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Healthcare costs and utilization of diabetes-related complications in Taiwan

A claims database analysis

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Abstract

To estimate the healthcare utilization and costs of major diabetes mellitus (DM)-related complications in Taiwan in the year of first occurrence and in subsequent years.

This study is a retrospective claim database analysis using the longitudinal cohort of diabetes patients (LHDB) with 2012 as the base year. Occurrences of 8 DM-related complications of interest were identified using the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes. Annual healthcare costs and utilization of these DM-related complications in the LHDB cohorts of the years 2004 to 2009 were examined, and the generalized linear model was used to estimate annual total healthcare costs for each complication.

DM patients with complications were more likely to have at least 1 emergency room (ER) visit and at least 1 hospitalization (both $P < .001$), and they also had more outpatient visits, higher hospitalization costs, higher outpatient costs, and higher ER costs (all $P < .001$) than those without. The mean annual total healthcare cost of the patients with DM-related complications was US $4189, whereas the mean annual cost of those patients without complication was $1424 ($P < .001$). The complications with the greatest event costs were amputation ($7877; 95% confidence interval [CI]: $6628–$9322) and fatal MI ($4067; 95% CI: $3001–$5396) while the complication with the greatest state costs was end-stage renal disease (ESRD) ($2228; 95% CI: $2155 to $2302).

DM-related complications could significantly increase healthcare utilization and costs. The results of this study provide data that are useful for local economic evaluations of DM treatments.

Abbreviations: CHF = congestive heart failure, DCSI = diabetes complication severity index, DM = diabetes mellitus, DRG = diagnosis-related groups, ER = emergency room, ESRD = end-stage renal disease, GLM = generalized linear model, ICD-9-CM = International Classification of Diseases, Ninth Revision, Clinical Modification, IHD = ischemic heart disease, LHDB = longitudinal cohort of diabetes patients, LVD = large vessel disease, MI = myocardial infarction, NA = not applicable, NHIRD = National Health Insurance Research Database, P4P = Pay-for-Performance program, SD = standard deviation, TWD = Taiwan Dollars.

Keywords: complications, diabetes, healthcare costs, Taiwan

1. Introduction

Diabetes mellitus (DM) is a chronic condition that can lead to micro-vascular and macro-vascular complications. In Canada, DM is a leading cause of both end-stage renal disease (ESRD) and non-traumatic lower extremity amputation.[1] In Taiwan, the prevalence of large vessel disease (LVD) in DM versus non-diabetic patients was 20.0% and 12.9%, respectively.[2] Moreover, it was found that 15.8% of DM patients had ischemic heart disease (IHD), 1.7% had leg vessel disease, and 2.5% had stroke.[2] In addition to the high prevalence, many of these complications are very costly, accompanied not only by a physical and emotional burden for individuals, but also by an economic burden for the government.[3] Among the DM-related complications, a few major events (e.g., myocardial infarction [MI]) are often more costly than early-stage ones (e.g., microalbuminuria).[1]

In the United States, from 25% (emergency department) to 45% (hospital inpatient) of the DM-attributed medical expenditures were spent treating DM-related complications.[3] A few studies have been done to estimate the costs of DM-related complications.[4–6] The study findings showed that in Sweden the most frequently recorded complication was IHD while the complication with the highest diagnosis-related groups (DRG)-based cost was amputation with annual costs of €14,949.[4] In another study conducted in Australia, the findings showed that the most frequently recorded complication was also IHD while the complication with the highest event year costs was renal failure, with annual costs of $28,661.[5] In addition, in the United States, the annual event cost and state cost for DM-related ischemic stroke were $42,119 and $15,541, respectively.[6] Previous study findings also indicate that a DM-related complication significantly increases costs, not only in the year

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during which it occurs (i.e., event year), but also in subsequent years.[6–8]

There have been several cost estimations of DM-related complications conducted in Taiwan, but most used the diabetes complication severity index (DCSI) to analyze DM-related complications,[9,10] rather than calculating the medical costs incurred by each DM-related complication. The objective of our study was therefore to obtain a better understanding of the various healthcare costs and utilization of DM-related complications in Taiwan.

