Impact of Population Management With Direct Physician Feedback on Care of Patients With Type 2 Diabetes

RICHARD W. GRANT, MD, MPH[1,2]
HOPE E. HAMRICK[1]
CHRISTINE M. SULLIVAN, RN-C FNP[5]
ANIL K. DUBEY, MD[3]
HENRY C. CHUEH, MD[2,3]
ENRICO CAGLIERO, MD[4]
JAMES B. MEIGS, MD, MPH[1,2]

OBJECTIVE — Population-level strategies may improve primary care for diabetes. We designed a controlled study to assess the impact of population management versus usual care on metabolic risk factor testing and management in patients with type 2 diabetes. We also identified potential patient-related barriers to effective diabetes management.

RESEARCH DESIGN AND METHODS — We used novel clinical software to rank 910 patients in a diabetes registry at a single primary care clinic and thereby identify the 149 patients with the highest HbA_{1c} and cholesterol levels. After review of the medical records of these 149 patients, evidence-based guideline recommendations regarding metabolic testing and management were sent via e-mail to each intervention patient's primary care provider (PCP). Over a 3-month follow-up period, we assessed changes in the evidence-based management of intervention patients compared with a matched cohort of control patients receiving usual care at a second primary care clinic affiliated with the same academic medical center.

RESULTS — In the intervention cohort, PCPs followed testing recommendations more often (78%) than therapeutic change recommendations (36%, $P = 0.001$). Compared with the usual care control cohort, population management resulted in a greater overall proportion of evidence-based guideline practices being followed (59 vs. 45%, $P = 0.02$). Most intervention patients (62%) had potential barriers to effective care, including depression (35%), substance abuse (26%), and prior nonadherence to care plans (18%).

CONCLUSIONS — Population management with clinical recommendations sent to PCPs had a modest but statistically significant impact on the evidence-based management of diabetes compared with usual care. Depression and substance abuse are prevalent patient-level adherence barriers in patients with poor metabolic control.

Diabetes Care 26:2275–2280, 2003

Management of type 2 diabetes in the U.S. is expensive (representing 25% of the Medicare budget) (1), complex (patients often have hypertension, hyperlipidemia, and other comorbidities) (2–4), and generally falls short of evidence-based goals (most diabetic patients do not reach recommended levels of glycemic, blood pressure, or cholesterol control) (5,6). Patient-related factors such as adherence to medications and healthy lifestyle changes and societal factors such as costs and access to care are important but difficult-to-modify elements of diabetes management (7–10). In contrast, interventions directed toward primary care providers (PCPs) may be more likely to improve quality of diabetes care (11,12).

Prior interventions to improve quality of care by changing physician practice patterns have mostly been either physician-centered (e.g., intensive academic detailing, physician report cards) (13–15) or patient-specific and centered on clinic visits (e.g., computerized reminder systems) (12,16–20). In contrast, population-based diabetes management takes an overview perspective to monitor and deliver patient care (21,22). Population management allows a clinician to assess elements of care for a large panel of patients independent of individual clinic visits and to select patients for further intervention on the basis of specific care parameters relative to the rest of the population. This approach circumvents the time constraints that may limit changes in management during individual clinic visits and allows evaluation of patients who do not have pending follow-up appointments.

We undertook a controlled trial of population management for type 2 diabetes. We developed clinical software (Population Manager or PopMan) with the capacity to rank patients within an established diabetes registry according to various criteria, including most recent HbA_{1c}, cholesterol, or blood pressure levels, time since last clinic visit, and time since last laboratory test. A nurse practitioner at the intervention clinic with expertise in diabetes care, the population manager, used the PopMan software to identify patients with outlying results for further review. Applying the American Diabetes Association (ADA) Clinical Practice Recommendations (23) to patients in the registry with the highest HbA_{1c} and cholesterol

From the [1]General Medicine Division, Department of Medicine, Massachusetts General Hospital and Harvard Medical School, Boston, Massachusetts; the [2]Laboratory of Computer Science, Department of Medicine, Massachusetts General Hospital and Harvard Medical School, Boston, Massachusetts; the [3]Diabetes Unit, Department of Medicine, Massachusetts General Hospital and Harvard Medical School, Boston, Massachusetts; the [4]Clinical Research Program, Massachusetts General Hospital and Harvard Medical School, Boston, Massachusetts; and the [5]Revere HealthCare Center, Massachusetts General Hospital, Boston, Massachusetts.

