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Estimating the Cost of Complications of Diabetes in Australia Using Administrative Health-Care Data

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ABSTRACT

Objectives: To estimate Australian health-care costs in the year of first occurrence and subsequent years for major diabetes-related complications using administrative health-care data.

Methods: The costs were estimated using administrative information on hospital services and primary health-care services financed through Australia's national health insurance system Medicare. Data were available for 70,340 patients with diabetes in Western Australia (mean duration of 4.5 years of follow-up). Multiple regression analysis was used to estimate inpatient and primary care costs.

Results: For a man aged 60 years, the average costs in the year the event first occurred were: amputation $20,416 (95% CI 18,670–22,411); nonfatal myocardial infarction (MI) $11,660 (10,931–12,450); nonfatal stroke $14,012 (12,849–15,183); ischaemic heart disease $12,577 (12,026–13,123); heart failure $15,530 (13,965–17,009); renal failure $28,661 (22,989–34,202); and chronic leg ulcer $15,413 (13,089–18,123). The costs in subsequent years for a man aged 60 years range from 14% for nonfatal MI to 106% for renal failure, of event costs.

Conclusions: Estimates of the health-care costs associated with diabetes-related complications can be used in modeling the long-term costs of diabetes and in evaluating the cost-effectiveness of improving care.

Keywords: Australia, diabetes mellitus, diabetes-related complications, health-care costs, record linkage.

Introduction

An important issue in undertaking economic evaluation of new therapies and health-care technologies is to ascertain the degree to which the costs of an intervention can at least be partly offset by reductions in future use of health care [1]. When evaluating therapies for treating or preventing diabetes mellitus, this usually involves estimating the potential saving that accrue from reducing complications associated with the disease [2,3]. In this regard, it is important to obtain accurate estimates of the costs associated with the treatment of various types of complications (e.g., myocardial infarction [MI]) to quantify a long-term profile of costs of the disease and its complications. Several computer simulation models have been developed to inform economic evaluations of interventions to prevent or treat diabetes [4]. These models typically use discrete annual cycles to predict a profile of costs over time [5,6]. Unfortunately estimates of annual costs associated with common diabetes complications, that are a necessary input for these simulation models, are not available in many countries [7]. For example, in Australia, the most common sources of cost data are those based on diagnosis related group (DRG) cost weights [8]. However, DRG cost weights have potential limitations because they only capture the costs associated with a single hospital episode and therefore do not reflect the cost of subsequent admissions, or increases in resource use in other parts of the health system. Hence, the use of DRG cost weights as the basis for costing complications may impart a bias, because it will fail to capture a significant proportion of the medium and long-term costs associated with the disease.

The dearth of disease specific costs for people with diabetes may in part be due to difficulties in estimating the expected annual costs associated with complications, because many types of events elevate the risks of comorbidities which would necessitate the use of complex decision trees to fully capture the expected costs. Another approach is employ statistical methods on linked administrative health-care data to estimate cost functions for common complications. Advantages of the latter approach is that it potentially captures

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medium and long-term health-care costs including costs associated with comorbidities and is available for patients in older age groups that are often excluded from clinical studies. Understanding whether the cost of treating complications differs by age is useful when estimating life-time health cost-profiles, which are often recommended as an appropriate time horizon [9] for economic evaluation.

The primary purpose of this study is to use a large linked administrative data set to illustrate how annual acute and long-term costs can be estimated for major complications of diabetes that can be used in simulation modeling. The study focuses on the acute and long-term costs of eight complications: MI; other ischaemic heart disease (IHD); stroke; congestive heart failure; blindness; amputation, renal failure, and chronic leg ulcer. The data set contained both hospital records and Medicare information on the primary health-care use of people with diagnosed diabetes in Western Australia (WA). Multiple regression analysis is used to estimate the marginal cost of treating complications while controlling for other comorbidities. Further, because administrative health-care data are not widely utilized by health economists, we illustrate how panel data regression methods can be used to derive these costs.

Patients and Methods

Background

Australia has a national tax financed health insurance system (Medicare) that covers a defined list of benefits including consultation fees for doctors, including specialists, radiology, and pathology services provided to admitted private patients and community patients. Patients admitted as public patients in a public (government funded) hospital have zero out-of-pocket costs. Voluntary private insurance can be purchased to cover the cost of treatment and accommodation as a private patient in hospital.