2. Methods

This study is a retrospective claims database analysis that was approved by the Shin-Kong Memorial Hospital Institutional Review Board (approval no. 20150712R).

2.1. Study database

The insurance claim database used in this study was the Longitudinal Cohort of Diabetes Patients (LHDB), a de-identified subset of data from the National Health Insurance Research Database (NHIRD).[11] The NHI program, a compulsory universal health care system in Taiwan, was instituted in 1995, and its population coverage has reached 99%. In the LHDB, patients who fit the following criteria were identified as DM patients: those with a history of hospitalization for DM or an in-hospital prescription for anti-hyperglycemic medications; those with ≥2 diagnoses of DM in outpatient settings within 1 year; or those with 1 outpatient diagnosis of DM and another outpatient visit with a prescription for anti-hyperglycemic medications.[12] Patients' incidence year was determined by the date of their first diagnosis with DM. Each year, a total of 120,000 incident cases were randomly selected to be included in the LHDB of that particular year, and all available healthcare data in NHIRD (from years 1999 to 2013) were then extracted for this subset of patients.[12] Incident cases were defined as those diagnosed with DM and with no medical history of DM for the preceding 3 years. In the LHDB, 7 sets of claim data were available for each case before and after his or her diagnosis of DM: ambulatory care costs by visits, details of ambulatory care orders, inpatient costs by admissions, details of inpatient orders, costs for prescriptions dispensed at contracted pharmacies, details of prescriptions dispensed at contracted pharmacies, and registry information about the beneficiaries.

2.2. Patient selection and outcome measures

For the annual healthcare cost and utilization examination, year 2012 was used as the base year, and only DM patients who had at least 1 or more medical claims in 2012 were selected. In order to ensure that the patient's complication occurring during the 3 years prior to the base year was DM-associated (i.e., did not occur before DM onset), only the LHDB cohorts of years 2004 to 2009 were included in the analysis. Moreover, the DM patients in these cohorts who met the following criteria were excluded: hospitalized once or visited the outpatient department twice for any of the 8 complications of interest in the 3 years prior to the onset of DM; aged <18 years in year 2012; pregnant in year 2012; or diagnosed with type 1 DM.

The annual healthcare costs and utilization in 2012 under analysis included having at least 1 hospitalization, having at least 1 emergency room (ER) visit, total number of outpatient visits, total healthcare costs, hospitalization costs, outpatient costs, and ER costs. Patients' demographic information was also extracted from the LHDB database, including age, sex, residential region, the presence of each complication in 2012, and the presence of each complication between 2009 and 2011.

For cost estimation, costs of each complication accrued in 2012 were divided into 2 components: event costs, defined as the complication costs accrued in year 2012 when the patient first experienced that particular complication, and subsequent-year costs, or state costs, defined as the costs accrued in the year 2012 that were associated with the management of a complication that patient had been dealing for since 2009, 2010, or 2011.

2.3. Identification of complications

Following the methodology of several previous studies,[4,5,13] we identified the presence of 8 DM-related complications of interest using the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes and the procedure codes listed in Table 1. A patient was considered to have a complication if he or she had 1 hospitalization or 2 outpatient visits associated with a primary or secondary diagnosis with an ICD-9-CM code or a corresponding procedure code for that complication. For complications that have a high fatality rate, such as MI and stroke, the outcomes examined were further divided into fatal and non-fatal events, making a total of 10 complications (i.e., fatal and non-fatal MI, fatal and non-fatal stroke, and the other 6 complications of interest) under examination. As the patients' death records were unavailable or unreliable in the LHDB database, a fatal event was defined as hospitalized in 2012 due to the complication (i.e., the primary diagnosis was the complication), having the discharge coded as "death" or "critically ill and discharged from the hospital voluntarily," and having no medical claim record in 2013.