Address correspondence and reprint requests to Richard W. Grant, MD, MPH, General Medicine Division, Massachusetts General Hospital, 50 Staniford St., 9th Floor, Boston, MA 02114. E-mail: rgrant@partners.org.

Received for publication 12 November 2002 and accepted in revised form 18 April 2003.

Abbreviations: ADA, American Diabetes Association; EMR, electronic medical record; FTE, full-time equivalent; PCP, primary care provider.

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

levels, the population manager sent an individualized clinical report to each patient's PCP by e-mail, providing specific management recommendations for risk factor testing and changes in therapy. The specific aim of this study was to determine the impact of these individualized management recommendations compared with usual care. A secondary aim was to characterize physician-reported barriers to effective clinical management in patients with poor metabolic control.

RESEARCH DESIGN AND METHODS

Study design

Patients and physicians at the intervention site received population management, whereas patients and physicians at the control clinic site continued with usual care. Within each clinic site, diabetes registries were created by screening the clinic population for diabetes-related billing claims (*International Classification of Diseases, 9th Revision* [ICD-9] codes 250.00–250.90). Potential diagnoses were then confirmed by detailed chart review. The PopMan clinical software was used to rank patients within the intervention site diabetes registry according to either highest HbA_{1c} or cholesterol levels. Once identified, the overall diabetes management of each intervention patient was reviewed. Appropriate testing intervals and goal risk factor levels for HbA_{1c}, cholesterol, and blood pressure were determined according to the ADA Clinical Practice Recommendations published in the year preceding the study (23). Applying these evidence-based criteria to the patients identified by the PopMan ranking program and to a similar, matched cohort of patients from the control clinic (23), we compared the proportion of patients with changes in the management of three diabetes-related metabolic risk factors—hyperglycemia, hypertension, and hyperlipidemia—over a 3-month interval. The study was approved by the Massachusetts General Hospital/Partners Health Care System Institutional Review Board. In accordance with section 903C of the Public Health Service Act (42 U.S.C.299a-1), confidentiality of all patient information was strictly maintained.

Clinical sites and participants

The intervention clinical site is an academically affiliated community health center serving a predominately working class community. A total of 910 patients were included in the diabetes registry at this site. Working approximately one-half day per week over the course of 1 year (from July 2001 to June 2002), the population manager (a family nurse-practitioner) used the PopMan software to identify patients in this registry with the highest HbA_{1c} and cholesterol levels. Although patients were initially selected on the basis of elevated HbA_{1c} or cholesterol level, multiple aspects of diabetes management were then assessed in these patients by applying the ADA Clinical Practice Recommendations for hyperglycemia, hypertension, and hyperlipidemia management (23). In each intervention patient, the following were assessed: interval since last HbA_{1c}, cholesterol, and blood pressure measurement; most recent measured value; and current medical regimen for each risk factor. Patient-specific recommendations were then summarized in an e-mail sent to the patient's PCP. The text of this e-mail was also entered as a clinical note in the electronic medical record (EMR) used for all patient care at this clinical site.

For each patient reviewed by the population manager within the defined study period, we characterized the nature of the recommendations made and assessed changes in clinical management over the subsequent 3 months in response to the recommendation. Changes in management were identified by reviewing the EMR for subsequent clinic visit notes, patient phone calls or letters, and laboratory testing results. Our primary outcome was percentage of specific recommendations that were followed. Recommendations were grouped into two categories: *1*) testing (for HbA_{1c}, blood pressure, or cholesterol) and 2) changes in therapy (to initiate or increase therapy for hyperglycemia, hypertension, or hyperlipidemia). For intervention patients evaluated more than once over the course of the study, only recommendations from the first e-mail were analyzed. For all intervention patients, we also recorded physician explanations for not following specific recommendations and tabulated potential barriers to effective care noted by the PCPs in the EMR.

To assess the impact of the population manager intervention beyond what changes may have occurred without her specific recommendations, we analyzed a comparison cohort in the control clinic. The comparison cohort consisted of diabetic patients from a second primary care practice affiliated with the same academic medical center. From an overall population of 2,240 diabetic patients in this clinic, we defined a group of control patients clinically similar to the 149 intervention patients by matching in a 1:1 ratio within 5 years of age, 0.5% of HbA_{1c}, and 10 mg/dl of total cholesterol. Our goal was to identify two groups of patients with comparable metabolic control who would generate similar overall management recommendations in the aggregate. For these control patients, we chose 1 March 2002 as the assessment date. Looking back from this date, we applied the same care guidelines used by the population manager to create a set of hypothetical recommendations for hyperglycemia, hypertension, and hyperlipidemia management applicable to the control cohort. We then looked forward 3 months from 1 March 2002 to determine whether these hypothetical recommendations were followed in the absence of prompting from a population manager. This study design allows a controlled test of management changes attributable to population management beyond changes that might be expected to occur in the course of usual care alone.

