceipt of the patient, clinic manager, or clinic medical director surveys or lack of baseline A1C, the 1,628 unique individuals across the clinic manager and medical director samples 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 diagnoses were 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 (14). The survey included other questions or scales to ascertain patient experience of care, adherence, readiness to change, and mental models of diabetes. Missing data from the patient survey–based measures of self-reported hypertension, dyslipidemia, depression, duration of diabetes, low income, and low education were imputed using missing-value multivariate regressions (15). Rates of missing data for these items were low, ranging from 3.2 to 5.0%.

Independent variables: office systems and quality improvement strategies

Separate surveys were used to query clinic medical directors and clinic managers regarding the use of office systems and improvement strategies related to the care of adults with diabetes, heart disease, or related conditions that were in place before the collection of the resource use data described below. Office systems refer to work systems, work plans, or tools used daily by clinics or medical groups to support the delivery of chronic disease care to individual patients. Office systems were further classified into these subdomains: care management strategies, patient education, patient registries, and information support. Quality improvement strategies refer to processes that occur at the clinic or medical group level that are developed for the purpose of directing or leading efforts to improve the quality of chronic disease care for many patients. Quality improvement strategies were further subdivided into two domains: overall quality improvement efforts, including holding formal quality improvement meetings and use of quality improvement teams, and specific quality improvement–based feedback strategies, such as periodic feedback of summary information on resource or pharmacy use to physicians. For example, a resource-based strategy might identify patients with high resource use so proactive care could be provided. A pharmacy-based strategy might identify patients with high cholesterol who are not receiving statin pharmacotherapy.

Each domain is modeled as a set of covariates rather than as a constructed or latent scale because we were interested in modeling the effect of specific systems and quality improvement efforts underway during the study period. Each covariate was identified by an affirmative response from the survey responder. An affirmative response included either a "yes" for a yes/no response or one of the top two of five possible answers to a Likert scale (for example, "to a considerable/great extent" when the other options were "not at all" and "to a limited/some extent"). Responses of "don't know" and nonresponse (missing values) were considered negative responses. Review of the data suggested that nonresponse often occurred during sets of similar questions where a missing value might be viewed as a negative response. For example, clinic medical directors responding as not having a clinic registry for diabetic patients typically did not respond to the remaining questions on registry characteristics. Similarly, a few medical directors responding as having a clinic registry answered affirmatively to some of the follow-up questions, leaving the remainder blank. This is a limitation in the data that may have led to underestimating the prevalence of certain characteristics.

Dependent variable: resource utilization

The main dependent variable of interest was total cost from the perspective of a health insurer. Claims and encounter data were obtained for study subjects for calendar years 1999–2002. These patients received care in 84 clinics within 18 medical groups that had contracts with HealthPartners to provide services to its members: 43% of study subjects were enrolled in a medical group with a fully capitated contract, 29% were under a fee-for-service contract, and 28% were under a contract that was partially capitated and partially fee for service. To avoid 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 used 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

Table 1—*Study sample characteristics*

	Clinic manager survey	Medical director survey
Demographics		
n	1,424	1,228
Female	680 (48.8)	557 (45.8)
Age (years)	63.1 ± 12.8	63.0 ± 12.9
Clinical		
A1C (%)	7.5 ± 1.5	7.5 ± 1.5
Diabetes duration (years)	12.1 ± 12.6	11.9 ± 12.3
Chronic disease		
CHD	361 (25.8)	294 (24.4)
Hypertension	939 (66.0)	786 (64.5)
Hyperlipidemia	899 (63.1)	760 (61.9)
Depression	353 (25.0)	289 (23.7)
Socioeconomic		
Annual family income <$25,000	273 (19.3)	236 (19.1)
Less than a high school education	99 (6.8)	93 (7.5)
Enrollment/coverage		
Years enrolled	2.6 ± 0.4	2.6 ± 0.4
Pharmacy coverage	1,114 (77.6)	957 (77.2)
3-year health care costs ($)		
Inpatient	7,825 ± 23,255	6,778 ± 17,828
Outpatient	8,990 ± 9,105	8,871 ± 9,409
Pharmacy	6,999 ± 8,258	6,967 ± 8,566
Skilled nursing and dialysis	902 ± 4,083	830 ± 3,792
Total health care costs ($)	24,717 ± 31,919	23,457 ± 28,008

