The Direct Medical Cost of Type 2 Diabetes

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OBJECTIVE — To describe the direct medical costs associated with type 2 diabetes, as well as its treatments, complications, and comorbidities.

RESEARCH DESIGN AND METHODS — We studied a random sample of 1,364 subjects with type 2 diabetes who were members of a Michigan health maintenance organization. Demographic characteristics, duration of diabetes, diabetes treatments, glycemic control, complications, and comorbidities were assessed by surveys and medical chart reviews. Annual resource utilization and costs were assessed using health insurance claims. The log-transformed annual direct medical costs were fitted by multiple linear regression to indicator variables for demographics, treatments, glycemic control, complications, and comorbidities.

RESULTS — The median annual direct medical costs for subjects with diet-controlled type 2 diabetes, BMI 30 kg/m^2, and no microvascular, neuropathic, or cardiovascular complications were $1,700 for white men and $2,100 for white women. A 10-kg/m^2 increase in BMI, treatment with oral antidiabetic or antihypertensive agents, diabetic kidney disease, cerebrovascular disease, and peripheral vascular disease were each associated with 10–30% increases in cost. Insulin treatment, angina, and MI were each associated with 60–90% increases in cost. Dialysis was associated with an 11-fold increase in cost.

CONCLUSIONS — Insulin treatment and diabetes complications have a substantial impact on the direct medical costs of type 2 diabetes. The estimates presented in this model may be used to analyze the cost-effectiveness of interventions for type 2 diabetes.

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The worldwide prevalence of diabetes is increasing (1), as is the demand for and cost of medical care (2). Many studies have described the economic impact diabetes has on the health system and society (3–6) and have compared the health care utilization of patients with and without diabetes (7–10). Only a few studies have assessed the relationship between patient characteristics, complications, and costs using patient-level data (11–16) and most have examined the relationship for aggregated end points (12,13,15,16). The purpose of this study was to describe the relationship between direct medical costs and individual demographic characteristics, treatments, glycemic control, complications, cardiovascular risk factors, and comorbidities in patients with type 2 diabetes.

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Abbreviations: CPT, current procedural terminology; DRG, diagnosis-related group; ESRD, end-stage renal disease; HMO, health maintenance organization; IQR, interquartile range; MI, myocardial infarction.

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

Previous models have assigned costs to specific diabetes-related health states (17–20). This approach is most appropriate for acute health states where interactions with other conditions are absent or clearly identifiable and of limited duration (21). A complex chronic disease like diabetes impacts many other apparently unrelated health problems and the resources used in their treatment. Therefore, it is important to extend the scope of a cost model beyond the direct complications of diabetes to include total direct medical costs. Only in this way can the true economic burden of diabetes be assessed.

RESEARCH DESIGN AND METHODS

— The study was reviewed and approved by the University of Michigan Institutional Review Board. All subjects were enrolled in commercial, Medicare, or Medicaid managed care programs offered by a large Michigan health maintenance organization (HMO). Subjects thus represented the employed, elderly, poor, and disabled population of southeastern Michigan. Eligible subjects had diabetes and were ≥18 years of age, nonpregnant, community-dwelling, continuously enrolled in the health plan for at least 18 months, had at least one claim for health services, and were able to give informed consent and to respond to a survey in English or Spanish. Type 2 diabetes was defined as diabetes with onset before 30 years of age without current insulin treatment or onset after 30 years of age with or without current insulin treatment.

A patient survey, administered either by computer-assisted telephone interview or in writing, and medical record abstraction were used to assess demographic characteristics, diabetes treatments, glycemic control, complications, and comorbidities (22). Demographic variables included age, sex, race, age at onset of diabetes, duration of diabetes, BMI, household income, and education. Disease state variables included diabetes treatment, HbA_{1c}, retinopathy, nephropathy, neuropathy, cerebrovascular disease, cardiovascular disease, peripheral vascular disease, hypertension, hypercholesterolemia, and cigarette smoking. Subjects were surveyed from April 2000 through February 2001. The survey response rate was 67%, and chart review data were available for 89% of respondents. Medians and 25th and 75th interquartile ranges (IQRs) were reported for continuous variables, and frequencies and proportions were reported for categorical variables.