Clinical care recommendations

For all patients in either the intervention or the control group, medical records were reviewed and the following recommendations were made: *1*) repeat HbA_{1c} testing if most recent results are more than 6 months out of date and repeat testing for either blood pressure or cholesterol if last measurements are more than a year out of date; 2) increase therapeutic regimen for glycemic, blood pressure, or cholesterol control if any of these levels are above the goal (HbA_{1c} >7%, blood pressure >135/80 mmHg, cholesterol >200 mg/dl, or LDL >130 mg/dl) and if the patient is either not on therapy or on an unchanged dose of therapy for more than 6 months.

Therefore, a patient selected because of elevated cholesterol level, for example, might be found to have an outdated HbA_{1c} result, untreated hyperlipidemia, and normal blood pressure. After reviewing the medical record for current therapy and medication allergies, the population manager would send an e-mail to the pa-

Table 1—*Characteristics of intervention and control clinics*

	Intervention site	Control site	*P*
Total number of physicians	19	40	
Years since graduation: *n* (SD)	12.9 (7.0)	22.9 (10.0)	<0.001
Women (%)	47	33	0.3
Number of physician FTEs	9.8	16.8	
Total patients/FTE: *n* (SD)	1,015 (382)	1,538 (589)	0.001
Annual patient visits/FTE: *n* (SD)	3,857 (1,484)	3,857 (1,408)	0.9
Diabetes patients/FTE: *n* (SD)	121 (98)	118 (69)	0.9
Annual diabetes patient visits/FTE (SD)	422 (349)	327 (190)	0.3

Data are *n* and proportions or means and SD. FTE = eight clinical sessions per week; annual testing rates = number of tests from January 1 to December 31, 2001. *P* values are derived using χ^2 test for proportions and Student's *t* tests for continuous variables.

tient's PCP recommending repeat HbA_{1c} testing and initiation of lipid-lowering therapy.

Statistical analysis

All analyses were performed using SAS statistical software (SAS Institute, Cary, NC) (24). Baseline comparison of clinic, physician, and patient characteristics used Student's *t* test for normally distributed continuous variables and χ^2 tests for proportions. Within the intervention group, χ^2 tests were used to compare proportions of recommendations followed, comparing the categories of testing and therapeutic change recommendations. For the primary outcome comparing changes in evidence-based management between the intervention and control groups, we used generalized estimating equations to account for possible effects of physician clustering (25). For all tests, a *P* value of <0.05 was considered statistically significant.

RESULTS

Comparison of intervention and control clinics

The intervention clinic was staffed by 19 full- and part-time internists representing 9.8 full-time equivalent (FTE) physicians (defined as eight clinical sessions per week) and two nurse practitioners (Table 1). A total of 40 internists (16.8 FTEs) and six nurse practitioners staffed the control clinic. The total number of patients with diabetes per FTE and the frequency of visits per FTE were similar at the two clinic sites.

Patient characteristics

The population manager identified 149 patients (16.4% of the diabetic patient population at the intervention site) with the highest HbA_{1c} and cholesterol levels. The mean age was 58 years (SD 14), 53% of the patients were women, the mean HbA_{1c} was 9.7% (SD 2.7%, range 5–15%), and the mean total cholesterol was 211 mg/dl (SD 51, range 112–343). The 149 patients in the matched control cohort were statistically similar with regard to age, sex, HbA_{1c}, and total cholesterol values at baseline, and testing rates for HbA_{1c} and LDL cholesterol in the prior year (Table 2).

Population management in the intervention group

We assessed recommendations made by the population manager and corresponding changes in care for the 149 intervention patients. Of these patients, 110 (74%) had a follow-up visit with their PCP in the subsequent 3-month period. Overall, the population manager made 216 management recommendations (1.4 recommendations per patient) related to testing or therapy for hyperglycemia, hypertension, or hyperlipidemia.

