Driving Distance as a Barrier to Glycemic Control in Diabetes

Kaitlin Strauss, BA,¹ Charles MacLean, MDCM,¹ Austin Troy, PhD,² Benjamin Littenberg, MD¹

¹College of Medicine, University of Vermont, Burlington, VT, USA; ²Rubenstein School of Natural Resources, University of Vermont, Burlington, VT, USA.

BACKGROUND: Despite advances in treatment of diabetes, many barriers to good glycemic control remain.

OBJECTIVE: To determine the relationship between glycemic control and the driving distance from home to the site of primary care.

DESIGN: Cross-sectional analysis of data from the Vermont Diabetes Information System.

PARTICIPANTS: Nine-hundred and seventy-three adults with diabetes in primary care. The mean age was 64.9 years, 57% were female, and 18.4% used insulin.

MEASUREMENTS: Hemoglobin A1c, shortest driving distance from a patient's home to the site of primary care calculated by geographic software, self-reported gender, age, education, income, marital status, race, insurance coverage, diabetic complications, and use of insulin and oral hypoglycemic agents.

RESULTS: Controlling for social, demographic, seasonal, and treatment variables, there was a positive, significant relationship between glycemic control and driving distance ($\beta = +0.07\%/10 \text{ km}$, $P < .001$, 95% confidence interval [CI] = $+0.03$, $+0.11$). Driving distance had a stronger association with glycemic control among insulin users ($\beta = +0.22\%/10 \text{ km}$, $P = .016$, 95% CI = $+0.04$, $+0.40$) than among non-insulin users ($\beta = +0.06\%/10 \text{ km}$, $P = .006$, 95% CI = $+0.02$, $+0.10$).

CONCLUSION: Longer driving distances from home to the site of primary care were associated with poorer glycemic control in this population of older, rural subjects. While the mechanism for this effect is not known, providers should be aware of this potential barrier to good glycemic control.

KEY WORDS: diabetes mellitus; Geographic Information Systems; rural health services; health services accessibility; transportation.

DOI: 10.1111/j.1525-1497.2006.00386.x

J GEN INTERN MED 2006; 21:378-380.

© 2006 by the Authors

Despite the availability of effective treatments, many patients with diabetes do not achieve optimal glycemic control.^{1,2} Obstacles include inefficient practice management and poor organization,³⁻⁵ nonadherence to medical advice,⁶ low health literacy,^{7,8} comorbid illnesses,⁹ and poor insurance coverage.¹⁰

Travel burden may be another obstacle, especially in rural areas. Travel was the most common concern among rural cancer patients treated at an urban hospital.¹¹ Travel burden includes arranging transportation, the time required to travel, arranging child care, the cost of missing work, and the cost of transportation. Driving distance is 1 aspect of travel burden, and may serve as a marker for at least some of the burden of obtaining care.

While some research has been carried out linking travel burden to health services utilization,^{12,13} the link between

driving distance and health outcomes has not been investigated. We examined the relationship between glycemic control and the driving distance from a patient's home to the site of primary care.

METHODS

We performed a cross-sectional analysis of the Vermont Diabetes Information System (VDIS), a study of diabetes outcomes in primary care practices in Vermont, New Hampshire, and northern New York.¹⁴ Laboratory data are collected daily from clinical laboratories and processed in a decision support database that feeds back to patients and providers. Although VDIS targets glycemic control, the data used in this study were collected before the VDIS intervention began. The University of Vermont Institutional Review Board approved the study.

All subjects in the VDIS were over age 18 and had a diagnosis of diabetes confirmed by their provider. Subjects were selected at random from participating practices and invited by phone to an in-home interview. We attempted to contact 4,209 patients and reached 1,576 (37.4%). Of these, 1,007 (23.9%) agreed to be interviewed. All interviews were completed between July 2003 and March 2005. All subjects gave written informed consent to participate in the interview, and received a \$20 gratuity.

Glycemic control was assessed by glycosylated hemoglobin (HbA1c) assay at 12 local laboratories, which all use the same method. The most recent measurement was used in statistical modeling. The median time between the measurement and the interview was 131 days with 90% within 366 days. The shortest driving distance along roads and highways from the patient's home to the site of primary care was calculated using a geographic dataset (TeleAtlas Inc., Lebanon, NH) and ArcView 3.3 (Environmental Systems Research Institute Inc., Redlands, CA). Other patient variables were collected by a questionnaire administered in the home.

Correlation was assessed by nonparametric Spearman rank-order correlations. Group differences in continuous variables were assessed by Wilcoxon rank sum tests. We divided the eligible subjects into 3 equally sized groups (tertiles) based on their driving distances. Trends across tertiles were assessed by an extension of Wilcoxon rank sum test.¹⁵ Because both HbA1c and driving distance were skewed and contained outliers, we used robust linear regression.¹⁶

To explore possible confounding, variables that were correlated with both distance and HbA1c with $P < .1$ were included in a multivariate regression. We tested variables that represent social and clinical factors that, if distributed differently among patients living nearer care than those living farther away, could explain the relationship between distance and glycemic control. The potential confounders tested were age, sex, race

The authors have no conflicts of interest to declare.

