Influence of Health Care Providers on the Development of Diabetes Complications

Long-term follow-up from the Pittsburgh Epidemiology of Diabetes Complications Study

JANICE C. ZGIBOR, PHD[1]
THOMAS J. SONGER, PHD[1]
SHERYL F. KELSEY, PHD[1]
ALLAN L. DRASH, MD[2]
TREVOR J. ORCHARD, MD[1]

OBJECTIVE — To quantify total diabetes care received (generalist or specialist) from diagnosis onward and its association with the incidence of diabetes complications in a representative cohort of patients with type 1 diabetes.

RESEARCH DESIGN AND METHODS — A total of 429 subjects from the Pittsburgh Epidemiology of Diabetes Complications Study, a prospective follow-up study of childhood-onset type 1 diabetic subjects first seen between 1986 and 1988 (mean age 28 years, mean duration 19 years), followed biennially for up to 10 years were studied. Specialist care was defined as care received from a board-certified endocrinologist, diabetologist, or diabetes clinic and quantified as the percent of diabetes duration spent in specialist care.

RESULTS — There was a significant trend for a higher incidence of neuropathy, overt nephropathy, and coronary artery disease with lower use of specialist care. Multivariate analyses controlling for diabetes duration, demographic characteristics, health care practices, and physiological risk factors demonstrated that higher past use of specialist care was found to be significantly protective against the development of overt nephropathy (risk ratio 0.43, 95% CI 0.21–0.88) and neuropathy (0.54, 0.35–0.83) and weakly protective against coronary artery disease (0.65, 0.37–1.1).

CONCLUSIONS — A higher proportion of diabetes duration spent in specialist care may result in delayed development of certain diabetes complications independent of other risk factors. This study thus supports the concept that the benefits of specialist care should be available to all patients with type 1 diabetes.

Diabetes Care 25:1584–1590, 2002

Primary care providers are the main source of care for patients with chronic disease (1,2). However, studies examining the quality of care delivered by provider type (generalist or specialist physician) in chronic diseases have generally demonstrated that specialists adopt newer, more effective treatment techniques (3,4), provide care that more closely adheres to established practice guidelines (5), deliver care that results in better outcomes (6,7), and may be more cost-effective (8) when compared with generalists. Studies comparing care received by specialists and generalists and use of preventive care services for people with diabetes have demonstrated higher rates of self-monitoring of blood glucose, intensive insulin therapy (more than two injections per day), and dilated eye examinations and better glycemic control in individuals receiving care from diabetes specialists (7,9,10).

Examination of the effect that health care providers have on long-term outcomes is complex because providers change over time, as does the therapeutic treatment of diabetes. To date, there have been few prospective data in cohorts of patients with diabetes examining the effect of care received over the duration of diabetes and complication incidence. Therefore, this study sought to quantify the diabetes care received (generalist or specialist) from diagnosis onward and its association with the incidence of diabetes complications in a representative cohort of patients with childhood-onset type 1 diabetes.

RESEARCH DESIGN AND METHODS

— Participants for this evaluation were identified from the Pittsburgh Epidemiology of Diabetes Complications Study (EDC) cohort: a 10-year prospective follow-up study of childhood-onset (<17 years of age) type 1 diabetes. The study design was a prospective cohort design examining the association of specialist care with the incidence of diabetes complications during the 10-year EDC follow-up period. The EDC has been previously described (11,12). Briefly, study participants were diagnosed between 1950 and 1980 and seen within 1 year of diagnosis at Children's Hospital of Pittsburgh. Although this population is clinic based, it was shown to be representative of the type 1 diabetic population of Allegheny County, Pennsylvania (13). By

From the [1]Department of Epidemiology, Graduate School of Public Health, University of Pittsburgh, Pittsburgh, Pennsylvania; and the [2]Department of Pediatrics, Division of Endocrinology, University of Pittsburgh, Pittsburgh, Pennsylvania.

Address correspondence and reprint requests to Janice Zgibor, PhD, Rm. 214, DLR Building, 3512 Fifth Ave., Pittsburgh, PA 15213. E-mail: edcjan@pitt.edu.

Received for publication 21 November 2001 and accepted in revised form 30 April 2002.

Abbreviations: AER, albumin excretion rate; CAD, coronary artery disease; CDSP, confirmed distal symmetric polyneuropathy; DCCT, Diabetes Control and Complications Trial; DCHS, Diabetes Care History Survey; DSP, distal symmetric polyneuropathy; EDC, Pittsburgh Epidemiology of Diabetes Complications Study; LEAD, lower-extremity arterial disease; ON, overt nephropathy; PR, proliferative retinopathy; RR, risk ratio.