In the subset of 110 patients with 3-month PCP follow-up visits, significantly more testing recommendations were followed by the PCPs than therapeutic change recommendations ($P = 0.001$) (Table 3). After reviewing PCP progress notes subsequent to the population man-

Table 2—*Patient characteristics*

	Intervention site		Control site		
	All diabetic patients	Intervention cohort	All diabetic patients	Control cohort	*P*
N	910	149	1,944	149	0.1
Age: years (SD)	64.9 (14)	57.8 (14)	63.0 (14)	57.8 (13)	0.9
Sex: % women	53	50	44	41	0.1
HbA_{1c}: %					
SD, range, % tested	8.1	9.7	7.7	9.2	0.08
	1.8, 4–17, 85	2.7, 5–15, 99	1.7, 4–17, 89	2.1, 6–14, 92	
Cholesterol: mg/dl					
SD, range, % tested	182	211	184	203	0.2
	46, 78–439, 70	51, 112–343, 99	46, 51–490, 86	45, 113–322, 98	
Tests in prior year					
HbA_{1c}	2.1 (1.2)	2.0 (1.3)	1.8 (1.3)	1.8 (1.2)	0.2
Total cholesterol	1.1 (1.0)	1.1 (0.9)	1.3 (1.1)	1.3 (1.0)	0.04
LDL cholesterol	0.9 (0.9)	0.9 (0.9)	1.2 (1.1)	1.0 (1.0)	0.6

Data are *n* and proportions or means and SD. % tested = % of cohort tested in preceding year. *P* values are for comparison of the intervention ($n = 149$) and control ($n = 149$) cohorts, using χ^2 test for proportions and Student's *t* tests for continuous variables.

Table 3—*Categories of population management recommendations and corresponding changes in care among 110 intervention patients with a clinic visit in the subsequent 3 months*

		Response to recommendation		
Recommendation	N	Done	Not done, with explanation	Not done, no explanation
Testing (for HbA_{1c}, blood pressure, or cholesterol)	88	69 (78)*	8 (9)	11 (13)
Changes in therapy (for glycemic, blood pressure, or cholesterol control)	74	27 (36)*	24 (32)	23 (31)
All recommendations	162	96 (59)	32 (20)	34 (21)

Data are n (%). *$P = 0.001$, comparing proportion of testing recommendations followed versus therapy recommendations followed in the subsequent 3 months.

ager's e-mail message, we found that explanations for not following a particular recommendation were more common for therapy recommendations than for testing recommendations ($P = 0.04$). Of the 24 therapy recommendations that were not followed, common explanations included trend of recent improvement ($n = 4$), pending laboratory results ($n = 4$), continued trial of lifestyle changes ($n = 3$), and patient nonadherence with current regimen ($n = 3$).

Adherence barriers to improved care in intervention patients

Physicians noted barriers to clinical care in the EMR for 93 patients in the intervention cohort (62%). The four most common barriers to effective care were: *1*) mental health problems (including depression or anxiety) in 52 patients (35% of the intervention cohort); *2*) prior history of poor adherence to care plans (39 patients, 26%); *3*) ongoing or prior substance abuse (27 patients, 18%); and *4*) serious comorbidity limiting effectiveness of diabetes care (14 patients, 9%). A total of 41 patients (28%) had more than one barrier reported in the EMR. In an exploratory analysis, we did not find any relationship between the proportion of recommendations followed by physicians and the presence of patient-level adherence barriers ($P = 0.9$ comparing proportion of recommendations followed in the intervention group between patients with and without adherence barriers).

Comparison of intervention and control groups

We tested the hypothesis that recommendations made by the population manager resulted in changes in management beyond what may have occurred during usual care. We applied identical testing and therapy management criteria to patients in the control cohort without forwarding the resulting recommendations to the control PCPs. Changes in management were then monitored for the 3-month follow-up period after control recommendations were made. Of the 149 control patients, 117 patients (79%) had a follow-up visit with their PCP in the subsequent 3-month period. A total of 204 control recommendations were made (1.4 recommendations per patient). There were no significant differences comparing intervention and control groups in the proportion of patients with PCP follow-up in 3 months ($P = 0.7$) or in the number of recommendations made per patient ($P = 0.7$).

