Glucose Control, Self-Care Behaviors, and the Presence of the Chronic Care Model in Primary Care Clinics

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OBJECTIVE — The purpose of this study was to examine the relationship between A1C and the extent to which care delivered to patients with type 2 diabetes in primary care clinics is consistent with the chronic care model (CCM), after controlling for self-care behaviors.

RESEARCH DESIGN AND METHODS — This was a cross-sectional, observational study of care provided to 618 patients with type 2 diabetes across 20 small, autonomous primary care clinics in South Texas. Subjects completed an exit survey. The medical record was abstracted for A1C values. Clinicians completed the Assessment of Chronic Illness Care (ACIC) survey, a validated measure of the extent to which care delivered is consistent with the CCM.

RESULTS — There was a significant relationship between ACIC score and A1C, but this relationship varied according to self-care behavior for exercise and was strongest for those who did not adhere to exercise recommendations: for every 1-point increase in ACIC score, A1C was 0.144% lower ($P < 0.001$). The relationship between ACIC score and A1C for those who adhered to their diet was similar to that for those who did not, after adjusting for exercise, but the overall level of control was better for those who adhered to their diet.

CONCLUSIONS — Characteristics of the primary care clinic where one receives care are an important predictor of glucose control. If resources for implementing the CCM are limited, one might want to focus on clinics with low ACIC scores that serve a population of patients who are sedentary because this population may be likely to realize the most benefit from improved glucose control.

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Evidence supporting the need for tight glucose control among people with type 2 diabetes has been widely disseminated, and knowledge of currently recommended target levels among physicians is high (1–4). Even so, control of A1C among people with type 2 diabetes in the U.S. has shown no significant improvement over the past decade (5). A number of studies suggest that patient characteristics such as age, race/ethnicity, sex, and self-care behaviors predict A1C control (6–9). In addition, recent research also suggests that a significant amount of the observed variation in glucose control between patients can be attributed to the clinic where the patient receives care (10,11). Because 97% of adults with type 2 diabetes receive the majority of their diabetes care in primary care settings, a better understanding of the relationship between clinic characteristics and glucose control is needed (12–15).

The chronic care model (CCM) describes characteristics of a clinic that, if present, should result in improved outcomes for diabetes care: organizational support, self-management support, delivery system design, decision support, clinical information systems, and community linkages (15). Primary care clinics where these elements are strong should have prepared, proactive primary care practice teams who interact with informed, activated patients, resulting in optimal outcomes such as glucose control (16,17).

Prior studies have shown that the presence of the elements of the CCM in primary care clinics predicts process measures of quality such as appropriate test ordering and referral for eye examinations (18–20). However, recent research suggests that variation in process of care measures across health plans or organizations are not associated with level of A1C, blood pressure, or lipid control (21). The purpose of this study was to examine the relationship between A1C control and the extent to which care delivered to patients with type 2 diabetes in primary care clinics is consistent with the CCM after controlling for patient self-care behaviors.

RESEARCH DESIGN AND METHODS

The Direct Observation of Diabetes Care study was begun in 2002 with the primary aim of conducting an in-depth examination of the care delivered to patients with type 2 diabetes across a wide variety of primary care settings. Details of the study design have been published elsewhere (22). Briefly, the study was cross-sectional and observational: no interventions were performed, and participants received their usual care from their primary care physician. The study took place in 20 primary care clinics with 45 primary care physicians. None of the physicians were trainees. Clinics were recruited in a "snowball" fashion from the South Texas Ambulatory Research Network (STARNet), a regional practice-based research network. An attempt was made to identify and recruit small, autonomous primary care practices where people with type 2 diabetes are most likely to seek care: solo practice physician clinics (n = 11; physicians = 11), group practice settings (n = 3; physi-

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Abbreviations: ACIC, Assessment of Chronic Illness Care; CCM, chronic care model.
A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.
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Table 1—*Sample characteristics and most recent A1C values*