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

See accompanying editorials on p. 1654 and p. 1657.

definition, all subjects received at least 1 year, and in some cases as many as 18 years, of specialist care. Of the current cohort, 35.7% continued to receive diabetes specialist care immediately after stopping care at Children's Hospital. There were 658 subjects who participated in the baseline examination (1986–1988) and who received care in the general community. The 429 subjects included in these analyses (mean age 27 years, mean duration 19 years at baseline, mean age at diagnosis 8 years) were participants of the sixth biennial examination (10-year follow-up: 1996–1998). Before their scheduled clinic visit, participants were sent questionnaires concerning demographic, health care, self-care, and medical history information. Included in these surveys was the Diabetes Care History Survey (DCHS). In this instrument, participants were asked to provide information on providers of their diabetes care from the time of diagnosis until the 10-year follow-up examination. If participants saw more than one physician during any year for their diabetes care, they were asked to list the two physicians seen most frequently during that year. Before the questionnaire was mailed to the participant, information known about the participants' health care history was supplied for them on a year-by-year basis given their responses to previous EDC questionnaires. On completion of the DCHS, physician specialty was classified according to the American Medical Directory (14) and further defined using the Official American Board of Medical Specialties (ABMS) Directory of Board Certified Medical Specialists (15). A diabetes specialist was defined as a board-certified endocrinologist or diabetologist (any physician not board-certified in endocrinology but whose self-reported specialty was diabetes or endocrinology) or a diabetes clinic (defined as hospital-based clinics offering a fellowship training program in endocrinology). Providers with more than one classification (e.g., internist and endocrinologist) were coded according to their highest level of certification or practice specialty.

Definition of outcome complications and risk factors

Several micro- and macrovascular complications of diabetes have been assessed in the EDC. Proliferative retinopathy (PR) was determined by stereo fundus photography (classified by the Arlie House System) (16) or a history of laser therapy for proliferative disease. Overt nephropathy (ON) was defined as an albumin excretion rate (AER) >200 μg/min on at least two of three timed urine samples or, in the absence of urine, a serum creatinine level >2 mg/dl, renal failure, or renal transplant. Distal symmetric polyneuropathy (DSP) was considered present if, on examination, according to the Diabetes Control and Complications Trial (DCCT) protocol (17), the participant had at least two of the following: symptoms consistent with DSP, decreased or absent deep tendon reflexes, or signs of sensory loss. At the 4-year follow-up examination and thereafter (i.e., for 101 of 108 incident subjects), confirmed DSP (CDSP) was determined by the presence of a vibratory threshold above the age-specific normal range using the Vibratron II tester (Physitemp Instruments, Clifton, NJ). Coronary artery disease (CAD) was determined by EDC physician–diagnosed angina, or myocardial infarction was confirmed by Q-waves on an electrocardiogram or through hospital records (Minnesota codes 1.1 or 1.2), or by angiographic stenosis $\geq$50%, coronary artery bypass surgery, angioplasty, or ischemic electrocardiogram changes (Minnesota codes 1.3, 4.1, 4.2, 5.1, 5.2, and 7.1). Lower-extremity arterial disease (LEAD) was defined by a history of amputation or claudication, or an ankle brachial index $<$0.9 at rest. Hypertension was defined as blood pressure $\geq$140/90 mmHg or use of antihypertensive medication. Stable glycosylated hemoglobin (HbA_1) was measured by ion-exchange chromatography (Isolab, Akron, OH) and subsequently by automated high-performance liquid chromatography (Diamat; BioRad, Hercules, CA). Readings with the two methods were almost identical ($r = 0.95$). HDL cholesterol was determined by a precipitation technique (heparin and manganese chloride) with a modification (18) of the Lipid Research Clinics method (19). Cholesterol and triglycerides were measured enzymatically (20,21). LDL cholesterol levels were calculated from measurements of the levels of total cholesterol, triglycerides, and HDL using the Friedewald equation (22). Household income, level of education, health care practices, and smoking status (ever/never) were obtained via self-report.