Data are means ± SD or *n* (%).

stay were combined with patient's age and sex in order to calculate a DRG for the 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. Thirty-four admissions (0.6%) had high enough charges that they would likely qualify for outlier payments. We approximated DRG outlier payments for these admissions by adding to the DRG payment 60% of inpatient charges above the specific DRG charge threshold.

Costs for physician services in the hospital, in the outpatient hospital, and in outpatient clinic settings, as well as costs for all other outpatient services such as nursing services and laboratory services, were based on relative value units (RVUs). Each service was assigned an RVU based on the procedure code recorded. RVUs were 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 in order 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 (16). 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 date of disenrollment, death, or the study end date (31 December 2002) divided by the number of days and multiplied by 1,095.75 (3 × 365.25).

Analysis plan

Generalized linear models (17) were used to estimate the relationship between total costs (or outpatient costs or pharmacy costs) and covariates for each domain while controlling for individual level factors (baseline A1C, comorbidity, duration of diabetes, age and sex, pharmacy coverage, income, and education). In one domain, substantial overlap in the use of registries required us to run the covariates individually (e.g., all registries indicating cardiovascular risk by definition had a registry and most were updated regularly, identified the regular physician, etc.). Three-year cost was modeled using a gamma distribution with a log-link function (18). Observations were weighted by each individual's number of years in the study. Marginal effects were calculated as the average marginal effect of each covariate standardized over the characteristics of the population. For example, the marginal effect of having an established quality improvement team on total costs was calculated as the mean cost across all individuals, assuming that an established quality improvement team was present minus the mean cost across all people assuming that an established quality improvement team was not present. SEs were calculated using the delta method, with corrections for heteroscedasticity and clustering of patients within clinics.

RESULTS — Population characteristics are summarized in Table 1. Overall, 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, dyslipidemia, and self-reported depressive symptoms among these patients with diabetes. Mean 3-year health care costs were $24,134 (SD = $31,387) and were about evenly split between inpatient, outpatient, and pharmacy care. Table 2 shows the mapping of the covariates to system and quality improvement domains.

Table 3 presents the marginal effects of each of the office system and quality improvement strategy covariates on total costs. Among office systems, the care management strategy of clinicians meeting to discuss patient care problems was associated with fewer costs (−$3,963, P = 0.002). Diabetes education for patients was not related to costs, either positively or negatively. Simple existence of a registry for patients with diabetes did not affect costs, nor did five of six registry characteristics. However, use of more sophisticated registries that were used to prioritize patients based on cardiovascular risk was associated with fewer total costs (−$2,916, P = 0.019). Use of information systems to monitor lab results was associated with greater total costs ($2,439, P = 0.038).

Overall, most quality improvement strategies were not associated with costs. Specific quality improvement strategies for diabetes, heart disease, and depression that focused on pharmacy utilization and resource use were associated with costs. Strategies focused on resource use for diabetes care (−$2,883, P = 0.017) or heart disease care (−$3,228, P = 0.014)