The study is based on administrative health-care use data from WA over a 10-year period—i.e., in the period from January 1, 1990 to December 31, 1999 which combines records from four separate sources: 1) Medicare insurance claims for medical and diagnostic services which include date and type of service, the amount claimed, out-of-pocket costs, post-code of the service provider; 2) information on prescriptions for pharmaceuticals by drug type and strength; 3) hospital records of inpatient episodes (including day-only admissions) for public and private hospitals; and 4) WA State death records.

These data were confidentially linked at the individual patient level using a protocol designed to protect privacy which was developed specifically for this type of study [10]. The protocol included the requirement for Human Research Ethics Committee approval in addition to agreement from all data custodians. A two-step process was used to enable the probabilistic linkage of personal identifiers without the inclusion of clinical data. The de-identified clinical data were then supplied by each custodian directly to the researchers and linked using a unique coded key.

Not all of the administrative data sets contain information on diagnosis. Although hospital separations and death records include diagnoses, this is not the case in Medicare or PBS data. To maximize accuracy of ascertainment for this study, people were classified as having diabetes if they satisfied any of the following criteria. If they had: 1) filled a prescription for a diabetes-related medication; 2) claimed for an HbA_{1c} test; or 3) been admitted to hospital with a primary or secondary diagnosis of diabetes (ICD-9250); or 4) died with diabetes listed as a cause on their death certificate. From January 1, 1990 until December 31, 1999, a total of 91,475 subjects were included in the study if they fulfilled one or more of these criteria. In 1999, the last year of the study, there were 80,574 people with diabetes. This constitutes 4.3% of the estimate residential population of WA [11].

Study population. Because this study is primarily concerned with costs of complications of people with diabetes, we used demographic and health service information on a total of 76,953 persons more than the age of 35 years. To reduce the influence of events that occur before the period of analysis, we excluded 4059 individuals that had one or more events from January 1, 1990 to December 31, 1991. For these individuals, it is difficult to determine whether costs relate to the observed events or prior events. People were included either from January 1, 1992 if there was prior evidence of diabetes, or for years when they met any of the above criteria (i.e., we included all health-care information from the calendar year of diagnosis onward).

Because the study only included WA hospitals, we also excluded persons whose pattern of medical use indicated that they may have migrated (i.e., Medicare records indicated provider or patient were located outside WA). This left a total of 70,340 persons with a mean of 4.5 years' follow-up, generating 318,586 person-years of data. The Venn diagram in Figure 1 can be used to classify study subjects by the criteria of diagnosis. The most common method of ascertainment was having an HbA_{1c} test (identifying 90% of subjects), followed by diagnosis of diabetes indicated on hospital records (identifying 49% of subjects). Almost two-thirds of subjects had a flag for diabetes indicated in more than one administrative data set. The remainder were mainly identified through use of HbA_{1c} tests (29% of subjects). A further analysis of the number of times diabetes was flagged during the study showed that 95% of subjects had more than one indication of diabetes during the study.

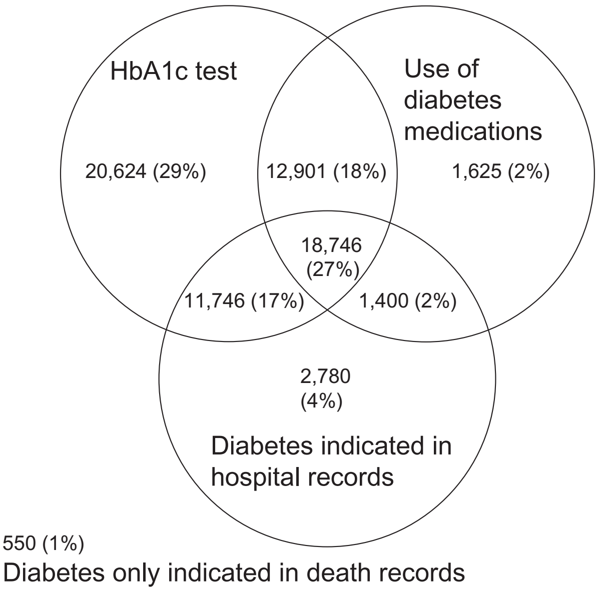

Figure 1 Venn diagram setting out the sample by category of diagnostic criteria. Notes: (1) No. of individuals and the proportion of the sample in brackets.

All available health-care data from the calendar year in which diabetes was first identified were extracted for these patients. This resulted in 262,105 records of hospital separations and 6,835,263 Medicare claims for medical and diagnostic services and these formed the basis of the costing estimates used in this study.