Overall, a significantly greater proportion of evidence-based guideline practices were followed in the intervention group than in the control group (59 vs. 45%, $P = 0.02$; Table 4), suggesting that population management improved diabetes management beyond what changes may have occurred during usual care over a 3-month period. Although not statistically significant when analyzed separately, both testing rates (78 vs. 71%, $P = 0.4$) and changes in therapy (36 vs. 30%, $P = 0.3$) were greater in the intervention group compared with the control group.

CONCLUSIONS

— We compared changes in the process of care for patients receiving population management with those in a matched cohort of patients without population management in similar academic primary care practices. We found that population management with patient-specific provider feedback led to increased rates of testing and therapy changes over a 3-month follow-up period when compared to usual care. Over a longer period of observation, it is likely that such evidence-based changes in management would result in an overall improvement in metabolic control.

A secondary goal of this study was to assess the prevalence of potential patient-related barriers to effective management. It is straightforward to audit the EMRs of a cohort of patients and find flaws relative to evidence-based management goals. The assumption that pointing out these flaws will lead to improved metabolic control fails to account for the multitude

Table 4—*Changes in clinical management, comparing intervention versus control patients with a clinic visit in the subsequent 3 months*

	Corresponding change in management		
Recommendation category	Intervention ($n = 110$)	Control ($n = 117$)	P
Total recommendations, recommendation followed/total recommendations made	96/162 (59)	84/186 (45)	0.02
Repeat testing, recommendation followed/total recommendations made	69/88 (78)	50/72 (71)	0.4
Changes in therapy, recommendation followed/total recommendations made	27/74 (36)	34/114 (30)	0.3

Data are n (%). Repeat testing = for HbA_{1c}, blood pressure, or cholesterol; changes in therapy = for glycemic, blood pressure, or cholesterol control. P values are for χ^2 tests comparing intervention versus control groups for proportion of recommendations in each category that were followed in the subsequent 3 months.

of "real world" barriers that interfere with evidence-based management. Physicians reported barriers to effective clinical care for most patients in the intervention cohort. Among these patients with poor glycemic and/or lipid control, there was a very high prevalence of depression and other mental health problems, substance abuse, and poor prior adherence to care plans.

Population management represents a novel approach to reducing clinical inertia and increasing patient engagement with the medical system. Distinct from case management, a time-intensive approach that relies on directing substantial resources toward individual patients with the greatest needs, population management seeks to more efficiently harness existing resources to improve the overall level of care for a given patient population. The population manager who reviewed the diabetes registry in our intervention site was a nurse practitioner who was familiar with medical therapies for diabetes. However, many of her recommendations could have been made by a less experienced provider, such as a licensed practical nurse (LPN) or other clinic staff member, following explicit algorithms for testing and visit frequency.

Our findings of a modest but significant impact on overall care parameters suggest that population management is a valuable approach to care. Our method of sending recommendations via e-mail directly to PCPs represents a relatively simple intervention. Strategies to implement changes in care for patients with poor metabolic control that do not require actions by PCPs, such as sending letters and laboratory testing requisitions directly to identified patients and scheduling follow-up appointments with PCPs, nutritionists, or diabetes educators as indicated, may have an even greater impact and should be studied. Future interventions to improve metabolic control in populations of patients with type 2 diabetes must also address the high prevalence of mental health and substance abuse problems and barriers to medication adherence and healthy lifestyle changes.

Acknowledgments— This study is part of the MGH Diabetes Mellitus: Putting Evidence into Practice Project, which is supported by grants from the Aetna Quality Care Research Fund and Pfizer Pharmaceuticals and by the MGH Primary Care Operations Improvement and Clinical Research Programs. R.W.G. received support from National Research Service Award 2-T3211001-14 and J.B.M. is supported by a career development award from the ADA.

We thank Nancy Wong, BS, Jessica A. Sandberg, MPH, and Jo Ann David-Kasdan, RN, MS, for assistance with data abstraction and analysis.