Medical encounter and/or claims data were obtained from the HMO to describe total direct medical costs including inpatient, outpatient, laboratory, and pharmacy utilization for each subject over the year immediately preceding the subjects' interview. Costs reflect the HMO's (or in the case of end-stage renal disease [ESRD], Medicare's) contracted payment or reimbursement rates and represent total direct medical costs from the perspective of a large health system. Patient copayments and deductibles were not included in the total direct medical costs. We estimate that these accounted for ~5% of total direct medical costs. Since costs were not normally distributed, they were transformed to $\log_{10}$ costs. Costs were expressed in year 2000 U.S. dollars.

The transformed annual direct medical costs were fitted by a multiple linear regression model to demographic and disease state variables. Since the group treated with oral antidiabetic medications was the largest diabetes treatment group (n = 830), we used it as the reference group in the model fitting process. After the best model was determined, we reran the final model so that the group treated with diet or exercise only was the reference group. This did not affect the estimated costs produced by the model. Variables with multiple categories were represented by indicator variables. In the fitting process, all variables were initially entered into the regression model and all possible two-way interactions were examined. The estimates of the variables were computed and correlation among variables, different levels of variables, and interactions were noted. The model-fitting process was repeated using a backward stepwise deletion with a constraint that the ordering of all variable coefficients increased in severity within a disease status category such as nephropathy (e.g., the ordering of coefficients for nephropathy increased in severity from microalbuminuria to proteinuria to ESRD with dialysis). When coefficients did not increase with severity, the levels that had inconsistent orderings were collapsed into one level. Because our primary interest was to model annual direct medical costs as a function of a wide range of demographic characteristics, treatments, and complications, all variables ordered in increasing severity were kept in the model regardless of P value. The coefficients were then transformed back to the original scale in the form of multipliers. Therefore, to calculate cost in dollars for any subject, the annual direct medical cost for diet-controlled white male subjects with BMI of 30 kg/m^2, and without microvascular, neuropathic, or cardiovascular complications, is multiplied by the multiplicative factors for each of the characteristics, treatments, and complications for that subject. The multiplicative coefficients of the indicator variables represent the cost factor associated with each variable.

Annual direct medical costs associated with incident stroke, myocardial infarction (MI), and amputation were assessed by studying medical encounter and claims data for all members with diabetes who experienced such events from 1 January 1997 to 31 January 2001. Subjects with acute events were identified by diagnosis-related group (DRG) or current procedural terminology (CPT) codes. Direct medical costs were assessed for 1 year after the onset of the acute event.

All statistical analyses were performed using SAS software version 8.0 (SAS Institute, Cary, NC).

RESULTS — The characteristics of the 1,364 subjects with type 2 diabetes are presented in Table 1. The median age was 66 years and the median duration of diabetes was 8 years. More than 50% of the subjects were obese (BMI ≥30 kg/m^2). Five percent of subjects were treated with diet and/or exercise alone, >60% with oral antidiabetic medications, and about a third with insulin.