Identification and Costing of Complications and Procedures

Following the methodology of several previous studies [12,13], we divided disease specific costs into two time periods; event costs that accrue within the year in which a complication first occurs and state costs that are intended to reflect the ongoing costs in subsequent years that are associated with the management of the complication (including subsequent events of the same type). Eight major diabetes-related complications were identified from hospital records using the ICD-9 CM codes for the principal diagnosis and principal procedure. This approach was chosen because the previous validation study using Australian administrative data shows that the principal diagnosis is most likely to accord with clinical assessment [14]. The codes used to define each complication are listed in Table 1. The hospital records extracted from the administrative data provide information on the patient's age and sex, as well as the principal procedure, principal diagnosis, and the year in which the episodes occurred.

To derive hospital costs, each hospital episode, including episodes of day surgery, was grouped into a DRG [8]. DRGs are a method of classifying episodes with similar levels of resource consumption into the same group. The associated weights are meant to reflect the intensity of resource use and have been used as a basis for funding hospital services in Australia. Updated annual national DRG weights were then used to assign a cost to each episode [15]. Separate cost weights were used for public and private hospital episodes to reflect differences in resource use. In the case of private hospital admissions, the DRG cost weight does not reflect the patients' medical costs (including pathology and radiology costs) [16] and so we added the cost of Medicare funded services used by patients while they were in hospital to quantify the total costs associated with the admission.

This study also included several categories of non-hospital costs. In particular, for ambulant health-care use, the cost of all medical services (including pathology and diagnostic services) can be derived using Medicare claims data. Because Medicare provides a universal system health insurance of health insurance, it provides insurance coverage for medical services for most of the Australian population.

There are several categories of costs which have not been included in the study because of data limitations. These include the costs associated with emergency room visits, some allied care not covered by Medicare and the costs of home blood glucose testing. These items could not be included in the study because information was not captured in the linked administrative data set. There were also limitations with the data on pharmaceutical use over this period (only those holding a health-care card are captured in the data set). Because this is likely to introduce a downward bias

Table 1 Definitions of diabetes-related complications included in the regression analysis

Category	Predefined diagnostic definitions and diagnosis codes
Myocardial infarction	Either nonfatal myocardial infarction (ICD-9 code 410), or fatal cardiac event (ICD-9 code ≥410 and ≤414.9, or ≥428 and ≤428.9), or sudden death (ICD-9 code ≥798 and ≤798.9).
Other ischemic heart disease	Nonfatal events that are classified as ICD-9 code 411–414.9.
Stroke	Either major stroke (ICD-9 code ≥430 and ≤434.9, or 436) or fatal stroke (ICD-9 code ≥430 and ≤438.9).
Heart failure	ICD-9 codes 428–428.1.
Amputation	Major limb complications requiring amputation of digit or limb for any reason (procedure codes 84.10–84.19).
Renal failure	Any acute intercurrent illness (ICD-9 codes 250.3 and ≥585 and ≤586) and death because of renal failure (ICD-9 codes ≥580 and ≤593.9).
Blindness	ICD-9 codes 369–369.9.
Ulcer	Chronic ulcer of lower limb ICD-9 707.10.

into estimates of pharmaceutical costs, we have excluded these from the current analysis. The total costs of inpatient and noninpatient health care were aggregated into annual amounts and then adjusted using a hospital and medical services price inflator [17] into 1999 Australian dollars.

Methods of Analysis

After presenting summary statistics for patient characteristics and resource use, we examined the relationship between health-care costs and eight diabetes-related complication states defined in Table 1. Given the high fatality rate associated with some types of events, the analysis focuses on 10 event categories (the diabetes-related complications plus fatal MI and fatal stroke).

Separate panel data regression analyses [18,19] were undertaken to examine how complications impacted on two cost categories:

1. Hospital inpatient: those associated with public and private hospital inpatient stays (including day-only admissions).
2. Nonhospital costs: arising from noninpatient health-care use including fees for general practitioner (GP) and specialist visits as well as diagnostic tests and investigations (e.g., HbA_{1c} tests).

To examine whether there are differences in the cost of treating complications for different age groups, separate costing were undertaken for the 10 complications when they occurred in individuals above and below the age of 65 years.