2.4. Statistical analysis

Baseline characteristics of the selected patients and the outcomes of interest are reported by summary statistics. To compare the healthcare costs and utilization between DM patients with a certain complication and those without, the Chi-square test was performed for categorical variables while the Wilcoxon rank sum test was used to analyze the number of outpatient visits and

Table 1

Definitions of DM-related complications.

Category	ICD-9 codes[4,5,13]
Ischemic heart disease (IHD)	Nonfatal events (ICD-9 code 411–414.9)
Myocardial infarction (MI)	Nonfatal myocardial infarction (ICD-9 code 410)
Congestive heart failure (CHF)	ICD-9 codes 428
Stroke	Major stroke (ICD-9 code ≥430 and ≤434.9, or 436)
Amputation	Major limb complications requiring amputation of digit or limb for any reason (procedure codes 84.10–84.19)
Blindness	ICD-9 codes 369–369.9
End-stage renal disease (ESRD)[14–16]	Advanced nephropathy (ICD-9 codes 585 and 586) Hemodialysis (procedure code 39.95) or peritoneal dialysis (procedure code 54.98) Renal transplantation (procedure code 55.61 or 55.69)
Ulcer	Chronic ulcer of lower limb (ICD-9 code 707.10)

ICD-9 = International Classification of Diseases 9th edition.

Table 2

Patient characteristics (LHDB cohorts 2004–2009).

	All	Presence of complication in 2012		
		Yes	No	*P* value
Number of patients	453,147	69,314	383,833	
Female (%)	222,422 (49.1)	29,792 (43.0)	192,630 (50.2)	<.001
Mean (SD) age, y*	58.8 (13.6)	65.8 (12.4)	57.6 (13.5)	<.001
Mean (SD) DM duration, y	5.4 (1.7)	5.7 (1.7)	5.4 (1.7)	<.001
Region† (%)				<.001
North	208,298 (45.9)	30,926 (44.6)	177,372 (46.2)	
Central	102,240 (22.6)	15,890 (22.9)	86,350 (22.5)	
South	128,656 (28.4)	20,035 (28.9)	108,621 (28.3)	
East	12,496 (2.8)	2263 (3.3)	10,233 (2.7)	
Islands	1455 (0.3)	200 (0.3)	1255 (0.3)	
Complication				
IHD		37,003 (8.2%)	417,088 (91.8%)	
Non-fatal MI		2199 (0.5%)	451,147 (99.5%)	
Fatal MI		106 (0.02%)	452,842 (99.98%)	
Non-fatal stroke		18,216 (4.0%)	435,932 (96.0%)	
Fatal stroke		194 (0.04%)	451,952 (99.96%)	
CHF		9025 (2.0%)	444,122 (98.0%)	
Amputation		287 (0.06%)	452,860 (99.94%)	
Blindness		87 (0.02%)	453,060 (99.98%)	
ESRD		13,809 (3.1%)	439,338 (96.9%)	
Ulcer		267 (0.06%)	452,880 (99.94%)	

CHF = congestive heart failure, ESRD = end-stage renal disease, IHD = ischemic heart disease, LHDB = longitudinal cohort of diabetes patients, MI = myocardial infarction, SD = standard deviation.

* Patient age was calculated by the difference between patient's birth year and 2012.

† Data may not add up to 100% because of missing data.

various types of annual costs. Moreover, for each complication of interest, the total annual cost was estimated using a generalized linear model (GLM) with a gamma distribution and a log link. Furthermore, in order to take into account the influence of both complications that first occurred in 2012 (i.e., event costs) and those that had begun before 2012 (i.e., state costs), for each complication in the GLM model, patients who did not have that complication in 2012 or during the years 2009 to 2011 were assigned to the reference group. That reference group was then compared with the other 2 groups: those with the complication in 2012 who had no history of that complication from 2009 to 2011 (i.e., those who incurred the event cost of the complication in 2012), and those with the presence of the complication at some point between 2009 and 2011 (i.e., those who incurred the state cost of the complication in 2012). For fatal MI and fatal stroke, only event costs were evaluated because patients having these conditions expired and state costs could not be calculated.