Statistical analysis

The type of provider listed by the participants often changed. Thus, specialist care was calculated as a variable based on the total percent of diabetes duration that a patient was treated by a specialist provider. To calculate the care received, the number of years treated by each listed provider was totaled. The totals were then divided by the duration of diabetes to derive a percent of diabetes duration spent in specialist care. Because participants could list the names of two health care providers for any given year, each provider was equally weighted. Patients prevalent for the complication at baseline were excluded from all incidence analyses. Univariate associations of baseline data were performed using the χ^2 test, Student's *t* test, or the Wilcoxon's rank-sum test. The Cochran Armitage test for trend was used to examine associations between tertiles of specialist care and incident complication rate to examine a possible dose-response relationship. Independent associations between specialist care and incident complications were assessed using Cox proportional hazards modeling. The outcome variable in these models was the complication of interest. Explanatory variables from the baseline examination were included using the following series of regression models with specialist care (up to and including the baseline examination) and duration forced into all models: model 1 (base model) = specialist care + diabetes duration; model 2 = model 1 + sex + income; model 3 = model 2 + physician visit in previous 12 months + test blood glucose at least weekly + more than two insulin injections/day; model 4 = model 3 + other variables primarily found to be associated with the complication of interest (enumerated in Table 3). Explanatory variables chosen for inclusion in the models were not limited by statistical significance but were based on literature review and analyses previously conducted in the EDC in addition to the current analyses. Potential confounders were entered into models 1–3 to examine if these indeed affected results. Explanatory variables with the exception of specialist care and diabetes duration were entered into the models in a forward stepwise fashion. Follow-up time for participants who did not develop the complication ended at examination 6. Because the specialist care variable was not normally distributed, it

Table 1—*Baseline sociodemographic characteristics, lifestyle behaviors, health care practices, and clinical characteristics according to use of specialist care: EDC*

Characteristic	Nonspecialist	Specialist	*P*
n	215	214	—
Demographic			
Age (years)	30.5 ± 6.9	24.0 ± 7.3	<0.0001
Duration (years)	21.5 ± 7.3	16.2 ± 6.7	<0.0001
Sex (%male)	52.6 (113)	43.9 (94)	0.07
Income (earning >$20,000/year)	86.0 (154)	86.7 (143)	0.86
Educational level (beyond high school)	61.5 (126)	70.7 (116)	0.06
Health care practices			
Weekly testing of blood glucose	50.0 (105)	65.2 (135)	0.002
More than two insulin injections per day	6.7 (14)	9.2 (19)	0.34
Saw physician in last year	78.5 (146)	90.5 (180)	0.001
Saw eye doctor in the last 2 years	67.9 (125)	74.6 (132)	0.16
Clinical characteristics			
HbA_1 (%)	10.2 ± 1.7	10.3 ± 1.8	0.35
HDL cholesterol (mg/dl)	55.0 ± 13.3	54.4 ± 1.7	0.62
LDL cholesterol (mg/dl)	116.2 ± 33.1	108.2 ± 30.8	0.01
Total/cholesterol (mg/dl)	190.2 ± 38.6	180.3 ± 36.8	0.007
Triglycerides (mg/dl)*	97.9 ± 69.4	93.3 ± 58.5	0.54
AER (μg/min)	347.8 (984.7)	178.5 (599.1)	0.0003
Hypertensive	17.2 (37)	8.4 (18)	0.006
Lifestyle behaviors			
Alcohol use (drinks/week)	4.7 ± 7.8	3.9 ± 6.8	0.36
Ever smoked	42.4 (89)	23.8 (49)	0.001

Data are means ± SD or % (*n*). *Natural log-transformed before analyses. Specialist care is defined as the percent of diabetes duration spent in specialist care (>65%) compared with nonspecialist care (≤65%).

was dichotomized at the median value of 65% for specialist care comparisons and regression analyses. Results were considered significant at $P \leq 0.05$.

RESULTS

Baseline characteristics

Of the original 658 EDC participants, 429 completed questionnaires at the 10-year follow-up examination (68 participants had died since the baseline examination). Nonparticipants of this examination had no cumulative historical provider data available and are thus not included in these incidence analyses. Individuals providing data for the 10-year follow-up did not differ by sex (48.3 vs. 54.7% male), diabetes duration (mean 18.9 years [range 7.7–36] vs. 18.0 years [7.8–37.3]), or complication status (DSP, ON, PR, CAD, and LEAD) from those eligible but not participating in examination 6 ($n = 161$). However, participants were older (27.3 years [range 8–44.8] vs. 25.7 years [9.8–46.3], $P = 0.03$), were more likely to have an income >$20,000 per year (86.3 vs. 78.3%, $P = 0.04$), and had lower HbA_1 (10.3 vs. 10.6%, $P = 0.06$) and triglyceride (95.6 vs. 117.2 mg/dl, $P = 0.02$) levels.

Specialist care and complication risk factors

Comparisons between individuals reporting a higher (defined as >65% of diabetes duration in specialist care) or lower (defined as ≤65% diabetes duration in specialist care) proportion of specialist care are summarized in Table 1. People with a higher proportion of specialist care were younger, had shorter diabetes duration, and were more likely to have seen a physician in the previous year and to test blood glucose. They had better lipid profiles (no significant difference in HDL cholesterol) and were less likely to be hypertensive or to have ever smoked.

