Health Care and Productivity Costs Associated With Diabetic Patients With Macrovascular Comorbid Conditions

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OBJECTIVE — To examine and quantify from the societal perspective the impact of macrovascular comorbid conditions (MVCCs) on health care and productivity costs in diabetic patients in the U.S.

RESEARCH DESIGN AND METHODS — With use of the pooled Medical Expenditure Panel Survey (MEPS) 2004 and 2006 data, a nationally representative adult sample (aged ≥18 years) was included in the study. Health care cost was measured by the annual health care expenditure. Productivity cost was calculated from the lost productivity from missed work days and additional bed days due to illness/injury based on the 2006 average national hourly wage. Both 2004 and 2006 cost data were adjusted to 2006 dollars. Given the heavily right-skewed distribution of the cost data, the generalized linear model with log-link function and γ variance was used to identify the relationship between MVCCs and costs after controlling for age, sex, race, ethnicity, education, income, employment status, smoking status, health insurance, diabetes severity, and comorbidities. Negative binomial models were applied to analyze the outcomes of missed work days and bed days. All statistics were adjusted using the proper sampling weight from MEPS.

RESULTS — Compared with diabetic patients without MVCCs (n = 3,320), those with MVCCs (n = 913) had statistically significant higher annual health care costs (5,120 USD, $P <$ 0.001), more missed work days (13.03 days, $P <$ 0.001), and more bed days (7.60 days, P = 0.025) per patient after controlling for differences in sociodemographics, smoking, diabetes severity, and comorbidities. The marginal lost productivity cost was 2,388 USD annually per patient.

CONCLUSIONS — From the U.S. societal perspective, MVCCs in diabetic patients are associated with increased health care and lost productivity costs.

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Diabetes is one of the most prevalent and costly chronic disease conditions in the U.S. (1,2). In 2007, the diabetes-related total cost was 174 billion dollars in the U.S., including 116 billion dollars in direct health care expense and 58 billion dollars in indirect cost for loss of work productivity (2). Patients with diabetes have an increased risk of developing vascular complications including microvascular and macrovascular complications (3). Among them, macrovascular complications are a major concern because a substantial proportion of deaths from diabetes results from these complications. In 1999, ~65% of deaths in patients with type 2 diabetes were caused by macrovascular disease (4). The risk of macrovascular death in patients with diabetes is double that in patients without diabetes (5,6), and patients with diabetes have the same risk of cardiovascular death as patients with a history of myocardial infarction (5,7).

Studies have shown that macrovascular comorbid conditions (MVCCs) are a major driver of health care costs in patients with diabetes in the U.S. (8,9). Using a population-based sample, in 1988 Glauber and Brown (10) reported that cardiovascular disease accounted for at least 24% of the total health care costs in patients with diabetes compared with just 12% of the total health care costs in patients without diabetes. Nichols and Brown (11) used 1999 data and reported that the average health care costs for patients with both diabetes and cardiovascular disease were 10,172 USD annually, compared with 4,402 USD for those with diabetes but without cardiovascular disease. Using 2003 data, Gandra et al. (12) found that macrovascular disease nearly tripled annual health care costs in patients with type 2 diabetes: 10,450 vs. 3,385 USD for those with and without macrovascular diseases, respectively. However, all of these studies relied on claims data from HMOs, which may not be representative of the U.S. national population. In addition, certain important patient characteristics, such as education and income level, were not available in the databases. The inadequate control of these covariates can bias the quantified relationship between costs and MVCCs in diabetes.

There is also lack of data on the impact of MVCCs on indirect costs resulting from lost productivity for patients with diabetes. Only one early study (13) addressed this topic by using aggregated national estimates. Nonetheless, to estimate the full economic impact from the U.S. societal perspective, both direct and indirect costs must be included. The purpose of the current study, therefore, was to examine the economic impact of MVCCs on patients with diabetes in a nationally representative community-dwelling sample of U.S. adults.