All monetary values were reported in Taiwan dollars (TWD) while the estimated event and state costs were further converted to US dollars ($) by the 2012 exchange rate (1:29.04). Statistical significance was defined as a 2-sided *P* value of <.05. All statistical analyses were performed using SAS software, version 9.4 (SAS Institute, Cary, NC).

3. Results

3.1. Patient characteristics

A total of 453,147 eligible patients were identified and included in the analysis, among which, a majority (383,833 patients, 84.7%) did not have any of the complications of interest in 2012. The characteristics of the patients, including age, sex, region, and presence of complications, are summarized in Table 2. The mean age of the study cohort was 58.8 years (±13.6 years), and approximately half of them (49.1%) were women. Most of the patients lived in the northern region of Taiwan (45.9%). The most common complications were IHD (8.2%), non-fatal stroke (4.0%), and ESRD (3.1%). The results also showed that men were more likely than women to have DM-related complications (57.0% vs 43.0%). In addition, compared with patients without a DM-related complication, patients with a complication were older (mean ± SD: 65.8 ± 12.4 vs 57.6 ± 13.5 years, $P < .001$) and had suffered from DM for a longer amount of time (5.7 ± 1.7 vs 5.4 ± 1.7 years, $P < .001$). The regional distribution was similar between patients with complications and those without.

As shown in Table 3, the mean annual total healthcare costs of the patients with DM-related complications was TWD 121,646.2 (US $4189), whereas the mean annual costs of those without any complication was TWD 41,348.0 (US $1424) ($P < .001$). In addition, the group with complications was more likely to have at least 1 ER visit and at least 1 hospitalization (both $P < .001$). They also had more outpatient visits, higher hospitalization costs, higher outpatient costs, and higher ER costs (all $P < .001$) than those without a complication. Moreover, DM patients with any of the 10 complications of interest, compared with those without that specific complication, had a higher likelihood of ER and hospitalization visits and incurred higher healthcare costs in all aspects under evaluation (Table 4).

The GLM analysis results are shown in Table 5. The exponential of β values derived from the GLM can be interpreted as the ratio of the state or event costs of patients with a certain complication to those of the patients without it. First, the exponential of beta values were calculated for each complication. Then we subtracted one from these values and multiplied them by the estimated mean annual total healthcare costs of a 60-year-old man with no complication who lived in the northern region of Taiwan. The product values derived from these steps were the estimated incremental state or event costs of that particular

Table 3

Comparison of annual healthcare costs and utilization (with at least one complication vs without).

	With at least one DM-related complication in 2012		
	Yes (n = 69,314)	No (n = 383,833)	*P* value
At least one hospitalization*			<.001
No	45,801 (66.1%)	336,966 (87.8%)	
Yes	23,513 (33.9%)	46,867 (12.2%)	
At least one ER visit*			<.001
No	45,763 (66.0%)	315,403 (82.2%)	
Yes	23,551 (34.0%)	68,430 (17.8%)	
Number of outpatient visits†	37.2 (24.5)	26.9 (19.7)	<.001
Total healthcare costs†	121,646.2 (220,850.6)	41,348.0 (105,922.9)	<.001
Hospitalization costs†	54,389.8 (174,757.0)	13,120.5 (77,619.2)	<.001
Outpatient costs†	63,806.3 (121,548.2)	27,244.0 (60,514.2)	<.001
ER costs†	3450.1 (10,061.1)	983.5 (4383.0)	<.001

DM = diabetes mellitus, ER = emergency room.

* Chi-square test.

† Wilcoxon rank sum test.

complication. For example, the exponential of IHD state costs' β value was 1.39208; thus, the estimated incremental state costs were $(1.39208-1)\times 37843.3 = 14837.7$. After the calculation, the estimated event costs ranged from TWD 36,323.4 for IHD to TWD 228,739.6 for amputation while state costs ranged from TWD 10,397.5 for non-fatal MI to TWD 64,701.0 for ESRD.