Incidence of complications

The number of incident cases and incidence density for each complication is shown in Table 2. The mean proportion of diabetes duration spent in specialist care through the baseline visit is also shown for individuals who were incident cases and for those who remained free from complications. This proportion was significantly higher in individuals who did not develop DSP, ON, and CAD. The association was not significant for PR or LEAD.

Figure 1 shows the proportion of incident cases for each complication by tertile of specialist care. For CDSP, ON, and CAD, the group of individuals with the lowest proportion of diabetes duration spent in specialist care had the largest proportion of patients developing the complication. The test for trend was significant for CDSP, ON, and CAD.

Independent effect of specialist care

As previously described, a series of four multivariate models were used to examine the independent influence of specialist care on complication outcomes. Higher use of specialist care was significantly and independently associated with lower CDSP until physiological risk factors were introduced (model 4). Risk ra-

Table 2—*Incidence and percent of diabetes duration spent in specialist care by the 10-year incidence of diabetes complications in type 1 diabetes: EDC*

Complication	Cases (*n*)	Incidence density (per 100 person-years)	Mean % (SD) duration in specialist care		*P**
			With complications	Without complications	
CDSP	108	3.9	49.6 (35.8)	68.9 (35.2)	0.0001
ON	41	1.2	46.5 (40.6)	63.2 (33.6)	0.005
PR	113	4.1	62.1 (34.7)	62.4 (36.5)	0.85
CAD	68	1.7	47.1 (34.7)	61.9 (34.7)	0.002
LEAD	95	2.7	55.9 (35.40)	60.3 (35.5)	0.23

*Determined by the Wilcoxon rank-sum test.

tios (RRs) were 0.48, 0.44, 0.53, and 0.76 for models 1–4, respectively. Sex, income, seeing a physician in the previous year, and intensive insulin therapy had little effect on the RRs when introduced into the model (models 2 and 3). Results demonstrated that a higher use of specialist care was also significantly and independently associated with less ON across all four models (RR = 0.46, 0.32, 0.34, and 0.21 for models 1–4, respectively). Higher income and self-monitoring were also significantly associated with less ON; however, both income and self-monitoring lost significance when physiological risk factors were introduced into the model. Although associations between specialist care and CAD were not significant, RRs remained protective across models (CAD RR = 0.63, 0.60, 0.59, and 0.87 for models 1–4, respectively). Neither income nor sex was significantly associated with CAD. Higher AER was associated with an increased risk of CAD, whereas a higher HDL cholesterol level was protective. Significant associations were not found between specialist care and LEAD and PR after multivariate adjustment. Because of the potential influence of missing data on the results, models were confirmed by introducing only those variables significantly associated with outcomes in the final model together with specialist care and diabetes duration. These results are presented in Table 3. Because specialist care was related to ON, which is defined by the AER, models were also examined without AER, with no change to the interpretation of the association between specialist care and complications. Further, level of education and household income combined with level of education were introduced into the models. The overall interpretation of the association between specialist care and complications did not change, with the exception of the LEAD model. When education was in the model, the association between specialist care and LEAD became protective but not significantly so (RR = 0.81 [95% CI 0.45–1.5]). The specialist care variable was also entered into the models after being divided into tertiles. Again, the overall interpretation of the results did not change; however, the positive association between specialist care and proliferative retinopathy became borderline significant. Additionally, the CIs around the hazard ratios for specialist care narrowed for all complications.

CONCLUSIONS — These analyses examined the influence of diabetes specialist care (quantified since diagnosis) on the incidence of diabetes complications in a representative cohort of patients with type 1 diabetes. Results demonstrated that a higher proportion of diabetes duration spent in specialist care was associated with a lower incidence of ON and neuropathy. In addition, the relative risk for CAD was also consistently reduced, albeit statistically nonsignificantly in individuals with greater specialist care. This relationship remained independently protective for the development of ON after adjusting for related variables, including diabetes duration, sex, health care practices (e.g., seeing a physician in the previous year, self-monitoring of blood glucose, and intensive insulin therapy [more than two injections per day]), and physiological risk factors. Although the independent influence of specialist care was attenuated for CDSP and CAD in the final models, when physiological risk factors were in-