The costs associated with each demographic characteristic and complication are presented in Table 2. The baseline cost of $1,684 can be interpreted as the median annual direct medical cost for a white man with diet-controlled type 2 diabetes and BMI of 30 kg/m^2 and no microvascular, neuropathic, or cardiovascular risk factors or complications. If a subject has any of the characteristics or complications listed in Table 2, the annual direct medical cost is then estimated by the product of the baseline cost and the multipliers corresponding to each of the subject's characteristics or complications. In each disease status category, only the multiplier associated with the most severe level of a complication is used in the calculation. The median annual direct medical cost for a white woman with diet-controlled type 2 diabetes and BMI of 30 kg/m^2 is 1.25 times that of a white man ($2,105). The median annual direct medical cost for an African-American man with type 2 diabetes is 82% the cost of a white man ($1,380). For a white man with type 2 diabetes and a BMI of 35 kg/m^2, the baseline direct medical cost is multiplied by 1.01^5 or 1.05 ($1,770). Subjects who are treated with oral antidiabetic or antihypertensive agents or experience microalbuminuria, proteinuria, cerebrovascular disease, or peripheral vascular disease have 1.10–1.31 times the median annual direct medical costs for each treatment or complication experienced. Subjects who are treated with insulin or experience angina or MI have 1.59–1.90 times the cost for each treatment or complication experienced. Subjects with ESRD treated with dialysis have 10.53 times the cost. For example, the median annual direct medical cost for a white man with BMI of 38 kg/m^2, insulin-treated type 2 diabetes, treated high blood pressure, microalbuminuria, history of MI, and peripheral vascular disease is $10,500 ($1,684 $\times$ 1.01^8 $\times$ 1.59 $\times$ 1.24 $\times$ 1.17 $\times$ 1.90 $\times$ 1.31).

Age, duration of diabetes, HbA_{1c}, education, household income, smoking, hypercholesterolemia, retinopathy, neuropathy, and history of amputation were not associated with significant increases in annual direct medical costs after including the factors in the model and were excluded from the final model. As presented, the final model accounts for about one-fifth of the total variance in cost (R^2 = 0.205).

Table 3 shows the annual direct medical costs for incident stroke, MI, and amputation. The median direct medical costs for 1 year after the onset of stroke, acute MI, and amputation were $27,000, $25,000, and $38,000, respectively.

CONCLUSIONS — Our economic model describes the annual direct medical cost of type 2 diabetes by demographic characteristics, treatments, and complications. The annual direct medical costs for

Table 1—*Characteristics of study population*

Characteristic	
N	1,364
Age (years)	66 (54–72)
Diabetes duration (years)	8 (4–16)
Sex	
Male	681 (50)
Race	
White	1,005 (74)
African American	176 (13)
BMI (kg/m^2)	30.7 (27.1–36.1)
HbA_{1c} (%)	7.1 (6.3–8.2)
Education	
Not a high school graduate	244 (18)
High school graduate	397 (29)
Some college	383 (28)
College graduate	133 (10)
Any postgraduate work	153 (11)
Missing*	54 (4)
Household income	
<$40,000	903 (66)
$40,000–69,999	289 (21)
≥$70,000	172 (13)
Diabetes treatment	
Diet or exercise only	69 (5)
Oral antidiabetic medication	870 (64)
Insulin	425 (31)
Retinopathy status	
Nonproliferative retinopathy	170 (12)
Proliferative retinopathy	41 (3)
Macular edema	29 (2)
Missing	248 (18)
Nephropathy status	
Microalbuminuria	99 (2)
Proteinuria	207 (15)
ESRD with dialysis	6 (0.4)
Missing	248 (18)
Neuropathy status	
Neuropathy	544 (40)
History of amputation	25 (2)
Cerebrovascular disease	
Cerebrovascular disease	199 (15)
Missing	217 (16)
Cardiovascular status	
Angina	58 (4)
History of MI	363 (27)
Missing	205 (15)
Peripheral vascular disease	
Peripheral vascular disease	538 (39)
Missing	248 (18)
High blood pressure status	
BP ≥140/90 mmHg without treatment	481 (35)
Treated with medication	416 (31)
Missing	253 (19)
Cholesterol status	
LDL ≥100 mg/dl without treatment	386 (28)
Treated with medication	404 (30)
Missing	248 (18)
Cigarette smoking	
Current smoker	233 (17)
Missing	17 (1)
Total cost	3,715 (1,894–7,719)

Data are median (IQR) or *n* (%). *Patients lacking information about the specific disease state. BP, blood pressure.