	Sample	Most recent A1C value
Age (years)	58.6 ± 12.9	
Sex		
Female	51.5	7.85 ± 2.14
Male	48.5	7.62 ± 1.99
Hispanic	57.3	8.10 ± 2.17*
Non-Hispanic	42.7	7.26 ± 1.82
Maintenance stage of change?		
For diet		
Yes	46	7.31 ± 1.79*
No	54	8.13 ± 2.22
For exercise		
Yes	45	7.51 ± 1.94†
No	55	7.92 ± 2.16
For self-monitoring of blood glucose		
Yes	61	7.58 ± 1.87†
No	39	8.04 ± 2.33
For medication adherence		
Yes	85	7.61 ± 1.89*
No	15	8.53 ± 2.62

Data are means ± SD or %. $n = 618$. *$P < 0.01$; †$P < 0.05$.

cians = 10), community health centers ($n = 1$; physicians = 1), Veterans Affairs primary care clinics ($n = 2$; physicians = 11), and city/county health clinics for uninsured patients ($n = 3$; physicians = 12).

Within each clinic, ~30 consecutive patients presenting with an established diagnosis of type 2 diabetes were recruited to participate in the study. None of the patients approached declined to participate. After the physician encounter, patients completed a survey and had their medical record abstracted. Up to five A1C values in the medical record up to 36 months before the encounter were recorded.

Definition of variables

Patient characteristics and self-care behaviors. Patient characteristics were obtained by survey: age, sex, and race/ethnicity. Self-care behaviors for diet, exercise, self-monitoring of blood glucose, and medication adherence were assessed using single-item questions with response categories corresponding to stage of change from the transtheoretical model: precontemplation, contemplation, preparation, action, and maintenance (6,23–25). For the analysis, we constructed the stage of change variable as a dichotomous outcome: yes, the patient is in the maintenance stage of change, or no, for each self-care behavior. Patients in the maintenance stage of change reported that they had been adherent to diet, exercise, or other items for at least the past 6 months.

CCM in each practice. The extent to which the care delivered in each clinic is consistent with the elements of the chronic illness care model was measured with the Assessment of Chronic Illness Care (ACIC) survey (26). The ACIC is a 25-item survey that measures the presence of the six elements of the CCM. Each item is scored on a 0–11 scale and provides subscale scores for each of the six CCM components as well as a total score. The presentation of the scales on the instrument is such that scores from 0 to 2 represent "limited support," 3 to 5 represent "basic support," 6 to 8 represent "good support," and 9 to 11 represent "fully developed support." This survey was completed by all clinicians in each clinic—physicians, nurse practitioners, and physicians assistants—and a mean score was calculated for each clinic.

The validity of the instrument is supported by the findings of several studies. In a study of an intervention for diabetes and congestive heart failure, all six subscales were responsive to process-of-care improvement (26). In a separate study, the RAND Corporation conducted an evaluation of a national chronic care collaborative intervention study overseen by the Institute for Healthcare Improvement. Ratings by an external team on the depth of implementation of the elements of the CCM were significantly associated with the overall ACIC score for five of the six elements (27).

Analysis

We examined control of A1C using a random-effects or mixed-effects model. This technique allowed us to account for clustering of repeated measure of A1C within patients and for patients within clinics. By modeling the repeated measure of A1C within each patient, we are able to examine both the intercept (mean at baseline) and the slope (rate of change) over time. This technique also allows for greater precision when one estimates the effect of each predictor in the model (28). Four random-effects models were fitted to the data. In the first model, the only predictor variables entered were patient characteristics, with no predictors at the clinic level. The second model added indicator variables for the maintenance stage of change for each self-care behavior at the patient level but no predictors at the clinic level. The third model included patient characteristics, self-care behaviors, and the total ACIC score at the clinic level. The fourth and final model included interaction terms. Descriptive and univariate statistics were performed with SPSS (version 13.0; SPSS, Chicago, IL) All random-effects models were performed using S-PLUS 6.2 (Insightful).

RESULTS — A total of 617 patients were enrolled across the 20 primary care clinics. Characteristics of the subjects are found in Table 1. The majority were female and Hispanic. Of the subjects, slightly less than 50% reported that they adhered to their diet for the last 6 months or had been exercising as instructed for the prior 6 months. More than 80% reported adherence to medication. The most recent A1C value was 7.74 ± 2.10 (mean ± SD). On a scale from 0 to 11, the ACIC score across all 20 clinics was 6.3 ± 1.7, with a range from 2.9 to 9.5. Regarding the four category anchors for the ACIC scale discussed above, 1 clinic's overall ACIC score fell within the "limited support" range, 5 within the "basic support " range, 13 in the "good support" group, and 1 within the "fully developed" category.