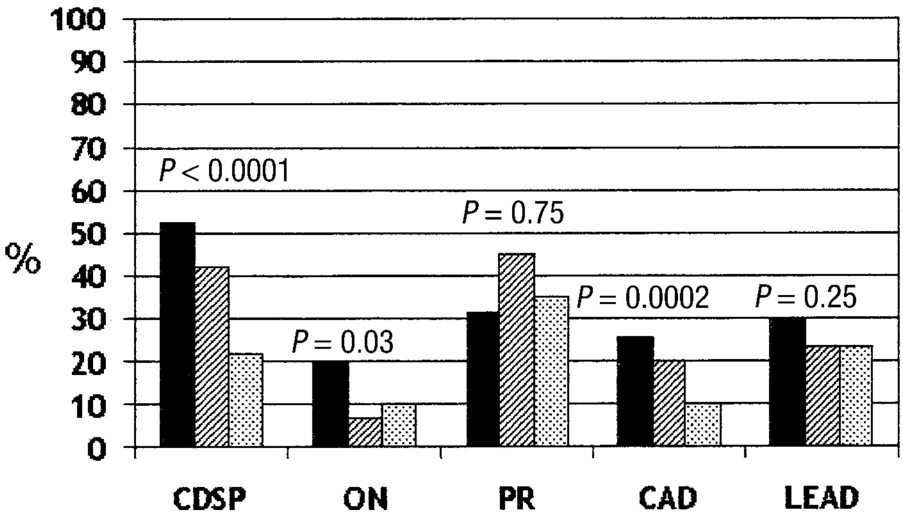

Figure 1—*The 10-year incidence of diabetes complications by tertile of specialist care: EDC. The proportion of patients' incident for each of the complications presented by tertile of specialist care is represented. Low use of specialist care (■) (0–33.3% of diabetes duration), moderate use of specialist care (▨) (>33.3–66.7% of diabetes duration), and high use of specialist care (▤) (>66.7–100% of diabetes duration) are shown.*

Table 3—*Independent risk factors associated with incidence of diabetes complications: Cox regression analysis, EDC*

Model	Total *n* (events)	Risk factor	RR	95% CI
CDSP	307 (107)	Specialist care (high:low)	0.54	0.35–0.83*
		Diabetes duration (years)	1.3	1.0–1.6†
		HbA_{1c} (%)	1.6	1.3–2.0‡
		Height (cm)	1.0	1.0–1.0†
		AER (μg/min)	1.3	1.0–1.5†
		Hypertension (yes:no)	2.8	1.6–5.0‡
		Smoking (yes:no)	1.5	0.98–2.2
ON	339 (39)	Specialist care (high:low)	0.43	0.21–0.88†
		Diabetes duration (years)	0.79	0.54–1.1
		HbA_{1c} (%)	2.0	1.5–2.7‡
		HDL cholesterol (mg/dl)	0.71	0.49–1.0
		Hypertension (yes:no)	3.2	1.2–8.7†
PR	314 (112)	Specialist care (high:low)	1.1	0.79–1.8
		Diabetes duration (years)	1.0	0.87–1.4
		HbA_{1c} (%)	1.6	1.3–1.9‡
		AER (μg/min)	1.4	1.2–1.8‡
		Systolic blood pressure (mmHg)	1.2	1.0–1.3†
CAD	404 (67)	Specialist care (high:low)	0.65	0.37–1.1
		Diabetes duration (years)	2.2	1.6–2.9‡
		HDL cholesterol (mg/dl)	0.68	0.51–0.9*
		AER (μg/min)	1.5	1.2–1.9‡
LEAD	205 (57)	Specialist care (high:low)	0.95	0.53–1.7
		Diabetes duration (years)	1.3	0.96–1.8
		Alcohol (drinks/week)	0.69	0.46–1.0
		Hypertension (yes:no)	2.7	1.5–5.1*

Specialist care (>65%: ≤65%) and diabetes duration were included in all models. *$P < 0.01$; †$P < 0.05$; ‡$P < 0.001$. Additional risk factors were made available to the final models as follows: *CDSP:* Sex, HbA_{1c}, height, AER, hypertension, smoking; *ON:* HbA_{1c}, HDL cholesterol, hypertension; *PR:* HbA_{1c}, AER, systolic blood pressure; *CAD:* HDL cholesterol, AER; *LEAD:* alcohol consumption, HbA_{1c}, triglycerides, hypertension. All risk factors presented are those significant in the model at the $P < 0.10$ level. RRs are presented per 1 SD increase for the following continuous variables: diabetes duration = 7.5 years, HbA_{1c} = 1.8%, AER = 1.9 μg/min, HDL cholesterol = 12.5 mg/dl, alcohol = 7.3 drinks/week, systolic blood pressure = 7.3 mmHg, triglycerides = 0.5 mg/dl. RRs for height are reported per 1-cm increase.