Table 2—*System of care and quality improvement covariates by domain*

	Patients	Clinic
Clinic manager survey (n = 1,424)		
Care management strategies		
Nonurgent appointments available the same day	162 (11.4)	5 (6.0)
Clinic coordinates care between providers	954 (67.0)	50 (59.5)
Clinic requires patients to have their own clinician	881 (61.9)	42 (50.0)
Clinicians to meet to discuss patient care problems	466 (32.7)	23 (27.4)
Clinic has medical information available when it is needed	1,171 (82.2)	54 (64.3)
Follow-up phone calls are made to patients after office visits	458 (32.2)	28 (33.3)
Patients are reminded when they need additional care	600 (42.1)	29 (34.5)
Medical director survey (n = 1,228)		
Patient education*		
Diabetes education on site	843 (68.7)	35 (41.7)
Diabetes education off site	531 (43.2)	28 (33.3)
Registries		
Clinic registry exists	915 (74.5)	46 (54.8)
Registry identifies the regular physician	899 (73.2)	44 (52.4)
Registry includes dates of laboratory tests	881 (71.8)	43 (51.2)
Registry includes test results	793 (64.6)	39 (46.4)
Registry indicates when services are due	745 (60.6)	30 (35.7)
Registry prioritizes patients on clinical status	296 (24.1)	14 (16.7)
Registries are updated regularly	795 (64.7)	38 (45.2)
Registry indicates patients' levels of cardiovascular risk	243 (19.8)	12 (14.3)
Information support		
Databases used to identify patients with diabetes	852 (69.3)	44 (52.4)
Database used to systematically monitor labs	683 (55.6)	33 (39.3)
EMR (provider entry of data)	366 (29.8)	14 (16.7)
Quality improvement efforts†		
Formal meetings held	384 (31.3)	17 (20.2)
Quality improvement team	562 (45.7)	28 (33.3)
Specific quality improvement performance-based strategies		
Diabetes		
Quality of care	1,032 (84.0)	51 (60.7)
Prescription utilization	600 (48.8)	24 (28.6)
Resource use	435 (35.4)	16 (19.0)
Heart disease		
Quality of care	769 (62.7)	36 (42.9)
Prescription utilization	628 (55.6)	27 (32.1)
Resource use	363 (29.6)	13 (15.5)
Depression		
Quality of care	48 (6.3)	5 (6.0)
Prescription utilization	513 (41.8)	21 (25.0)
Resource use	146 (11.9)	7 (8.3)

Data are n (%). *A clinic could provide on-site diabetes education, and, in addition (or instead), clinics may provide off-site diabetes education through a contracted provider. †Quality improvement efforts were defined as a hierarchy. A clinic could conduct formal quality improvement meetings or support a more defined quality improvement team.

were related to lower costs. Strategies that emphasized pharmaceutical use for heart disease ($3,059, P = 0.029) or depression ($2,962, P = 0.038) were related to higher costs.

CONCLUSIONS— These results provide estimates of 3-year cost impacts associated with the use of specific office systems and improvement strategies in medical group practices. It has become increasingly clear that both the right care strategies (i.e., office systems) and the right change management process for effectively implementing new care systems (i.e., improvement or change strategies) are important for improving the process and outcome of care for patients. Another critical element is organizational prioritization of the topic addressed in the change and care strategies. We have previously demonstrated that the leadership of at least 13 of 18 medical groups identified diabetes as a high priority for improvement, and 15 of these medical groups were participating in various regional diabetes improvement initiatives (19). These data are among the first to empirically demonstrate that specific office systems and improvement strategies for diabetes are predictive of future increases or decreases in cost of diabetes care.

The importance of identifying strategies that can reduce the costs of diabetes care is apparent because diabetes is a relatively common condition and because

Table 3—*Estimated marginal costs of system of care and quality improvement covariates by domain*