white men and women with diet-controlled type 2 diabetes and BMI of 30 kg/m^2 and no microvascular, neuropathic, or cardiovascular complications are $1,700 and $2,100, respectively. Although other studies have reported higher annual direct medical costs for subjects with type 2 diabetes and no macrovascular complications ($2,800–$4,600), they did not adjust for subject characteristics, treatments, or microvascular complications (13,14,23). Most subjects in our study were overweight, 95% received medications for diabetes, one-third were treated for high blood pressure, and about one-fifth had diabetic kidney disease (Table 1). The annual direct medical cost for a white woman with a BMI of 34 kg/m^2 who is treated with oral antidiabetic and antihypertensive medications and has microalbuminuria is $3,500 ($\$1,684 \times 1.25 \times 1.01^4 \times 1.10 \times 1.24 \times 1.17$). Application of these multiplicative factors to the baseline cost results in a total annual direct medical cost similar to that reported by others.

The average annual Medicare payment for ESRD with diabetes as primary cause has been reported to be $63,100 (24). Subjects with ESRD suffer from many diabetic complications and comorbidities. Our model suggests that the annual direct medical cost for a white woman with insulin-treated type 2 diabetes, treated high blood pressure, ESRD treated with dialysis, and peripheral vascular disease is $57,200 ($\$1,684 \times 1.25 \times 1.59 \times 1.24 \times 10.53 \times 1.31$), similar to the cost reported by Medicare.

Our final model explained 20.5% of the variance in annual direct medical costs of subjects with type 2 diabetes. Most of the previously reported models explained <10% of the variation in costs (15,25). It is likely that our model predicted more of the variation in costs because we assessed exposures more rigorously by assessing demographic characteristics, treatments, and complications by both survey and medical chart review. African Americans with type 2 diabetes incurred lower direct medical costs than white type 2 diabetic subjects, suggesting that African Americans may receive less care. Age, duration of diabetes, and HbA_{1c} did not enter our final model. This may be because of their association with both insulin treatment and diabetes complications, which are associated with higher costs. Since this was a cross-

Table 2—*Direct medical costs associated with demographic characteristics, treatments, diabetes complications, and comorbidities**

	Baseline cost	$1,684†
Disease status	Increment ± SE in $\log_{10}$ scale	Multiplier
Sex		
Female	0.095 ± 0.025	1.25
Age	‡	‡
Race		
African American	−0.088 ± 0.036	0.82
Duration		
Every 1 year after onset	‡	‡
BMI (kg/m^2)		
Every unit >30 kg/m^2	0.004 ± 0.002	1.01
Diabetes intervention		
Oral antidiabetic medication	0.040 ± 0.056	1.10
Insulin	0.200 ± 0.058	1.59
High blood pressure		
Treated blood pressure	0.092 ± 0.028	1.24
Retinopathy		
Nonproliferative retinopathy	‡	‡
Proliferative retinopathy	‡	‡
Macular edema	‡	‡
Nephropathy		
Microalbuminuria	0.067 ± 0.048	1.17
Proteinuria	0.113 ± 0.036	1.30
ESRD with dialysis	1.023 ± 0.183	10.53
Neuropathy		
Clinical neuropathy	‡	‡
History of amputation	‡	‡
Cerebrovascular disease	0.113 ± 0.035	1.30
Cardiovascular disease		
Angina	0.239 ± 0.061	1.73
History of MI	0.278 ± 0.029	1.90
Peripheral vascular disease	0.116 ± 0.028	1.31

*Annual direct medical cost = baseline cost multiplied by the multiplicative factors for the combination of characteristics, treatments, and complications. In each disease category, only the multiplier associated with the most severe level of the complication should be used. †The baseline cost represents the median annual direct medical cost for a diet-controlled white man with type 2 diabetes and BMI of 30 kg/m^2 and without microvas-
cular, neuropathic, or cardiovascular risk factors or complications. ‡Variables did not enter into the model.

sectional study, we could not assess the effect of improved glycemic control on costs. Others have demonstrated that sustained improvements in glycemic control may be associated with decreased costs (17–19,26). Not unexpectedly, direct medical costs during the first year after the onset of acute MI, stroke, and amputation were high (Table 3).