RESEARCH DESIGN AND METHODS

Data source

The Medical Expenditure Panel Survey (MEPS) is a U.S. nationally representative survey maintained and cosponsored by the Agency for Healthcare Research and Quality (AHRQ). The MEPS household survey collects detailed information on individual sociodemographic characteris-

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tics, health conditions, and various categories of health care utilization. The MEPS database provides national estimates of health care expenditures for the U.S. civilian noninstitutionalized population. The survey uses an overlapping panel design in which data are collected through preliminary contacts followed by five subsequent rounds of interviews per panel with a time lag of 4–5 months over a 2-year period. The present study pooled the 2004 and 2006 MEPS public use data to achieve a more robust sample size; the 2006 data are the most recent MEPS data that are publicly available. As the MEPS is conducted in a different sample every other year, the combined datasets contained all unique subjects.

Our study focused on adult subjects aged ≥18 years. The MEPS sample design includes stratification, clustering, multiple-stage selections, and disproportionate sampling (Hispanics and blacks are oversampled). The MEPS sampling weights were available to adjust for the complex design and questionnaire nonresponse (14).

Variables of interest

We measured the direct cost by the total health care expenditure of the calendar year for each subject. The 2004 and 2006 costs were adjusted to 2006 dollars using the medical care component of the consumer price index. Indirect productivity cost was calculated from both days of work missed due to illness or injury and additional missed days that the study subjects spent in bed due to illness or injury. In the MEPS, employed individuals were asked in each round how many days of work they missed due to illness or injury. An additional bed day was the measure of lost productivity for both employed and unemployed individuals. The cost of missed work days and additional bed days was estimated on the basis of the 2006 average national hourly wage across U.S. occupations with an hourly wage of 19.29 USD (15). Because MEPS does not differentiate between missed full and partial days, we assumed each missed day to be 6 h with the indirect cost of 115.74/day USD (19.29 USD/h × 6 h). The indirect cost per person was the product of the indirect cost per day and the total number of missed work days and additional bed days for an individual within a year.

We used clinical classification categories (CCCs) defined in the MEPS to represent disease conditions. CCCs were generated using the clinical classification software by AHRQ (16). It aggregates the ICD-9-CM conditions and V-codes into 260 mutually exclusive clinically homogeneous categories. We used CCC 49 "diabetes without complication" and CCC 50 "diabetes with complication" to identify patients with diabetes. The MVCCs were defined using CCC codes 100, 101, 104, and 108–115, which included cardiovascular disease (ischemic heart disease, congestive heart failure, aortic/visceral/peripheral aneurysms, visceral atherosclerosis, and peripheral vascular disease) and cerebrovascular disease (strokes and transient ischemic attacks).

Controlled covariates

To control for confounding, sociodemographic patient characteristics including age, sex, race, Hispanic ethnicity, education, income level, employment status, health insurance, and smoking status were included in the models. Race was categorized into whites, blacks, Asians, and all others. The education level, based on years of education, was categorized as no school (0 year), elementary grades (1–8 years), high school grades (9–11 years), high school graduation (12 years), college education (13–16 years), and more (>16 years). The income level was defined as a percentage of the poverty level and grouped into five categories: negative or poor (<100%), near poor (100–<125%), low income (125–<200%), middle income (200–<400%), and high income (≥400%). The health insurance variables include having Medicare, Medicaid, a private HMO, other private plans, and uninsured during the year. Potential overlapping of different insurance types was allowed because a subject might have more than one type of insurance, for example, dual Medicare and Medicaid status. Thus, the estimated coefficient on any insurance type should be interpreted as the marginal difference between subjects with this insurance type and those without.

We used comorbidity software, an algorithm that uses Elixhauser's coding algorithms (17) to create comorbidity variables for each individual, to calculate comorbidity. Based on the ICD-9-CM codes in the administrative data, the comorbidity software is newly developed with 30 unique comorbid categories. A recent version (3.4) of the comorbidity software from AHRQ was used in the study (18). If subjects claimed to have disease conditions other than those listed in the comorbidity software, an additional category was created to differentiate them from subjects without any other disease conditions. Therefore, we included the total number of comorbidity categories (diabetes and MVCCs excluded) to control for comorbidities in the analyses. In addition, we included three dummy variables, nephropathy, retinopathy, and neuropathy, to control for the severity of diabetes.