The relationship between patient characteristics, self-care behaviors, and the most recent A1C are shown in Table 1. These results do not account for the clustering of repeated A1C values within patients or the clustering of patients within clinics. All of the relationships were significant except for sex: there was no significant difference in the most recent A1C value between men and women. The A1C value was lower with increasing age (Pearson $r = -0.11$, $P < 0.01$) and was higher for Hispanics and those who were not in the maintenance stage of change for diet, exercise, self-monitoring of blood glucose, or medication adherence. In the unadjusted random-effects model, the ACIC score was associated with the most recent level of A1C. For every 1-unit increase in ACIC score, the A1C decreased by 0.10 ($P = 0.0001$).

Results of the random-effects model analyses are shown in Table 2. The size of the sample was reduced from 617 to 538 because of missing values in the predictor variables ($n = 37$) or having no A1C measurements in the chart ($n = 42$). Subjects in the final model were older (aged 59.9 ± 12.2 vs. 56.7 ± 13.8 years) and had a higher A1C (7.70 ± 1.89 vs. 6.90 ± 1.78). There was no significant temporal trend in the repeated values of A1C in the model. Thus, the results in Table 2 reflect the relationship between the predictors and the mean of the repeated measure of A1C for each subject. Older patients, men, and those who were non-Hispanic had significantly lower A1C values. These relationships remained significant in all four models. Those who were in the maintenance stage of change for diet had lower A1C values in all four models. The total ACIC score was inversely associated with A1C control after controlling for patient demographics and self-care behaviors: A1C was 0.07 points lower for each 1-point increase in ACIC score (model 3).

There were no significant interactions between ACIC score and age, race, sex, diet, or medication adherence. There were significant interactions between ACIC score and exercise as well as diet and exercise. Model 4 in Table 2 shows these results. Among those who did not adhere to exercise, A1C was 0.595 ± 0.13% (mean ± SEM) lower for those who were adherent to diet compared with those who were not. Additionally, the relationship between exercise and A1C varied by ACIC score. For example, for patients seen in a clinic with an ACIC score of 3, the A1C would be 0.68% lower for those who exercised compared with those who did not, but in clinics where the ACIC score was 6, the difference would be 0.21%. This inverse relationship was stronger among those who did not adhere to exercise after adjusting for their diet adherence behavior. Residual diagnostics were used to assess adequacy of the final model and revealed no trend in the residuals nor apparent departure from normality (28,29). Goodness of fit of the final model is also supported by R^2 of 0.50.

Table 2—*Random-effects models of A1C control*

	Model 1	Model 2	Model 3	Model 4
Patient* characteristics				
Age				
Coefficient	−0.018	−0.014	−0.013	−0.013
SE	0.004	0.004	0.004	0.004
P value	<0.001	<0.001	<0.001	<0.001
Male				
Coefficient	−0.212	−0.235	−0.192	−0.204
SE	0.086	0.087	0.088	0.088
P value	0.014	0.007	0.030	0.021
Hispanic				
Coefficient	0.714	0.667	0.659	0.658
SE	0.087	0.088	0.088	0.088
P value	<0.001	<0.001	<0.001	<0.001
Self-care is in maintenance stage of change				
Diet				
Coefficient		−0.383	−0.403	−0.595
SE		0.098	0.098	0.136
P value		<0.001	<0.001	0.009
Exercise				
Coefficient		0.019	0.050	−1.144
SE		0.097	0.098	0.347
P value		0.846	0.612	0.001
Self-monitoring of blood glucose				
Coefficient		−0.017	−0.017	−0.020
SE		0.101	0.101	0.100
P value		0.865	0.864	0.845
Medication adherence				
Coefficient		−0.285	−0.300	−0.275
SE		0.153	0.152	0.152
P value		0.062	0.049	0.071
Clinic ACIC score and interaction terms				
ACIC score				
Coefficient			−0.073	−0.144
SE			0.025	0.035
P value			0.004	<0.001
ACIC × exercise				
Coefficient				0.155
SE				0.050
P value				0.002
Diet × exercise				
Coefficient				0.420
SE				0.188
P value				0.026

*$n = 538$.