troduced, these findings did not diminish the importance of the relationship between specialist care and complications because it is likely these factors are true mediating variables that explain how specialist exerts its effect. Specialist care was not only associated with the complication outcome but was also associated with certain physiological risk factors (e.g., LDL cholesterol, HDL cholesterol, AER, and hypertension). Thus, adding these mediators to the model may attenuate the relationship between specialist care and complications because the physiological risk factors are also known to be associated with the outcome (23). Because individuals reporting a higher proportion of specialist care had better clinical profiles, specialist care may influence the development of complications indirectly. If so, it is not clear why specialist care did not demonstrate similar protective effects for proliferative retinopathy or LEAD. However, it may be that the high-risk group for the development of proliferative retinopathy has already progressed (prevalence was 26.8% at baseline), therefore eliminating a susceptible group from the incidence analyses (i.e., 314 of 429 available for incidence analyses). Additionally, participants may not have gone to specialists until having one or more complications, which could potentially underestimate the effect of specialist care.

Little prospective research is available that examines the influence of diabetes specialist care on complication outcomes. In a study by Schiel et al. (24), decentralization of diabetes care from specialist centers to general practice demonstrated an increase in rates of proliferative retinopathy and worse glycemic control in people with type 1 diabetes when comparing nonspecialized care in the decentralized system to centralized diabetes care. This study, however, did not follow the same cohort for the two time periods. In a cross-sectional comparison, Tabak et al. (25) found lower rates of proliferative retinopathy, albuminuria, and end-stage renal disease when comparing the Diab-Care Hungary, where diabetes care is specialized, with the EDC population, where care is a mixture of specialist and generalist providers. In the Verona Diabetes Study (26), individuals attending the diabetes center experienced a 17% lower mortality rate than individuals seeing family practitioners. Similarly, individuals regularly attending Steno Memorial Hospital (a diabetes specialty clinic) had better survival with later and less frequent occurrence of serious late diabetes complications than those with sporadic or no contact with the Steno Clinic. The excess mortality in the Steno study was due to an earlier and more common occurrence of renal disease in individuals with sporadic contact (27). These studies, together with the current study, demonstrate that differences in care delivery can affect outcomes in people with diabetes. Results from the Medical Outcomes Study (28) also demonstrated that endocrinologists achieved better foot ulcer infection outcomes, although the authors did not find any other significant associations with visual acuity, high rate of albumin excretion, or blood pressure control. The Medical Outcomes Study, however, did not consider care preceding the study. Because complications can develop over a longer period of time, the influence of specialist care may have been underestimated. Additionally, this study was limited to patients with type 2 diabetes; thus, results cannot be directly compared with the present evaluation.

In these analyses, there was no significant difference in glycemic control between individuals reporting specialist versus nonspecialist care. However, specialist care was not assessed concurrently with the HbA_1 measure but as a proportion of overall care. Also, in a previous analysis in this cohort, specialist care was found to be associated with better glycemic control when assessed concurrently. Self-testing, knowledge of HbA_{1c} testing, and the results of the DCCT were also found to be more prevalent in individuals receiving care from diabetes specialists (7). An analysis examining patients' perception of diabetes care indicated that specialists were more likely to encourage self-care, order HbA_{1c} tests, and to discuss HbA_{1c} results and home blood glucose monitoring (29). In another study, patients receiving care from specialists were more likely to perceive receipt of adequate care than patients receiving generalist care (29). The aforementioned studies support that outcomes may be better in patients who receive care from diabetes specialists. Additionally, patients' perceptions of care and satisfaction may result in better adherence to recommendations because they may feel more knowledgeable about self-management and self-efficacy. Thus, increased use of preventive health care and an increased knowledge base, characteristics associated with specialist care in this population, may promote better outcomes in these patients.

The DCHS, by design, asked that subjects recall their diabetes health care history for up to 48 years. This questionnaire, therefore, was subject to recall bias and potentially had low reliability. Although <5% of the data were missing (either left blank or the participant was unsure if he or she saw a health care provider in a given year), a repeatability study conducted in 19 participants demonstrated 95% agreement ($\kappa = 0.90$) assessing high or low use of specialist care between the first and second surveys administered an average of 17 months apart (range 3–26 months), thus indicating excellent reproducibility. Given that participants had to recall a long period of diabetes health care, a validation study using medical record review was also undertaken in these 19 participants. Complete medical record ascertainment was available for eight participants. Of the responses given by participants regarding the health care provider, 86% were validated through medical records provided by the physician named in the questionnaire.