Statistical analysis

This was a retrospective cross-sectional analysis. The main focus of the study was the incremental economic impact (including both direct health care cost and indirect productivity cost) of MVCCs on patients with diabetes. Cost data are typically right-skewed because a relatively small proportion of patients incur extremely high costs. Even if the estimate is unbiased from the linear regression models, it could be unstable, given the skewness and kurtosis of the data distribution, and inefficient due to the heteroscedasticity. Such problems were dealt with by logarithmic or other transformation of the cost data (19). However, this introduces additional problems while retransforming back to the dollar value (20). To avoid these problems, we used the generalized linear model with log-link and gamma variance functions (21) to identify the relationship between MVCCs and costs after controlling for covariates.

We used negative binomial models to estimate the impact of MVCCs on missed work days and additional bed days. The marginal effects of dummy variables in both generalized linear model and negative binomial models were estimated using the method of recycled predictions (22). To generalize the study results to the U.S. population, the complex sampling design of the MEPS was taken into account using the specified sample weight, variance estimation stratum, and primary sampling unit (clustering).

RESULTS — The MEPS 2004 and 2006 had 46,617 adults in total, of which 4,233 (8.0% with weight adjustment) were patients with diabetes. There were 913 (22.0%) diabetic subjects with MVCCs and the rest (n = 3,320) without MVCCs. Descriptive statistics for subjects with diabetes compared with the general adult population in the MEPS and subjects with and without MVCCs among those with diabetes are presented in Table 1. The av-

Table 1—*Population characteristics of U.S. adults (aged ≥18, MEPS 2004 and 2006)*

	All diabetes	Diabetes with MVCC	Diabetes without MVCC	All subjects
n	4,233	913	3,320	46,617
Annual health care expense (USD)	10,845	18,434	8,707	4,240
Missed work days	6.74	11.65	5.90	3.67
Additional bed days	13.00	23.79	9.95	4.47
Annual indirect cost loss (USD)	2,285	4,102	1,835	942
Age-groups (%)				
18–24 years	1.1	0.0	1.4	13.0
25–34 years	3.2	0.2	4.1	18.0
35–44 years	10.0	3.0	11.9	19.5
45–54 years	19.3	10.4	21.8	19.0
55–64 years	26.4	26.2	26.5	14.1
≥65 years	39.9	60.2	34.2	16.4
Female sex	51.5	46.0	53.1	51.7
Race (%)				
White	77.8	79.3	77.3	81.7
Black	15.0	14.8	15.0	11.5
Asian	3.4	2.2	3.7	4.4
Other race	3.9	3.7	4.0	2.5
Hispanic ethnicity	12.9	9.3	13.9	12.8
Education				
0 years	1.0	1.1	1.0	0.4
1–8 years	11.1	14.6	10.1	5.9
9–11 years	15.2	19.6	14.0	12.5
12 years	35.2	30.8	36.4	31.7
13–16 years	30.6	27.9	31.4	39.3
>16 years	6.8	6.1	7.1	10.2
Income level (%)				
Negative or poor	13.6	14.0	13.5	10.7
Near poor	6.7	7.4	6.5	4.1
Low income	16.5	18.5	15.9	13.0
Middle income	29.5	29.9	29.4	31.2
High income	33.7	30.2	34.7	40.9
Unemployed	53.1	71.7	47.9	26.8
Health insurance				
Medicare	47.3	71.1	40.6	18.8
Medicaid	16.8	21.6	15.5	9.3
Private HMO	18.6	14.9	19.6	24.1
Other private plan	35.0	30.2	36.3	39.2
Uninsured	9.5	4.6	10.9	19.4
Currently smoke	14.9	13.1	15.4	18.7
Number of comorbitidy software categories	2.53	3.28	2.31	1.55
Nephropathy	9.5	14.8	8.0	0.8
Retinopathy	18.9	26.6	16.7	2.1
Neuropathy	0.12	0.26	0.08	0.03

Data are % unless indicated otherwise.

erage annual health care expense for patients with diabetes was 10,845 USD. Among diabetic patients, the average annual health care expenses were 18,434 and 8,707 USD for those with and without MVCCs, respectively. The average annual missed work days due to illness or injury and additional bed days for patients with diabetes were 6.7 and 13.0, respectively, amounting to 2,285 USD in indirect costs. The annual losses associated with indirect cost were 4,102 and 1,835 USD for diabetic patients with and without MVCCs, respectively. Compared with diabetes without MVCCs, those with MVCCs were more likely to be aged ≥65 years, male, non-Hispanic, less educated, poor, and unemployed and to have nephropathy, retinopathy, and neuropathy.