Additionally, our cost data was right-skewed, so we also estimated the state and event costs using the median annual total healthcare costs of that same 60-year-old man without complications, rather than the mean. The estimated event costs ranged from TWD 17,694.5 for IHD to TWD 111,428.1 for amputation while state costs ranged from TWD 5065.0 for non-fatal MI to TWD 31,518.4 for ESRD. All the estimated costs derived from the GLM analysis were converted to US dollars (based on the exchange rate dated December 1, 2012: 29.04 New Taiwan dollars = 1 US dollar) and reported in Table 5. Using the mean value for the estimation, the complications with the greatest event costs were amputation ($7877; 95% CI: $6628–$9322) and fatal MI ($4067; 95% CI: $3001–$5396) while the complications with the greatest state costs were ESRD ($2228; 95% CI: $2155–$2302), followed by non-fatal stroke ($929; 95% CI: $896–$964) and congestive heart failure (CHF) ($748; 95% CI: $705–$792).

4. Discussion

This study is a retrospective claims database analysis that aimed to estimate the healthcare utilization and costs of major DM-related complications in Taiwan. In this study, as indicated by the exponential of β values derived from the GLM, the event cost of amputation was 7.0 times as much as that of patients without this complication, followed by fatal MI (4.1 times), non-fatal MI (4.0 times), fatal stroke (3.5 times), and non-fatal stroke (3.4 times). Moreover, almost all examined complications had a higher event year cost ratio than state year cost ratio. The only exception was the event cost ratio of ESRD (2.3 times), which was lower than its state cost ratio (2.7 times). Because patients with ESRD incurred more fixed medical expenses (e.g., dialysis) in the state year than in the event year, its state year cost ratio was found to be higher. Considering the great and increasing number of DM patients in Taiwan and its association with ESRD, this associated economic burden cannot be neglected.

The findings of previous similar studies[4,17] showed that nonfatal complications incurred higher costs than their fatal ones, which was different from our study findings. An explanation for this difference could be that the definition for fatal event in the present study is different from that of previous studies. Moreover, in the studies by Gerdtham et al[4] and Alva et al[17] the calculation of costs only included patients' hospitalization costs. As there were no hospitalization costs after the death of fatal patients, the costs in the fatal year they estimated were lower than those of the non-fatal condition. On the contrary, our estimation included all medical costs (including hospitalization, outpatient, and ER costs) of the patient in the year of death.

The results of this study show that the occurrence of DM-related complications significantly increased medical costs not only in event year but also in state years. Among obesity-induced diseases in Taiwan, the mean annual costs were estimated at TWD 63,733 for DM, TWD 43,982 for hypertension, TWD 43,757 for cerebrovascular disease accident, TWD 36,347 for IHD, TWD 26,568 for CHF, and TWD 19,552 for hyper-cholesterolaemia.[18] Based on these numbers and our study results, it is no doubt that DM and its related complications are relatively costly and pose a great economic burden to society.

Our study findings show that up to 84.7% of DM patients did not experience any complications. The finding could be partially explained by the limited number of complications examined in this study, which did not include those common diseases such as hypertension and hyperlipidemia. In addition, the low proportion of DM patients with a complication could also have resulted from the DM pay-for-performance (P4P) program that Taiwan's National Health Insurance has implemented since 2001. Previous studies indicate that the DM P4P program is cost-effective,[19,20] and the success of the program could have improved the outcomes of DM care and prevented the occurrence of complications. Nevertheless, if these patients' DM is not well controlled, they could experience undesirable effects and consume considerable health resources and incur considerable costs in the future. Therefore, we should pay attention to patients with potential risks. Interventions that can be made by health professionals during interactions with patients, such as encouraging lifestyle changes, providing DM education, making medication recommendations and adjustments, and overseeing patient compliance at follow-up. These tools are helpful not only for DM management, but also for the prevention of complications that may bring huge burdens. Alleviating these burdens,

Table 4

Comparison of annual healthcare costs and utilization (with vs without a complication).