	Coefficient ± SE	*P* value
Clinic manager survey (n = 1,424)		
Care management strategies		
Nonurgent appointments available the same day	−3,488 ± 2,474	0.159
Clinic coordinates care between providers	−322 ± 1,757	0.855
Clinic requires patients to have their own clinician	1,409 ± 1,473	0.339
Clinicians to meet to discuss patient care problems	−3,962 ± 1,254	0.002
Clinic has medical information available when it is needed	705 ± 1,874	0.707
Follow-up phone calls are made to patients after office visits	−242 ± 1,562	0.877
Patients are reminded when they need additional care	1,296 ± 1,560	0.406
Medical director survey (n = 1,228)		
Patient education		
Diabetes education on-site	626 ± 1,529	0.682
Diabetes education off-site	−165 ± 1,307	0.900
Registries*		
Clinic registry exists	−1,533 ± 1,540	0.320
Registry identifies the regular physician	−877 ± 1,526	0.561
Registry includes dates of laboratory tests	−1,104 ± 1,446	0.446
Registry includes test results	48 ± 1,301	0.971
Registry indicates when services are due	−1,545 ± 1,333	0.247
Registry prioritizes patients on clinical status	−1,727 ± 1,326	0.193
Registries are updated regularly	−76 ± 1,361	0.956
Registry indicates patients' levels of cardiovascular risk	−2,916 ± 1,243	0.019
Information support		
Databases used to identify patients with diabetes	122 ± 1,416	0.932
Database used to systematically monitor labs	2,439 ± 1,172	0.038
EMR (provider entry of data)	809 ± 1,148	0.481
Quality improvement efforts		
Formal meetings held	−966 ± 1,661	0.561
Quality improvement team	−2,404 ± 1,561	0.124
Specific quality improvement performance-based strategies†		
Diabetes		
Quality of care	1,891 ± 1,404	0.178
Prescription utilization	1,429 ± 1,358	0.293
Resource use	−2,883 ± 1,206	0.017
Heart disease		
Quality of care	−660 ± 1,494	0.659
Prescription utilization	3,059 ± 1,400	0.029
Resource use	−3,228 ± 1,317	0.014
Depression		
Quality of care	−391 ± 2,263	0.863
Prescription utilization	2,962 ± 1,427	0.038
Resource use	−3,037 ± 2,078	0.144

Variables are run as sets with individual-level adjustment for age, sex, comorbidity, income, education, and pharmacy coverage, unless otherwise noted. *Due to substantial overlap, these covariates are run individually with individual-level adjustment for age, sex, comorbidity, income, education, and pharmacy coverage. †Due to substantial overlap, these covariates are run in sets of three with individual-level adjustment for age, sex, comorbidity, income, education, and pharmacy coverage.

the costs of diabetic patients are relatively high compared with the costs of most other patients (16). In our analysis, use of "smart registries" that facilitate prioritization of high-risk patients was associated with lower costs of care. The mechanism by which registries that assess cardiovascular risk lower costs may be related to the fact that patients with diabetes and CHD have ~300% higher costs of care than those with diabetes alone, and that up to 54% of major cardiovascular events in such patients are potentially preventable with comprehensive diabetes care (16,20).

Physician meetings to discuss patient care were associated with significantly lower costs. However, this is not an activity that is reimbursed by insurers or encouraged by many productivity-oriented medical groups. The occurrence of such meetings likely reflects better patterns of communication across physicians. They may expand an individual physician's repertoire of effective clinical management strategies and could also contribute to anticipating and sometimes avoiding hospitalization when a moderately ill patient encounters a series of providers in a single episode of illness. Such clinically oriented meetings may also provide a forum for physician-nurse communication that benefits care.

Quality improvement strategies that focus physician attention on resource use were associated with lower costs and quality improvement strategies that encourage more pharmaceutical use with higher costs. The use of such strategies has many ethical and policy implications, and the impact of such strategies on quality of care and patient satisfaction is a complex issue that involves the cost and benefit of specific pharmaceuticals, the details of a patient's clinical condition, provider preferences, and treatment patterns. A deeper understanding of these issues will depend upon future qualitative and quantitative research efforts in these domains (21).

Electronic medical records (EMRs) had no effect on costs, positive or negative, although ~30% of evaluated patients received care from clinics that used EMRs. In previous reports, EMR use was unrelated to quality of diabetes care (22–24). However, this is the first report that carefully assesses impact of EMR use on costs of diabetic patients. It is likely that the effect of currently available EMRs on diabetes care quality and costs is limited by their rudimentary clinical decision support and their limited ability to support customized patient self-management efforts. Assuming that these and other deficits in EMR design can be addressed, the future impact of EMRs on quality of care and costs may improve. The possibility that EMRs may be effectively used to provide customized patient education/patient activation support at lower cost than traditional education strategies deserves further attention.