Address correspondence and requests for reprints to Ms. Strauss: College of Medicine, University of Vermont, 371 Pearl St, Burlington, VT 05401 (e-mail: kstrauss@uvm.edu).

Manuscript received July 13, 2005

Initial editorial decision September 14, 2005

Final acceptance December 2, 2005

(white vs other), marital status (married or living as married vs other), education (in 7 ordered categories), income (in 7 ordered categories), 5 insurance types (private, Medicare, Medicaid, Military or Veterans Affairs, and none), duration of diabetes, the self-reported presence of each of 5 diabetic complications (foot ulcers, retinopathy, neuropathy, gastropathy, and nephropathy), use of insulin, and use of oral hypoglycemic medications. To assess the possible effect of seasonal variation in glycemic control,¹⁷ each regression also included an indicator variable for the month of the year in which HbA1c was measured.

RESULTS

We completed 1,007 interviews, but excluded 34 subjects with missing data: medication list (1), age (1), HbA1c (7), or driving distance (25). The baseline characteristics of the 973 final participants are shown in Table 1. This group was older (median 66 vs 63 years, $P<.001$), had shorter driving distances (median 7.7 vs 9.0 km, $P=.006$), and poorer glycemic control (median 6.9% vs 6.7%, $P<.001$) than the other 7,738 VDIS participants.

Glycemic control varied with driving distance. Those in the nearest tertile (under 3.6 km) had a median A1C of 6.8%. The middle tertile had a median HbA1c of 6.85%. Those driving over 13.3 km had a median HbA1c of 7.0%. The trend was statistically significant with $P=.022$.

The only variables associated with both glycemic control and driving distance were age, Medicare insurance, and use of insulin. Because Medicare insurance coverage was strongly associated with age and had 10 missing values, we elected to

retain age in the model instead. Controlling for age, seasonality, and insulin use in multivariate robust linear regression, distance was significantly associated with HbA1c ($\beta=+0.07\%/10\text{ km}$, $P=.001$, 95% CI= $+0.03$, $+0.11$).

Because we found a significant interaction between driving distance and insulin use ($P=.03$), we stratified the analysis. Among 794 noninsulin users, controlling for age and month, driving distance was significantly associated with glycemic control ($\beta=+0.06\%/10\text{ km}$, $P=.006$, 95% CI= $+0.02$, $+0.10$). Among 179 insulin users, the coefficient was substantially greater ($\beta=+0.22\%/10\text{ km}$, $P=.016$, 95% CI= $+0.04$, $+0.40$).

CONCLUSIONS

Driving distance was significantly associated with glycemic control in this population of older, rural subjects. Each 35 km (22 miles) of driving distance was associated with a 0.25% increase in HbA1c. This effect was independent of sex, marital status, education, income, insurance coverage, seasonal variations, and diabetic complications. The effect was more pronounced among insulin users. For comparison, adding an oral agent to the regimen of a patient with type 2 diabetes will typically produce a 0.5% to 1.0% improvement in HbA1c. Several mechanisms may contribute to this relationship. Longer driving distances may mean fewer office visits and less monitoring. Additionally, those who live farther away may be perceived to be at greater risk for hypoglycemic complications, leading to less aggressive care. This idea is supported by the higher coefficient observed among insulin users.

There were several limitations to this study. Driving distance from home to the site of primary care is not a perfect measure of travel burden. Some subjects may not travel to their primary care provider directly from their home. Some roads are more difficult to travel on than others, especially in the winter. There are financial costs associated with lost work, child care, and fuel, as well as other factors. For those who are unable to drive, access to public transportation or transportation from a friend or relative also affects travel burden. These potential errors are likely to be randomly assorted and would be expected to reduce the precision of our estimates without introducing bias. Because the subjects are largely from rural areas, and there are few racial minorities, this study has limited generalizability to urban areas and areas with more diverse populations. Possibly, some patients were not included because they did not have an HbA1c test within 2 years of the study start. To confound the relationship between driving distance and glycemic control, the omitted subjects with poor control would have to tend to live nearer to the site of primary care than the included subjects. This seems highly unlikely. There was some evidence of nonrandom sampling from the underlying population, perhaps because older, retired subjects were more willing to participate. However, age and distance are not significantly correlated in these data (correlation= -0.04 ; $P=.21$), indicating no confounding. Finally, unmeasured confounders associated with both longer distances and higher A1C values may be responsible for the observed relationship.