The EDC is a prospective follow-up study of subjects shown to be representative of the childhood-onset type 1 diabetes population in Allegheny County, Pennsylvania (13). By design, this study provided clinical, socioeconomic, and demographic data for up to 10 years of follow-up in these patients, thus allowing the evaluation of the influence of a variety of risk factors on complication outcomes. This substudy is original in its design. Other studies, to the knowledge of the authors, have not examined the influence of specialist or generalist care on the incidence of diabetes complications during a patient's duration of diabetes. Although the provider data were historical in nature, complications were assessed prospectively, thus allowing the influence of type of provider on the incidence of complications to be assessed. Other studies examining effects of specialist care have not used standardized methods to classify care, as was done in this study. Additionally, studies examining this research question have been cross-sectional in nature (3,4,24,28,30) or conducted in clinic populations (5,9,10,31) with few examining complication outcomes. Studies examining the interrelationship between types of care received, socioeconomic factors, and complication outcomes appear to be absent in the literature. The current study adds to the available literature because it documents health care history and associations with the subsequent development of complications of the same cohort. One limitation of the current study is that other practice characteristics, e.g., solo versus group, and practice stability over time were not studied because these data were not fully available for the >700 providers studied. However, because most of the specialists were in stable group practices, the potential for further analysis is limited. This result does demonstrate the need for further study to identify characteristics of "best practices" and to translate these findings because the current analyses did not capture certain aspects of specialist care, such as frequency of self-monitoring or provider practice characteristics that may lead to an acute improvement in glycemic control, consequently affecting complication onset.

The results of this study suggest that specialist care may play a role in influencing health care practices and incidence of ON and neuropathy in patients with type 1 diabetes. This study did demonstrate associations between specialist care, socioeconomic status, and complication, mediating variables that can influence the development of complications. The interrelationship between the role of health care provider, socioeconomic status, and clinical characteristics as they relate to outcomes is a complex issue to disentangle. Although it is not feasible for all patients with diabetes to be seen by a diabetes specialist and some generalists may indeed deliver high-quality diabetes care, efforts aimed at the primary and secondary prevention of diabetes complications should focus on the identification of aspects of high-quality care that may lead to better outcomes, coordinated care between specialist and generalist physicians, and mechanisms that increase both patient and provider awareness of preventive service use.

Acknowledgments— This study was supported by National Institutes of Health Grant DK-34818.

This study was presented in part at the 60th Scientific Sessions of the American Diabetes Association, San Antonio, Texas, 9–13 June 2000 (Abstract 186).