Our cost analysis reflects the point of view of the health plan or payer. In interpreting these findings, medical groups need to consider three other factors. First, strategies that increase numbers of visits and tests may translate into increased revenue. Second, the cost of establishing the information systems and having physician meetings may be borne by the medical group and is not included in the analysis. Third, ineffective strategies designed to improve care or control costs may be discontinued with resulting resource savings.

Several factors limit the interpretation of these data. First, the generalizability of our results is limited by the research setting and the fact that our sample was older and more likely to have CHD than the overall population of individuals with diabetes. About 23% of study subjects did not have pharmacy coverage through HealthPartners; we elected not to impute pharmacy costs for these subjects, and this decision could have a small but measurable effect on our estimated cost in Table 1. Second, it is possible that unmeasured confounding variables could modify the observed associations. While the analysis is adjusted for obvious confounders in patient populations with diabetes, our data limited our ability to adjust for severity of diabetes beyond adjustment for duration of diabetes, baseline A1C, and comorbidity for patients with recognized macrovascular complications and depression. Third, power limitations precluded detailed assessment of types of costs, as well as possible joint effects of multiple office systems and quality improvement strategies. Fourth, although we adjusted for clustering of patients within clinics, we did not account for clustering of clinics within medical groups. This decision was based on previously reported low intraclass correlation coefficients at both levels and is unlikely to affect the estimates reported here (25). Fifth, the observational design of the study precludes causal inference. That is, even though we estimate a relationship between a clinic system or quality improvement strategy and costs, this does not mean that changing that factor will affect costs by the estimated amount.

In summary, these data are among the first to identify specific office systems and quality improvement strategies that are significant predictors of future health care costs for adults with diabetes, after controlling for patient demographics, comorbidity, and socioeconomic status. Findings support the hypothesis that specific office systems and improvement strategies may substantially affect cost of diabetes care, although the observed differential cost impacts must be considered conjointly with the impact of these systems and strategies on quality of care and health status (6). Our results identify specific office systems and quality improvement strategies that are associated with costs of care to payers. The mechanisms by which these office systems and quality improvement strategies affect costs and the relationship of costs to clinical outcomes of patients deserve further investigation.

Acknowledgments— This work was supported by the Agency for Healthcare Research and Quality through Grant RO1 HS 09946 to HealthPartners Research Foundation and was presented at the Academy Health 2005 Annual Research Meeting.

References

1. Diabetes Control and Complications Trial: The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. *N Engl J Med* 329:977–986, 1993
2. UK Prospective Diabetes Study Group: Intensive blood-glucose control with sulphonylureas or insulin compared with conventional treatment and risk of complications in patients with type 2 diabetes (UKPDS 33). *Lancet* 352:837–853, 1998
3. UK Prospective Diabetes Study Group: Effect of intensive blood-glucose control with metformin on complications in overweight patients with type 2 diabetes (UKPDS 34). *Lancet* 352:854–865, 1998
4. UK Prospective Diabetes Study Group: Efficacy of atenolol and captopril in reducing risk of macrovascular and microvascular complications in type 2 diabetes: UKPDS 39. *BMJ* 317:713–720, 1998
5. Bodenheimer T, Wagner EH, Grumbach K: Improving primary care for patients with chronic illness. *JAMA* 288:1775–1779, 2002
6. Casalino L, Gillies RR, Shortell SM, Schmittdiel JA, Bodenheimer T, Robinson JC, Rundall T, Oswald N, Schauffler H, Wang MC: External incentives, information technology, and organized processes to improve health care quality for patients with chronic diseases. *JAMA* 289:434–441, 2003
7. Bodenheimer T: Interventions to improve chronic illness care: evaluating their effectiveness. *Dis Manag* 6:63–71, 2003
8. Ward MM, Yankey JW, Vaughn TE, BootsMiller BJ, Flach SD, Welke KF, Pendergast JF, Perlin J, Doebbeling BN: Physician process and patient outcome measures for diabetes care: relationships to organizational characteristics. *Med Care* 42:840–850, 2004
9. Gilmer T, Kronick R: It's the premiums, stupid: projections of the uninsured through 2013. *Health Aff (Millwood)* web exclusives:W5–143–W5–151, 2005
10. Solberg LI, Lyles CA, Shore AD, Lemke KW, Weiner JP: Is quality free? The relationship between cost and quality across 18 provider groups. *Am J Manag Care* 8:413–422, 2002
11. Wagner EH, Sandhu N, Newton KM, McCulloch DK, Ramsey SD, Grothaus LC: Effect of improved glycemic control on health care costs and utilization. *JAMA* 285:182–189, 2001
12. Kerr EA, McGlynn EA, Adams J, Keesey J, Asch SM: Profiling the quality of care in twelve communities: results from the CQI study. *Health Aff (Millwood)* 23:247–256, 2004
13. O'Connor P, Rush W, Pronk N, Cherney L: Identifying diabetes mellitus or heart disease among health maintenance orga-