This study also had several strengths. The large sample size increases confidence that the findings are not because of random error. Many potential confounders were measured and controlled for. The exact addresses of both the patient's home and the primary care provider's office were known. Each

Table 1. Study Population Characteristics (n=973)*

Characteristic	Result
Driving distance (km), mean (standard deviation)	12.2 (16.7)
A1C (%), mean (standard deviation)	7.11 (1.28)
A1C < 7%	57
Age in years, mean (standard deviation)	64.9 (12.0)
Gender (female)	55
Race (white)	97
Married (or living as married)	62
Education less than high school	24
High school graduate without college	36
Bachelor's degree or higher	18
Income < \$15,000/y	32
Income \$75,000/y or more	8
Health insurance†	
Private or commercial	58
Medicare	60
Medicaid	21
Military or Veterans Affairs	5
None	2
Duration of diabetes in years, mean (standard deviation)	10.3 (10.3)
Complications of diabetes	
Foot ulcers	11
Vision problems	20
Peripheral neuropathy	31
Gastropathy	6
Sexual problems	26
Nephropathy	8
Treatment	
Insulin	18.4
Oral hypoglycemic agent	67

*Results are percentages except where noted.

†Some subjects had more than 1 insurance type.

patient's diagnosis of diabetes was confirmed by their primary care provider, rather than deduced from laboratory tests or billing data.

Primary care providers should be aware of driving distance as a potential barrier to aggressive management of diabetes and to glycemic control. In the long term, it may be useful to minimize travel burden for diabetic patients, perhaps by enhanced public transportation, more clinic locations in rural areas, telephone or other electronic links, or home care. Further research should be conducted into more effective ways to connect primary care providers and rural patients.

This work was funded by the National Institute of Diabetes and Digestive and Kidney Diseases (R01 DK61167 and K24 DK068380).

REFERENCES

1. **Saaddine JB, Engelgau MM, Beckles GL, Gregg EW, Thompson TJ, Narayan KM.** A diabetes report card for the United States: quality of care in the 1990s. *Ann Intern Med.* 2002;136:565-74.
2. **Saydah SH, Fradkin J, Cowie CC.** Poor control of risk factors for vascular disease among adults with previously diagnosed diabetes. *JAMA.* 2004;291:335-42.
3. **Frame PS.** Health maintenance in clinical practice: strategies and barriers. *Am Fam Physician.* 1992;45:1192-200.
4. **Stolar MW.** Clinical management of the NIDDM patient. Impact of the American Diabetes Association practice guidelines, 1985-1993. Endocrine Fellows Foundation Study Group. *Diabetes Care.* 1995;18:701-7.
5. **Cabana MD, Rand CS, Powe NR, et al.** Why don't physicians follow clinical practice guidelines? A framework for improvement. *JAMA.* 1999;282:1458-65.
6. **Warren L, Hixenbaugh P.** Adherence and diabetes. In: Meyers LB, Midence K, eds. *Adherence to Treatment in Medical Conditions.* Amsterdam: Harwood; 1998:423-53.
7. **Williams MV, Parker RM, Baker DW, et al.** Inadequate functional health literacy among patients at two public hospitals. *JAMA.* 1995;274:1677-82.
8. **Schillinger D, Grumbach K, Piette J, et al.** Association of health literacy with diabetes outcomes. *JAMA.* 2002;288:475-82.
9. **Goel A, MacLean CD, Walrath D, et al.** Adapting root cause analysis to chronic medical conditions. *Jt Comm J Qual Saf.* 2004;30:175-86.
10. **Harris MI.** Health care and health status and outcomes for patients with type 2 diabetes. *Diabetes Care.* 2000;23:754-8.
11. **Hegney D, Pearce S, Rogers-Clark C, Martin-McDonald K, Buikstra E.** Close, but still too far. The experience of Australian people with cancer commuting from a regional to a capital city for radiotherapy treatment. *Eur J Cancer Care.* 2005;14:75-82.
12. **Borders TF, Rohrer JE, Hilsenrath PE, Ward MM.** Why rural residents migrate for family physician care. *J Rural Health.* 2000;16:337-48.
13. **Arcury TA, Preisser JS, Gesler WM, Powers JM.** Access to transportation and health care utilization in a rural region. *J Rural Health.* 2005;21:31-8.
14. **MacLean CD, Littenberg B, Gagnon M, Reardon M, Turner PW, Jordan C.** The Vermont Diabetes Information System (VDIS): study design and subject recruitment for a cluster randomized trial of a decision support system in a regional sample of primary care practices. *Clin Trials.* 2004;1:523-44.
15. **Cuzick J.** A Wilcoxon-type test for trend. *Stat Med.* 1985;4:87-90.
16. **Hamilton L.** How robust is regression? *Stata Tech Bull.* 1991;2:21-6.
17. **Tseng CL, Brimacombe M, Xie M, et al.** Seasonal patterns in monthly hemoglobin A1c values. *Am J Epidemiol.* 2005;161:565-74.