	With IHD in 2012		With non-fatal MI in 2012		With fatal MI in 2012	
	Yes (n = 37,003)	No (n = 416,144)	Yes (n = 2199)	No (n = 450,948)	Yes (n = 106)	No (n = 453,041)
At least one hospitalization*						
No	26,161 (70.7%)	356,606 (85.7%)	800 (36.4%)	381,967 (84.7%)	0 (0%)	382,767 (84.5%)
Yes	10,842 (29.3%)	59,538 (14.3%)	1399 (63.6%)	68,981 (15.3%)	106 (100%)	70,274 (15.5%)
At least one ER visit*						
No	25,785 (69.7%)	335,381 (80.6%)	1037 (47.2%)	360,129 (79.9%)	35 (33.0%)	361,131 (79.7%)
Yes	11,218 (30.3%)	80,763 (19.4%)	1162 (52.8%)	90,819 (20.1%)	71 (67.0%)	91,910 (20.3%)
Number of outpatient visits†	37.5 (24.1)	27.7 (20.3)	32.4 (22.4)	28.4 (20.8)	16.9 (17.1)	28.5 (20.8)
Total healthcare costs†	92,522.9 (168,559.3)	50,172.3 (129,264.9)	227,438.9 (290,765.7)	52,783.0 (131,628.9)	427,015.1 (449,511.7)	53,543.2 (133,132.2)
Hospitalization costs†	40,582.7 (132,935.9)	17,552.5 (96,277.6)	159,693.1 (256,554.2)	18,749.2 (98,116.1)	372,016.6 (443,932.7)	19,350.6 (99,613.3)
Outpatient costs†	49,193.0 (83,493.7)	31,382.2 (73,357.0)	59,747.6 (106,537.8)	32,705.4 (74,182.0)	41,865.1 (105,936.8)	32,834.5 (74,387.7)
ER costs†	2747.2 (9634.2)	1237.5 (5196.0)	7998.3 (18,145.0)	1328.4 (5557.1)	13,133.4 (25,110.9)	1358.0 (5689.7)

	With non-fatal stroke in 2012		With fatal stroke in 2012		With CHF in 2012	
	Yes (n = 18,216)	No (n = 434,931)	Yes (n = 194)	No (n = 452,953)	Yes (n = 9025)	No (n = 444,122)
At least one hospitalization*						
No	10,388 (57.0%)	372,379 (85.6%)	0 (0%)	382,767 (84.5%)	3918 (43.4%)	378,849 (85.3%)
Yes	7828 (43.0%)	62,552 (14.4%)	194 (100%)	70,186 (15.5%)	5107 (56.6%)	65,273 (14.7%)
At least one ER visit*						
No	10,716 (58.8%)	350,450 (80.6%)	41 (21.1%)	361,125 (79.7%)	4566 (50.6%)	356,600 (80.3%)
Yes	7500 (41.2%)	84,481 (19.4%)	153 (78.9%)	91,828 (20.3%)	4459 (49.4%)	87,522 (19.7%)
Number of outpatient visits†	38.3 (26.5)	28.0 (20.4)	14.1 (14.6)	28.5 (20.8)	37.6 (25.6)	28.27 (20.7)
Total healthcare costs†	135,032.1 (232,202.3)	50,221.2 (126,482.1)	228,413.62 (265,749.2)	53,555.67 (133,281.4)	190,335.1 (293,029.7)	50,852.6 (126,605.7)
Hospitalization costs†	74,463.8 (213,217.0)	17,128.3 (91,530.2)	183,037.2 (240,166.1)	19,363.06 (99,817.2)	118,265.6 (260,303.6)	17,424.8 (92,839.0)
Outpatient costs†	56,046.7 (74,009.9)	31,864.5 (74,254.7)	33,432.8 (84,337.7)	32,836.4 (74,392.1)	65,238.9 (115,168.4)	32,178.2 (73,185.1)
ER costs†	4521.6 (9861.4)	1228.4 (5422.0)	11,943.6 (12,952.1)	1356.3 (5695.4)	6830.7 (16,109.3)	1249.6 (5226.0)