nization members: sensitivity, specificity, predictive value and cost of survey and database methods. *Am J Manag Care* 4: 335–342, 1998
14. Stein AD, Lederman RI, Shea S: The Behavioral Risk Factor Surveillance System questionnaire: its reliability in a statewide sample. *Am J Public Health Dec* 83:1768–1772, 1993
15. Little RJA, Rubin DB: *Statistical Analysis With Missing Data*. New York, Wiley and Sons, 1987
16. Gilmer TP, O'Connor PJ, Rush WA, Crain AL, Whitebird RR, Hanson AM, Solberg LI: Predictors of health care costs in adults with diabetes. *Diabetes Care* 28:59–64, 2005
17. McCullagh P, Nelder J: *Generalized Linear Models*. 2nd ed. London, Chapman & Hall, 1989
18. Blough DK, Madden CW, Hornbrook MC: Modeling risk using generalized linear models. *J Health Econ* 18:153–171, 1999
19. Solberg LI, O'Connor PJ, Christianson JB, Whitebird RR, Rush WA, Amundson GM: The QUEST for quality: what are medical groups doing about it? *Jt Comm J Qual Patient Saf* 31:211–219, 2005
20. Gaede P, Vedel P, Larsen N, Jensen GV, Parving HH, Pedersen O: Multifactorial intervention and cardiovascular disease in patients with type 2 diabetes. *N Engl J Med* 348:383–393, 2003
21. O'Connor P, Sperl-Hillen J, Pronk N, Murray T: Factors associated with successful chronic disease improvement in primary care practice. *Dis Manage Health Outcomes* 9:691–698, 2001
22. Montori VM, Dinneen SF, Gorman CA, Zimmerman BR, Rizza RA, Bjornsen SS, Green EM, Bryant SC, Smith SA, the Translation Project Investigator Group: The impact of planned care and a diabetes electronic management system on community-based diabetes care: the Mayo Health System Diabetes Translation Project. *Diabetes Care* 25:1952–1957, 2002
23. Meigs JB, Cagliero E, Dubey A, Murphy-Sheehy P, Gildesgame C, Chueh H, Barry MJ, Singer DE, Nathan DM: A controlled trial of web-based diabetes disease management: the MGH diabetes primary care improvement project. *Diabetes Care* 26: 750–757, 2003
24. O'Connor PJ, Crain AL, Rush WA, Sperl-Hillen JM, Gutenkauf JJ, Duncan JE: Impact of an electronic medical record on diabetes quality of care. *Ann Fam Med* 3:300–306, 2005
25. O'Connor PK, Rush WA, Gilmer TP, Solberg LI, Whitebird RR, Crain AL, Christiansen J, Johnson PE, Van de Ven AH, Louis TA, Asche SE, Nelson AF: *Organizational Characteristics and Chronic Disease Care*. Washington, DC, AHRQ, 2004 (HS 09946)