We conducted the regression analyses group I for all diabetic subjects (n = 4,233) and the regression group II for all adult subjects (n = 46,617). The marginal effects for the variables of interest are reported in Table 2. The full regression results can be found in supplemental

Table 2—*Impact of diabetes and MVCCs on health care expense, missed work days, and additional bed days due to illness/injury (marginal effect on the dependent variables)*

Dependent variables	Annual health care expense ($)	Missed work days due to illness/injury	Additional bed days due to illness/injury
Regression group I (all diabetes, n = 4,233)			
Diabetes with MVCCs	5,119.93*	13.03*	7.60†
Diabetes MVCCs (reference)			
Regression group II (all subjects, n = 46,617)			
Diabetes	3,337.86*	0.90†	5.29†
MVCCs	6,201.16*	3.50*	5.29‡
Diabetes × MVCCs	−2,880.07*	2.22	−2.49
No diabetes or MVCCs (reference)			

Age, sex, race, ethnicity, education, income, employment status, smoking status, health insurance, diabetes severity, and number of comorbidity software categories were controlled for in all regressions; interaction term of diabetes and MVCCs included for regression group II. *$P < 0.001$; †$P < 0.05$; ‡$P < 0.01$.

Appendices 1–6, available at http://care.diabetesjournals.org/cgi/content/full/dc09-1128/DC1. Compared with diabetic patients without MVCCs, those with MVCCs had statistically significantly higher annual health care expenses (5,120 USD, $P < 0.001$), more missed work days (13.03, $P < 0.001$), and more bed days (7.60, $P = 0.025$). The marginal lost productivity cost was 2,388 USD annually (115.74 USD/day × [13.03 + 7.60] days). The total annual incremental cost for MVCCs per diabetic subject, therefore, was 7,508 USD (5,120 USD in health care expenses + 2,388 USD in lost productivity). Compared with individuals without diabetes and MVCCs, those with diabetes or MVCCs spent significantly more on health care by 3,338 or 6,201 USD ($P < 0.001$), respectively, and had more missed work days and more bed days after controlling for sociodemographic characteristics, smoking status, diabetes severity, and comorbidities. However, the interaction term between diabetes and MVCCs was significantly negative on health care expense (−2,880.07, $P <$ 0.001), indicating that the incremental health care cost of MVCCs for patients with diabetes is lower than that for patients without diabetes.

Figure 1 illustrates the marginal impact of diabetes without MVCCs, MVCCs without diabetes, and diabetes with MVCCs on both direct health care cost and indirect productivity cost, relative to subjects without diabetes and MVCCs, after controlling for sociodemographic characteristics, smoking status, diabetes severity, and comorbidities. The results were derived from regression group II. It is evident that the incremental economic impact of diabetes or MVCCs alone is substantial, and such an impact for patients with both diabetes and MVCCs is even more considerable than that for patients with diabetes or MVCCs alone.

CONCLUSIONS — The results of this nationally representative study in the U.S. demonstrate that both diabetes and macrovascular conditions are associated with a considerable economic impact on society, including both increased direct health care cost and lost indirect productivity cost, and that the impact of MVCCs on diabetic patients is also substantial. We estimate that the incremental economic impact of MVCCs on society is ~7,500 USD annually per diabetic patient. In addition, the incremental health care cost of MVCCs for patients with diabetes may actually be lower than that for patients without diabetes. Our study provides up-to-date data that may help policy makers have a better understanding of the economic impact of comorbid macrovascular conditions on patients with diabetes from the U.S. societal perspective.

Previously published research has examined the impact of MVCCs, primarily, on direct health care costs in the U.S. In general, similar associations have been found (10–12). However, these studies estimated the average health care costs for patients with and without diabetes and MVCCs, whereas our study focused on the incremental cost impact, which is more useful from an economic standpoint. In addition, these past studies were conducted using HMO claims data, with one study examining predominantly older individuals (11) and another examining only subjects aged <65 years (12). These study samples are probably different from the general community-dwelling population in the U.S. Specifically, Gandra et al. (12) found that the health care expenses for diabetic patients with and without MVCCs were 10,450 and 3,385 USD per patient per year after matching by age and sex. It implies an incremental cost of 7,065 USD in health care, which is higher than our estimate of 5,120 USD. In addition, our regression results show that the coefficients of the HMO variable are primarily positive and statistically significant, indicating that the HMO patients on average have higher health care and productivity costs than those without HMO insurance coverage. Therefore, the estimated cost results using HMO data are not a good representation of the community-dwelling population and are probably overestimated.