Different strategies were employed to estimate hospital and nonhospital costs. For hospital costs a two-part model was employed [20]. The equation in the first part estimates the probability of being hospitalized in any given year and in the second part the total annual hospital costs are estimated for those that incur costs. An important feature of these administrative data is that the occurrence of events was ascertained using hospital records and so the probability of attending hospital is equal to one in the year the event first occurs; hence, only the second equation is used to estimate these *event costs*. To estimate expected *state costs*, the product of the probability of hospitalization in subsequent years is multiplied by the complication-specific costs.

A panel logistic regression estimator was used in the first part to calculate the probability of incurring hospital costs based on a patient's history of complications recorded within the study. To determine the impact of various clinical events on the probability of attending hospital in the year after an event, we included an indicator variable for those patients with a history of each type of complication. The probability of hospitalization may depend on current age and so separate indicator variables for each complication were used to distinguish whether events occur in patients aged less than, or more than 65 years. Wald statistics were used to test for differences in cost between these age groups. This was undertaken at the 1% level of significance due to the large number of comparisons.

In the second part, either fixed-effects panel data regression, or a Generalized Estimating Equation [19] was used to estimate the hospital costs for patients who were admitted. The former was used to aid interpretation because it assumes complications have an additive impact on costs. The latter is a way of dealing with the skewed nature of cost data. For the sake of brevity, we only report the results of the fixed-effects model in the main results. Confidence intervals for predicted costs were based on bootstrap methods involving resampling the data 1000 times.

To separate the payer perspective from a broader societal perspective, we also quantified the proportion of costs that were paid by the user for each type of complication.

Results

The sample was divided into 33,619 (48%) males and 36,721 females. The age structure at entry to the study was: 19,838 (28%) less than 50 years; 28,241 (40%) between 50 and 65 years; 19,223 (27%) between 65 and 80 years; 3038 (4%) more than the age of 80 years.

Table 2 provides counts of the total number of people who experienced each event during the study. The most frequently recorded complication was IHD with 5575 events, followed by MI with 4487 of which 1932 were fatal. Table 2 also provides summary statistics for resource use. Patient without any diabetes-related complications had on average 0.6 (SD 3.0) hospital admissions per year, spent 2.9 (12.4) days in hospital and had 11.9 GP consultations, where as patents with complications tended to have multiple episodes of hospitalization and many more days in hospital. For example, a patient who had an amputation had 4.7 (11.1) episodes in hospital and spent on average 56.9 (50.9) days in hospital in the year this complication was first recorded. This increased use continued in subsequent years (i.e., an average 3.3 hospital episodes and 17.9 days in hospital). Many types of complications also increased the frequency of contact with GPs both in the year of the events and in subsequent years.

Estimates of Annual Event and State Costs

Table 3 shows predictions from the linear model for a man with diabetes at 60 (columns 2–4) and 70 years of age (columns 5–7). The second and fifth columns report the estimated expected mean hospital inpatient costs associated with each complication calculated using the logistic equation and fixed-effects model (see statistical appendix for further details). For a man aged 60 years, the event costs ranged from $8126 (5678–11,829) for blindness to $27,820 (22,136–33,283) for

Table 2 Annual health service use by complication status

	No. patient years*	Hospital episodes†	Days in hospital†	GP consultations†
No Complications	277,353	0.6 (3.0)	2.9 (12.4)	11.9 (10.9)
Year of first recorded event				
Fatal MI	1,932	1.9 (3.3)	16.5 (25.0)	10.9 (10.0)
Non fatal MI	2,555	2.8 (5.5)	17.7 (21.0)	16.7 (15.3)
Fatal stroke	632	1.6 (1.6)	21.0 (33.8)	9.7 (8.1)
Non fatal stroke	2,688	2.7 (5.5)	33.9 (38.5)	15.5 (11.7)
Ischaemic heart disease	5,557	2.9 (5.5)	14.2 (20.1)	18.2 (12.9)
Heart failure	2,814	3.7 (7.8)	26.5 (30.2)	19.3 (14.2)
Amputation	907	4.7 (11.1)	56.9 (50.9)	16.7 (13.7)
Renal failure	391	18.3 (30.2)	46.4 (44.8)	14.4 (12.9)
Blindness	463	3.4 (8.6)	31.1 (37.4)	16.6 (12.4)
Ulcer	703	4.2 (9.1)	47.6 (49.1)	18.3 (15.7)
History of event				
Non fatal MI	6,825	1.2 (5.1)	6.7 (18.4)	14.5 (12.9)
Non fatal stroke	6,081	0.8 (4.4)	9.3 (24.5)	14.6 (11.5)
Ischaemic heart disease	15,616	1.3 (5.9)	6.2 (17.6)	15.3 (12.8)
Heart failure	5,632	2.8 (11.3)	14.9 (27.8)	16.0 (13.0)
Amputation	522	3.3 (14.9)	17.9 (35.2)	15.0 (14.2)
Renal failure	1,908	39.8 (54.9)	57.2 (63.0)	11.0 (12.0)
Blindness	874	1.7 (6.5)	12.7 (27.7)	15.3 (12.2)
Ulcer	1,730	2.6 (10.8)	18.7 (34.4)	15.3 (13.3)