References

1. American Diabetes Association: Economic consequences of diabetes mellitus in the U.S. in 1997. *Diabetes Care* 21:296–309, 1998
2. Grant RW, Cagliero E, Murphy-Sheehy P, Singer DE, Nathan DM, Meigs JB: Comparison of hyperglycemia, hypertension, and hypercholesterolemia management in patients with type 2 diabetes. *Am J Med* 112:603–609, 2002
3. Matthews DR: The natural history of diabetes-related complications: the UKPDS experience: United Kingdom Prospective Diabetes Study. *Diabetes Obes Metab* 1 (Suppl. 2):S7–S13, 1999
4. American Heart Association: Diabetes mellitus: a major risk factor for cardiovascular disease: a joint editorial statement by the American Diabetes Association; The National Heart, Lung, and Blood Institute; The Juvenile Diabetes Foundation International; The National Institute of Diabetes and Digestive and Kidney Diseases; and The American Heart Association. *Circulation* 100:1132–1133, 1999
5. Shorr RI, Franse LV, Resnick HE, Di Bari M, Johnson KC, Pahor M: Glycemic control of older adults with type 2 diabetes: findings from the Third National Health and Nutrition Examination Survey, 1988–1994. *J Am Geriatr Soc* 48:264–267, 2000
6. Saaddine JB, Engelgau MM, Beckles GL, Gregg EW, Thompson TJ, Venkat Narayan KM: A diabetes report card for the United States: quality of care in the 1990's. *Ann Intern Med* 136:565–574, 2002
7. Nelson KM, Reiber G, Boyko EJ: Diet and exercise among adults with type 2 diabetes: findings from the Third National Health and Nutrition Examination Survey (NHANES III). *Diabetes Care* 25:1722–1728, 2002
8. Andrulis DP: Access to care is the centerpiece in the elimination of socioeconomic disparities in health. *Ann Intern Med* 129: 412–416, 1998
9. Glasgow RE, Hampson SE, Strycker LA, Ruggiero L: Personal-model beliefs and social-environmental barriers related to diabetes self-management. *Diabetes Care* 20:556–561, 1997
10. Ruggiero L, Glasgow R, Dryfoos JM, Rossi JS, Prochaska JO, Orleans CT, Prokhorov AV, Rossi SR, Greene GW, Reed GR, Kelly K, Chobanian L, Johnson S: Diabetes self-management: self-reported recommendations and patterns in a large population. *Diabetes Care* 20:568–576, 1997
11. Renders CM, Valk GD, Griffin SJ, Wagner EH, Eijk Van JT, Assendelft WJ: Interventions to improve the management of diabetes in primary care, outpatient, and community settings: a systematic review. *Diabetes Care* 24:1821–1833, 2001
12. 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
13. Nyman MA, Murphy ME, Schryver PG, Naessens JM, Smith SA: Improving performance in diabetes care: a multicomponent intervention. *Effective Clinical Practice* 3: 205–212, 2000
14. Petitti DB: Evaluation of the effect of performance monitoring and feedback on care process, utilization, and outcome. *Diabetes Care* 23:192–196, 2000
15. Phillips LS, Branch WT, Cook CB, Doyle JP, el-Kebbi IM, Gallina DL, Miller CD, Ziemer DC, Barnes CS: Clinical inertia. *Ann Intern Med* 135:825–834, 2001
16. McDonald CJ, Overhage JM, Tierney WM, Abernathy GR, Dexter PR: The promise of computerized feedback systems for diabetes care. *Ann Intern Med* 124:56–62, 1996
17. Balas EA, Weingarten S, Garb CT, Blumenthal D, Boren SA, Brown GD: Improving preventive care by prompting physicians. *Archiv Intern Med* 160:301–308, 2000
18. Hunt DL, Haynes R, Hanna S, Smith K: Effects of computer-based clinical decision support systems on physician performance and patient outcomes: a systematic review. *JAMA* 280:1339–1346, 1998
19. Hunt DL, Haynes RB, Hayward RS, Pim MA, Horsman J: Patient-specific evidence-based care recommendations for diabetes mellitus: development and initial clinic experience with a computerized decision support system. *Int J Med Inform* 51:127–135, 1998
20. Classen DC: Clinical decision support systems to improve clinical practice and quality of care. *JAMA* 280:1360–1361, 1998
21. Ibrahim MA, Savitz LA, Carey TS, Wagner EH: Population-based health principles in

medical and public health practice. *J Public Health Manage Pract* 7:75–81, 2001
22. Grant RW, Meigs JB: The use of computers in population-based diabetes management. *J Clin Outcomes Management* 9:390–396, 2002
23. American Diabetes Association: Clinical Practice Recommendations 2001. *Diabetes Care* 24 (Suppl. 1):S1–S133, 2001
24. SAS Institute: *SAS/STAT Software: Changes and Enhancements Through Release 6.12*. Cary, NC, SAS Institute, 1997
25. Zeger SL, Liang K-Y: Longitudinal data analysis for discrete and continuous outcomes. *Biometrika* 42:121–130, 1986