Similar to our study, these previous publications (10–12) have, to some extent, controlled for differences in baseline characteristics between diabetic patients with and without MVCCs. However, the HMO claims data did not contain a full array of sociodemographic information such as race/ethnicity, education, and income, as the MEPS data do. The inability to control for these covariates may have biased the quantified estimates between MVCCs and costs of diabetes. Specifically, in their study, Nichols and Brown (11) suggested that the health care cost of MVCCs for diabetic patients is higher than that for patients without diabetes. On the contrary, our results indicated that the incremental health care cost of MVCCs for patients with diabetes may actually be lower than that for patients without diabetes. The cost outcomes in the study of Nichols and Brown (11) were primarily descriptive and only controlled for age and sex. The difference between our study findings and theirs could have resulted from our control of more covariates, especially diabetes severity and comorbidities. The additional sensitivity analyses we conducted show that, even without the control of education and income, the direct cost would be underestimated by 4% and indirect cost would be overestimated by 7%. The MEPS is one of the most detailed U.S. nationally representative data sources available to examine questions related to medical conditions, health care expense, and missed work with comprehensive sociodemographic information. More impor-

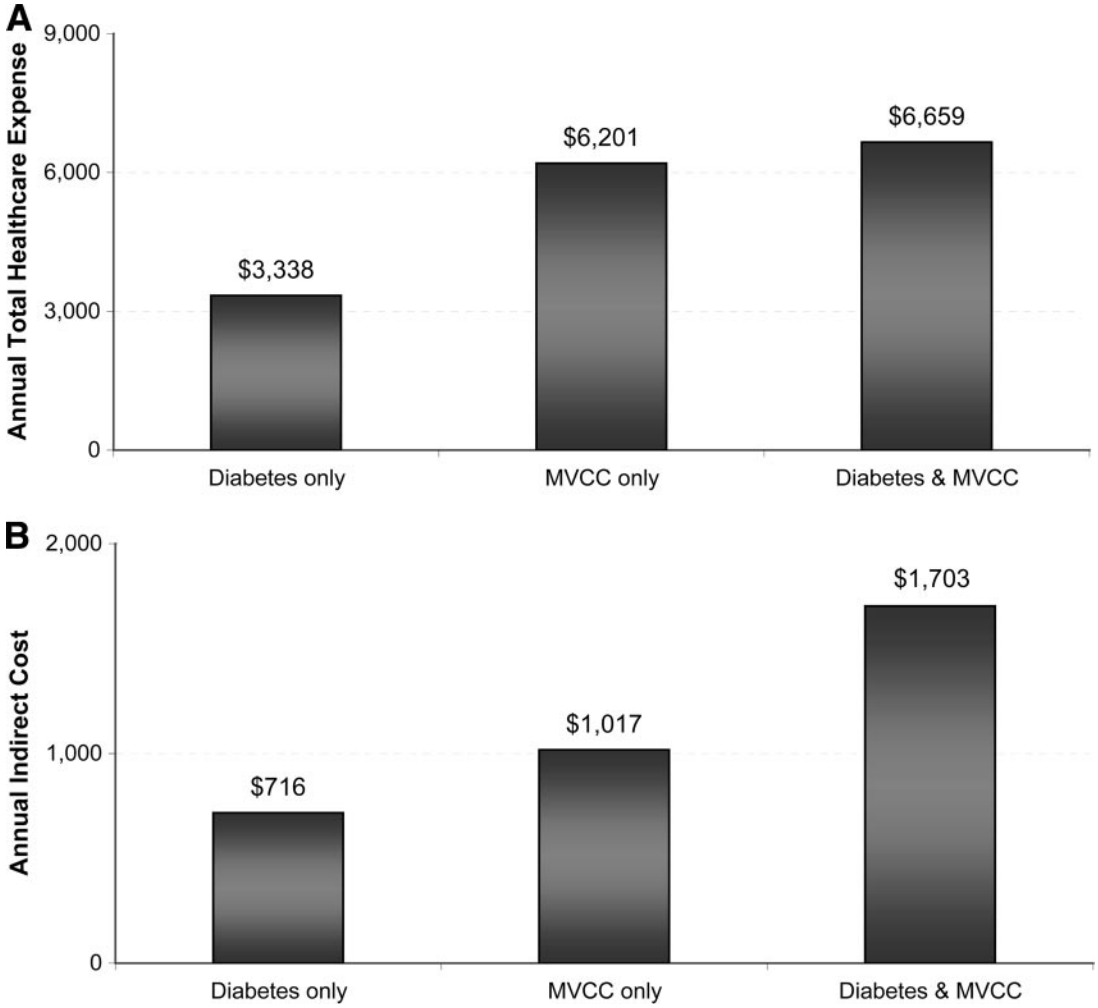

Figure 1—*Marginal impact of diabetes or MVCCs individually or combined on direct* (A) *and indirect* (B) *costs (controlling for age, sex, race, ethnicity, education, income, employment status, smoking status, health insurance, diabetes severity, and number of comorbid categories).*

tantly, none of these aforementioned studies included the indirect productivity cost in the outcome. The findings from those studies, therefore, can be informative mostly from the third party payers' perspective. With the inclusion of indirect cost, our study evaluated the incremental economic impact from the broader societal perspective.

It is worth noting that 6 h/day was assumed to calculate the loss of productivity cost because MEPS does not differentiate between missed full and partial days. If each day of lost work was assumed to be 4 or 8 h, the marginal lost productivity cost results in 1,592 or 3,184 USD per patient, respectively, when diabetic patients with MVCCs are compared with those without MVCCs. In addition, Druss et al. (23) used 1996 MEPS data to estimate the economic impact of five chronic conditions including diabetes. Both indirect productivity cost associated with work loss and direct health care cost were estimated. Nevertheless, the incremental impact of MVCCs on diabetic patients was not a focus.