The relationships between A1C and ACIC score by diet and exercise categories are shown graphically in Fig. 1. This figure graphs the fitted model 4 equation for patients who did or did not adhere to diet and exercise. The results of model 4 as illustrated in the figure indicate that *1*) the relationship between ACIC score and A1C is strongest for those who have not adhered to exercise; *2*) the relationship between ACIC score and A1C for those who adhered to their diet was similar to that for those who did not adhere to their diet after adjusting for exercise, but the overall level of control was better for those who adhered to their diet; *4*) the relationship between ACIC score and A1C was significantly different for those who ad-

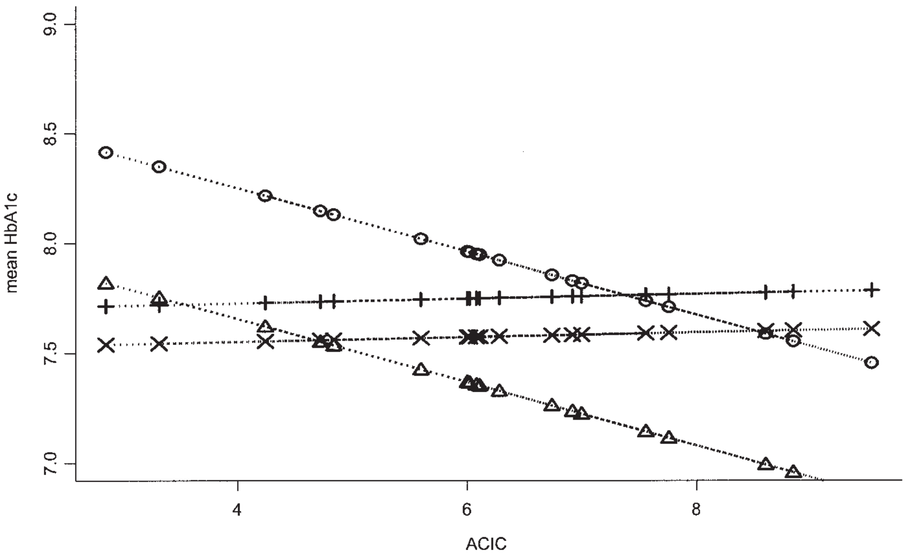

Figure 1—*Fitted model 4: ACIC score and A1C control by category of diet and exercise behavior.* ○, *exercise: no, diet: no;* △, *exercise: no, diet: yes;* +, *exercise: yes, diet: no;* ×, *exercise: yes, diet: yes.*

hered to exercise compared with those who do not; and 5) for those who did not adhere to exercise (regardless of diet behavior), for every 1-point increase in ACIC, the A1C was 0.144% lower.

CONCLUSIONS — Glucose control was associated with the extent to which the care delivered was consistent with the CCM after accounting for patient characteristics and patient self-care behaviors such as diet and exercise. However, the relationship between ACIC score and A1C differed based on patients' self-care behavior, specifically for exercise. This inverse relationship was strongest for patients who had not adhered to exercise for the past 6 months. Diet was also associated with A1C control independent of exercise: those who had adhered to diet for at least 6 months had lower values of A1C compared with those who had not, consistent with other studies (6,30). There was also a strong association between diet and exercise behaviors: those who adhere to diet are likely to be those who adhere to exercise and vice versa ($\chi^2 = 328.2$, 1 d.f., data not shown)

What is the implication of the relationship between ACIC score and A1C control? Given the scaling of the ACIC instrument, a 3-point increase might be necessary to move from one category to the next. For example, for patients who did not adhere to exercise, if a clinic were to move two categories, from basic support for the CCM (range 3–5) to full support (range 9–11), the corresponding decrease in A1C would be between 0.56 and 1.12%. This magnitude of decline is comparable to the 0.5–1.0% decline in A1C reported for new classes of medications as monotherapy in type 2 diabetes (31,32). Alternatively, one could say that, for those who do not adhere to exercise recommendations, the impact on A1C of being seen in a clinic where the ACIC score is two categories higher is similar to the impact of diet adherence on A1C.