	With amputation in 2012		With blindness in 2012		With ESRD in 2012	
	Yes (n = 287)	No (n = 452,860)	Yes (n = 87)	No (n = 453,060)	Yes (n = 13,809)	No (n = 439,338)
At least one hospitalization*						
No	0 (0%)	382,767 (84.52%)	41 (47.1%)	382,726 (84.5%)	8349 (60.5%)	374,418 (85.2%)
Yes	287 (100%)	70,093 (15.48%)	46 (52.9%)	70,334 (15.5%)	5460 (39.5%)	64,920 (14.8%)
At least one ER visit*						
No	95 (33.1%)	361,071 (79.7%)	47 (54.0%)	361,119 (79.7%)	8447 (61.2%)	352,719 (80.3%)
Yes	192 (66.9%)	91,789 (20.3%)	40 (46.0%)	91,941 (20.3%)	5362 (38.8%)	86,619 (19.7%)
Number of outpatient visits†	33.2 (22.0)	28.5 (20.8)	42.6 (23.4)	28.5 (20.8)	39.6 (24.6)	28.1 (20.6)
Total healthcare costs†	452,122.5 (452,340.2)	53,378.0 (132,592.8)	142,906.7 (199,988.1)	53,613.4 (133,393.3)	235,682.4 (339,313.9)	47,908.4 (116,901.3)
Hospitalization costs†	349,230.3 (406,897.5)	19,224.1 (99,136.5)	75,315.6 (158,399.7)	19,422.4 (99,959.0)	81,567.0 (237,023.0)	17,480.2 (91,752.7)
Outpatient costs†	92,256.9 (151,385.1)	32,799.0 (74,307.8)	62,675.9 (114,596.8)	32,830.9 (74,385.8)	148,892.6 (236,073.3)	29,188.8 (59,334.6)
ER costs†	10,635.2 (23,983.5)	1354.9 (5669.8)	4915.12 (8332.1)	1360.1 (5703.9)	5222.8 (15,079.3)	1239.4 (5092.8)

	Ulcer in 2012	
	Yes (n = 267)	No (n = 452,880)
At least one hospitalization*		
No	109 (40.8%)	382,658 (84.5%)
Yes	158 (59.2%)	70,222 (15.5%)
At least one ER visit*		
No	140 (52.4%)	361,026 (79.7%)
Yes	127 (47.6%)	91,854 (20.3%)
Number of outpatient visits†	46.3 (31.8)	28.4 (20.8)
Total healthcare costs†	152,300.9 (189,798.8)	53,572.4 (133,353.2)
Hospitalization costs†	90,892.9 (159,504.2)	19,391.0 (99,915.9)
Outpatient costs†	57,173.5 (84,094.8)	32,822.3 (74,388.2)
ER costs†	4234.5 (8992.3)	1359.1 (5701.8)

CHF = congestive heart failure, ER = emergency room, ESRD = end-stage renal disease.
The numbers in parenthesizes are either percentage or standard deviation.
* Chi-square test.
† Wilcoxon rank sum test.
All $P < .001$.

both economic and otherwise, could decrease medical expenses and improve patients' outcomes and quality of life.

The main purpose of the present study was to provide the cost estimates of major DM-related complications, which data are an essential component in pharmacoeconomic analyses involving DM medication and non-medication treatments. Indeed, an economic model for DM treatment or the estimation of DM burden cannot be completed without taking into account the

Table 5

Estimates of annual state and event costs.