Our research is not without limitations. First, the results of this study are generalizable to the U.S. community-dwelling adults but may not be relevant for other populations. Second, the prevalence of diabetes and MVCCs we reported may be an underestimate of the true national prevalence because the MEPS is based on self-reporting. Previous research has shown that self-reported conditions may be underreported (24). In addition, estimates suggest that up to 35% of individuals with diabetes have been undiagnosed (25). This downward bias may result in smaller magnitude and significance of the estimates because the comparison group has no respective conditions and implies that the true economic impact may be even larger than we estimated. Third, we used the national average wage instead of actual wages to determine the productivity cost. On the other hand, use of actual wages would imply that there is no value to the lost time for home workers, retirees, and those who have to abandon their job due to disease conditions. Thus, application of the national average wage can better estimate the opportunity cost of lost time from the societal perspective. We also have to acknowledge that, for unemployed individuals in the MEPS data, the bed days due to illness/injury is the only measure of lost productivity. Missed work days do not apply to them. No record of missed work days implies that our estimate could serve as the lower bound for which the true lost productivity for this group may be larger. In addition, we have controlled for employment status in our analyses. This should have adjusted for most, if not all, of the productivity difference associated with unemployment.

There are other limitations to this research. The MEPS did not collect cost information on over-the-counter drugs and alternative care services. Because of the small dollar amount of these costs relative to others, such as inpatient and outpatient costs, the underestimation of overall direct health care cost may be trivial. In addition, we included both patients with type 1 and type 2 diabetes. Patients with type 2 diabetes tend to be older and more overweight and may have higher rates of MVCCs and complications. By including both types of diabetes, we may underestimate the costs of diabetes and MVCCs in patients with type 2 diabetes.

In summary, previous research has consistently shown the impact of diabetes and MVCCs alone and in combination on health care cost. The results of this study are mainly consistent with previous study findings but add new findings by studying the marginal impact of both the direct health care cost and the indirect productivity cost of MVCCs on the U.S. society for patients with diabetes. The marginal economic impact of MVCCs on society is ~7,500 USD annually per diabetic patient.

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