Others have evaluated the impact of an intervention to implement the CCM on intermediate clinical outcomes. In 17 primary care clinics in Minnesota, investigators found a significant improvement in the percentage of patients with A1C and LDL cholesterol at guideline recommended levels, but this improvement was not associated with a change in the overall ACIC score (33). One possible explanation for the difference in their findings and ours is our ability to control for patient self-care behaviors in the analysis.

Why should patients seen in clinics where care is more consistent with the CCM have better glucose control? Recent studies have demonstrated that primary care clinics demonstrate behaviors consistent with a complex adaptive system (34,35). Complex adaptive systems are a diverse collection of agents that have the capacity to adapt or coevolve with their environment or "fitness landscape" and are highly interconnected or interdependent (36). It is possible that the CCM describes characteristics of the environment or fitness landscape within the clinic, upon which agents in the clinic, including patients, interact, resulting in outcomes such as glucose control (37).

One implication of this theory is that no single element of the CCM will be equally effective for glucose control in all clinics because each clinic has its own unique internal fitness landscape (38). For example, in a meta-analysis of CCM interventions, no single element of the CCM was essential to improved outcomes (39). An examination of the relationships between individual CCM elements and A1C might be misleading because it might imply that one or more elements of the CCM are most important for A1C control. If one were then to conduct a trial of efforts to improve that element then, according to complexity theory, some clinics would improve and other clinics would not (39).

A limitation of this study is an inability to draw any conclusions about causality or the direction of the observed relationships because of the cross-sectional nature of the data. It is possible that some as yet unrecognized and unmeasured factor may influence both the ACIC score and the patient's A1C. For example, physicians who are more oriented toward chronic disease care may structure their clinics around the elements of the CCM as well as be more aggressive in intensifying medications for glucose control. This may represent some level of training or attitude by the physician that is responsible for both the ACIC score and the A1C value. Also, with only one physician in 11 of the 20 clinics, it may be difficult to distinguish organizational effects from the effects of the individual physician's orientation toward chronic illness care. There was also a wide diversity of clinic types. We compared clinics that were physician owned to ones in which the physicians were employees and also compared the four clinics that were community health center–type clinics with those that were not and found no significant differences in either ACIC scores or mean A1C values (data not shown)

Subjects in the final model were significantly older and had higher A1C values than those who were not included because of missing data. Thus, these results may be more applicable to clinics with older patients who have worse control of their diabetes. However, the inverse relationship between ACIC score and A1C in the unadjusted random effects model was similar when the 37 subjects with missing covariates but with some A1C measures were included in the analysis: the mean decrease in A1C was 0.08 ($P = 0.0004$) with a 1-unit increase in ACIC score.

Our measures of exercise and diet adherence depended on patients' perceptions of what exactly was recommended by their physician. It is possible that the content of the recommendation varied considerably across physicians and clinics. Thus, a patient seen by a physician who is content with any level of physical activity may report that the patient is in the maintenance stage for exercise, whereas a patient seen by a physician who insists on 30 min of uninterrupted moderate activity may state that the patient or she is in the preparation stage, even though both patients have similar levels of physical activity. Even so, both diet and exercise measures were associated with A1C levels, reflecting a degree of external validity.

In summary, characteristics of the primary care clinic where one receives diabetes care are an important predictor of glucose control, but this relationship is only important for those who are not adhering to exercise. One potential implication of this finding is that if resources for implementing the CCM across a number of clinics are limited, one might want to focus those resources on clinics with low ACIC scores that serve a population of sedentary patients, as they may be likely to realize the most benefit from improving glucose control. For example, in one of the clinics in the bottom quartile of ACIC scores, only 25% of patients were in the maintenance stage of change for exercise (the median value was 46%). Prospective studies are needed to further evaluate the effect of implementing the CCM in small, autonomous primary care clinics. In these studies, patient self-care behaviors should also be carefully observed and measured as covariates in evaluating the effect of the intervention on patient outcomes.

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