References

1. Clancy CM, Franks P: Utilization of specialty and primary care: the impact of HMO insurance and patient-related fac-

tors. *J Fam Pract* 45:500–508, 1997

2. Cooper PF, NIchols LM, Taylor AK: Patient choice of physician: do health insurance and physician characteristics matter? *Inquiry* 33:237–246, 1996
3. Fendrick AM, Hirth RA, Chernew ME: Differences between generalist and specialist physicians regarding helicobacter pylori and peptic ulcer disease. *Am J Gastroenterol* 91:1544–1548, 1996
4. Schreiber TL, Elkhatib A, Grines CL, O'Neill WW: Cardiologist versus internist management of patients with unstable angina: treatment patterns and outcomes. *J Am Coll Cardiol* 26:577–582, 1995
5. Vollmer WM, O'Hollaren M, Ettinger KM, Stibolt T, Wilkins J, Buist S, Linton KLP, Osborne ML: Specialty differences in the management of asthma: a cross-sectional assessment of allergists' patients and generalists' patients in a large HMO. *Arch Intern Med* 157:1201–1208, 1997
6. Zeiger RS, Heller S, Mellon MH, Wald J, Falkoff R, Schatz M: Facilitated referral to asthma specialist reduces relapses in asthma emergency room visits. *J Allergy Clin Immunol* 87:1160–1168, 1991
7. Zgibor JC, Songer TJ, Kelsey SF, Weissfeld J, Drash AL, Becker D, Orchard TJ: The association of diabetes specialist care with health care practices and glycemic control in patients with type 1 diabetes: a cross-sectional analysis from the Pittsburgh Epidemiology of Diabetes Complications Study. *Diabetes Care* 23:472–476, 2000
8. Levetan CS, Passaro MD, Jablonski KA, Ratner RE: Effect of physician specialty on outcomes in diabetic ketoacidosis. *Diabetes Care* 22:1790–1795, 1999
9. Bloomfield S, Farquhar JW: Is a specialist paediatric diabetic clinic better? *Arch Dis Child* 65:139–140, 1990
10. Ho M, Marger M, Beart J, Yip I, Shekele P: Is the quality of diabetes care better in a diabetes clinic or in a general medicine clinic? *Diabetes Care* 20:472–475, 1997
11. Orchard TJ, Dorman JS, Maser RE, Becker DJ, Drash AL, Ellis D, LaPorte RE, Kuller LH: Prevalence of complications in IDDM by sex and duration: Pittsburgh Epidemiology of Diabetes Complications Study II. *Diabetes* 39:1116–1124, 1990
12. Orchard TJ, Dorman JS, Maser RE, Becker DJ, Ellis D, LaPorte RE, Kuller LH, Wolfson SK, Drash AL: Factors associated with avoidance of severe complications after 25 years of IDDM: Pittsburgh Epidemiology of Diabetes Complications Study I. *Diabetes Care* 13:741–747, 1990
13. Wagener DK, Sacks JM, LaPorte RE, MacGregor JM: The Pittsburgh Study of Insulin-Dependent Diabetes Mellitus: risk for diabetes among relatives of IDDM. *Diabetes* 31:136–144, 1982
14. American Medical Association: *American Medical Directory*. Chicago, 1967–1998
15. *The Official ABMS Directory of Board Certified Medical Specialists* (formerly *The Marquis Who's Who Directory of Medical Specialists)*. New Providence, NJ, Marquis Who's Who, 1970–1998
16. Early Treatment of Diabetic Retinopathy Study Coordinating Center: *Manual of Operations*. Baltimore, MD, University of Maryland School of Medicine, 1980
17. DCCT Research Group: *Manual of Operations for the Diabetes Control and Complications Trial*. Washington, DC, U.S. Department of Commerce, 1987
18. Warnick GR, Albers JJ: Heparin-MN(2+) quantitation of high density lipoprotein cholesterol: an ultrafiltration procedure for lipemic samples. *Clin Chem* 24:900–904, 1978
19. National Institutes of Health Department of Health Education and Welfare: *Lipid Research Clinics Program*. Washington, DC, U.S. Government Printing Office, 1975
20. Allain CC, Poon LS, Chan CSG, Richmond W, Fu PC: Enzymatic determination of total serum cholesterol. *Clin Chem* 20:470–475, 1974
21. Bucolo G, David H: Quantitative determination of serum triglycerides by the use of enzymes. *Clin Chem* 19:476–482, 1973
22. Friedewald WT, Levy RI, Fredrickson DS: Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. *Clin Chem* 18:499–502, 1972
23. Baron RM, Kenny DA: The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. *J Pers Soc Psychol* 51:1173–1182, 1986
24. Schiel R, Muller UA, Sprott H, Schmelzer A, Mertes B, Hunger-Dathe W, Ross IS: The JEVIN trial: a population-based survey on the quality of diabetes care in Germany: 1994/1995 compared to 1989/1990. *Diabetologia* 40:1350–1357, 1997
25. Tabak AG, Tamas T, Zgibor J, Wilson R, Becker D, Kerenyi Z, Orchard TJ: Targets and reality: a comparison of health care indicators in the U.S. (Pittsburgh Epidemiology of Diabetes Complications Study) and Hungary (Diabetes Care Hungary). *Diabetes Care* 23:1284–1289, 2000
26. Verlato G, Muggeo M, Bonora E, Corbellini M, Bressan F, de Marco R: Attending the diabetes center is associated with increased 5-year survival probability of diabetic patients: The Verona Diabetes Study. *Diabetes Care* 19:211–213, 1996
27. Deckert T, Poulsen JE, Larsen M: Prognosis of diabetics with diabetes onset before the age of thirty-one. II. Factors influencing the prognosis. *Diabetologia* 14:371–377, 1978
28. Greenfield S, Rogers W, Mangotich M, Carney MF, Talov AR: Outcomes of patients with hypertension and non-insulin-dependent diabetes mellitus treated by different systems and specialties. *JAMA* 274:1436–1444, 1995
29. Champagne N, Serrano RB, Edelman SV: Patients' perception of care: differences between diabetes specialist and general practitioners (Abstract). *Diabetes* 49 (Suppl. 1):A325, 2000
30. Chin MH, Friedmann PD, Cassel CK, Lang RM: Differences in generalist and specialist physicians' knowledge and use of angiotensin-converting enzyme inhibitors for congestive heart failure. *J Gen Intern Med* 12:523–530, 1997
31. Koproski J, Pretto Z, Poretsky L: Effects of an intervention by a diabetes team in hospitalized patients with diabetes. *Diabetes Care* 20:1553–1555, 1997