Only a few studies have provided patient level estimates of the direct medical costs of diabetes (11,14,15). O'Brien et al. (11) developed an economic model to estimate the direct medical costs of 15 diabetes complications. Resource use was estimated from the likely course of treatment for each complication and unit costs were estimated from the peer-reviewed literature, acute care discharge databases, government reports, and fee schedules. The report did not assess variation in cost associated with demographic factors or diabetes treatments. The assessment of direct medical costs was not based on empirical data due to the lack of published data on actual practice (11).

Ramsey et al. (14) assessed the relative costs of six major diabetes-related complications using retrospective data from 8,905 subjects with type 1 or type 2 diabetes and 36,520 age- and sex-matched control subjects. The six diabetes-related complications were hypertension, eye disease, ESRD, foot ulcer, stroke, and MI. The relative costs for each complication were computed as ratios of total annual healthcare expenditure for subjects with diabetes and the complication compared with those with no diabetes and no complications. No distinction was made between type 1 and type 2 diabetes. The study assessed relative costs, not absolute costs. Like the study by O'Brien et al., it did not assess direct medical costs for different demographic characteristics and diabetes treatments and assessed costs from claims data only. In addition, unlike our model, the total direct medical cost for subjects with multiple complications may be overestimated, because some costs might be double counted.

Redekop et al. (15) examined the relationship between costs and demographic and clinical characteristics in 1,371 Dutch patients with type 2 diabetes using multivariate linear stepwise regression analyses. They demonstrated independent associations between age, insulin use, presence of macrovascular complications, presence of microvascular and macrovascular complications, hyperlipidemia, and costs. This study differed from ours in several ways. First, demographic characteristics, treatment, and complications were assessed by questionnaire but not with medical chart review. Second, costs were estimated with additive rather than multiplicative models. Third, they did not assess the association among individual microvascular and macrovascular complications and costs. Fourth, their model explained only 5.3% of the variance in costs, whereas our model explained 20.5% of the variance in

Table 3—*Direct medical costs for incident stroke, MI, and amputation*

Acute event	Subjects who survived first year (n)	Total costs for 1 year after onset of acute event for subject who survived first year
Stroke	88	$26,600 (15,400–44,900)
Acute MI	84	$24,500 (15,000–50,000)
Amputation	47	$37,600 (23,300–62,200)

Data are median (IQR).

costs. Finally, the costs represent the costs of subjects with type 2 diabetes in the Netherlands and are not comparable to the costs of type 2 diabetes in the U.S.

Some limitations of our study deserve mention. First, based on our definition of type 2 diabetes, we may have incorrectly classified a few subjects with type 1 diabetes as having type 2 diabetes and a few subjects with type 2 diabetes as having type 1 diabetes. Second, our study population was relatively small and limited to an HMO in Michigan. It represented the employed, elderly, poor, and disabled population of southeastern Michigan, but did not represent the general diabetic population of the U.S. as other states and regions were not represented and Asian Americans, Native Americans, and Hispanics were underrepresented. Third, the costs in our model reflect only direct medical costs from the perspective of a large health system. The costs do not include patient out-of-pocket costs, direct nonmedical costs, and indirect costs. Finally, not all diabetes complications entered the model. It is possible that these complications do not independently contribute to direct medical costs or that the costs associated with these complications are captured through closely associated complications such as diabetic kidney disease.

In summary, our economic model assessed patient-level direct medical costs of type 2 diabetes according to demographic characteristics, diabetes treatment, and complications. Major diabetes complications and insulin treatment have a substantial impact on total annual direct medical costs of type 2 diabetes. This economic model provides crucial information to describe and compare the direct medical costs of treatments, complications, and comorbidities within a type 2 diabetic population and for future cost-effectiveness analyses of new therapies for type 2 diabetes.

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