Complication	e^{β} (95% CI)	$(e^{\beta}-1)*37,843.3^{*}$ (in TWD)	$(e^{\beta}-1)*18,435.0^{\dagger}$ (in TWD)	Estimated annual event and state costs in 2012 US dollars (95% CI)
IHD (State)	1.39 (1.38,1.41)	14,837.7	7228.0	511 (491, 531)
IHD (Event)	1.96 (1.91,2.01)	36,323.4	17,694.5	1251 (1190, 1313)
Non-fatal MI (State)	1.27 (1.23,1.33)	10,397.5	5065.0	358 (293, 425)
Non-fatal MI (Event)	4.01 (3.73,4.30)	113,756.6	55,415.4	3917 (3564, 4296)
Fatal MI (Event)	4.12 (3.30,5.14)	118,100.4	57,531.4	4067 (3001, 5396)
Non-fatal stroke (State)	1.71 (1.69,1.74)	26,990.3	13,148.1	929 (896, 964)
Non-fatal stroke (Event)	3.40 (3.29,3.50)	90,640.8	44,154.7	3121 (2983, 3264)
Fatal stroke (Event)	3.54 (3.01,4.17)	96,059.6	46,794.4	3308 (2613, 4126)
CHF (State)	1.57 (1.54,1.61)	21,722.1	10,581.7	748 (705, 792)
CHF (Event)	2.49 (2.39,2.59)	56,276.2	27,414.4	1938 (1814, 2066)
Amputation (State)	1.43 (1.31,1.57)	16,461.1	8018.8	567 (401, 749)
Amputation (Event)	7.04 (6.09,8.15)	228,739.6	111,428.1	7877 (6628, 9322)
Blindness (State)	1.33 (1.12,1.57)	12,325.5	6004.3	424 (156, 742)
Blindness (Event)	2.52 (1.85,3.42)	57,376.2	27,950.2	1976 (1110, 3152)
ESRD (State)	2.71 (2.65,2.77)	64,701.0	31,518.4	2228 (2155, 2302)
ESRD (Event)	2.28 (2.21,2.35)	48,391.6	23,573.5	1666 (1579, 1757)
Ulcer (State)	1.54 (1.41,1.69)	20,527.4	9999.7	707 (533, 897)
Ulcer (Event)	2.51 (2.13,2.94)	56,982.8	27,758.6	1962 (1473, 2538)

CHF = congestive heart failure, CI = confidence interval, ESRD = end-stage renal disease, IHD = ischemic heart disease, MI = myocardial infarction, TWD = Taiwan dollars.

* 37,843.3 is the estimated mean annual total health care costs of a man without any complication and age 55 to 65 years old who lives in the northern region of Taiwan.

† 18,435.0 is the estimated median annual total health care costs of a man without any complication and age 55 to 65 years old who lives in the northern region of Taiwan.

costs of DM-related complications. In addition, with newer and more costly DM drugs coming onto the market, the estimation of these costs needs to be updated periodically.

There are limitations to this study. First, our way of identifying the presence of a complication cannot rule out patients with that particular complication in the years prior to 2009. It was assumed that DM-related complications did not occur in early years of DM after diagnosis. Second, without linking to death registries, we were unable to confirm the death of the patients or whether the death resulted from a particular complication. Our definition for fatal events was justifiable given the limitations of the study database. Third, state costs may not have been the same every year after the event year; however, to avoid further complexities, we did not take into account the changes in costs over time. Fourth, our identification of DM-related complications were based on ICD-9 codes listed in a claims database, where errors and incompleteness may have existed and resulted in the misclassification of patients in each complication group. However, a previous study evaluating the accuracy of the NHIRD for DM-related complications has shown high levels of diagnostic accuracy.[21] Lastly, due to the restrictions of the claims database, adjustments could only be made on observable and measured factors but not all potential confounders.

5. Conclusions

This study indicates that a DM-related complication significantly increases costs, not only in the event year, but also in state years. The results of this study provide data for use in future local economic evaluations of DM treatments. Other potential applications are the estimation of healthcare costs and utilization of people with T2DM as well as the estimation of overall economic burden of the disease.

Author contributions

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