*Count.
†Mean (SD).
GP, general practitioner; MI, myocardial infarction.

renal failure. Comparisons of the predicted cost of complications show some variation across the two age groups, but these differences were generally not statistically significantly different.

The third and sixth column of Table 3 shows the estimated expected mean nonhospital costs related to each complication, calculated using the fixed-effects equation (not reported). For example, on average patients aged 60 and 70 years old who experienced IHD incurred nonhospital costs of $1261 (1221–1305) and $1119 (1070–1175) in that year, respectively. Columns 4 and 7 of Table 3 report the expected mean of all costs of each complication, calculated as the sum of hospital inpatient and nonhospital expected mean costs. Renal failure is associated, on average, with the highest annual state costs, and the highest event cost in the younger age group. The cost of treating nonfatal stroke was around 25% higher than for nonfatal MI in both age groups. The proportion of these health costs that are paid for by the patient through medical charges that are not reimbursed by Medicare is small (around 2% of event costs and 3% of state costs).

Discussion

In this study, we have reported the results of a regression analysis based on large linked administrative health-care data sets to obtain empirical estimates of the annual hospital inpatient costs and noninpatient health-care costs associated with a set of common diabetes-related complications. Our estimates show the effect diabetes-related complications have on both hospital and nonhospital costs. The study shows that these complications have an immediate impact on costs in that they elevate costs in the year in which they occur. Diabetes-related complications also have a continuing impact on costs in subsequent years. For example, a 60-year-old man patient who suffers from heart failure has a 43% probability of being readmitted to hospital in subsequent years at a cost of $5550 (4204, 7351) and incurs annual nonhospital costs of $948 (863, 1038). The proportion of nonhospital costs range from 3% to 10% of all costs in the year of the event and then constituted around one-fifth of all state costs. Given that we have restricted our sample to those people with identified diabetes more than 35 years, our sample will predominantly consist of people with type 2 diabetes.

The primary motivation behind this analysis has been to develop a set of costs for major diabetes-related complications for Australia that can be used in simulation modeling. Economic evaluations are now routinely used in the development of clinical guidelines and in reimbursement decisions in Australia [21]. These evaluations, which typically involve the modeling of long-term outcomes, often require the use of disease specific cost estimates to predict the potential savings that arise from reduced rates of complications. Another possible use of these estimates is to forecast future health-care costs of people with diabetes and to estimate the overall economic burden of the disease. A spreadsheet-based cost calculator to estimate the cost associated with different types of complications based on the equations reported in statistical appendix is available from: http://www.health.usyd.edu.au/heconomics/. While the study has reported costs in 1999 Australian dollars (because this was the most recent year where cost

Table 3 Estimated expected annual nonhospital and hospital costs by first diabetes-related complication, during the year of complication and subsequent years (1999 Australian $)

	Male aged 60 years			Male aged 70 years		
	Hospital in-patient costs (95% CI) Column 1 ($)	Nonhospital cost (95% CI) Column 2 ($)	Total cost (95% CI) Column 3 ($)	Hospital in-patient costs (95% CI) Column 5 ($)	Nonhospital cost (95% CI) Column 6 ($)	Total cost (95% CI) Column 7 ($)
Estimates for the year in which the event occurred						
Fatal MI	9,108 (7,018–11,302)	485 (403–570)	9,592 (7,494–11,784)	9,453 (8,428–10,593)	486 (428–537)	9,938 (8,900–11,088)
Nonfatal MI	10,836 (10,124–11,606)	824 (758–884)	11,660 (10,931–12,450)	10,086 (9,470–10,737)	811 (758–861)	10,898 (10,274–11,558)
Fatal stroke	13,649 (8,623–19,131)	518 (273–856)	14,166 (9,089–19,617)	11,554 (10,054–13,274)	407 (330–484)	11,961 (10,418–13,711)
Nonfatal stroke	13,032 (11,897–14,210)	980 (913–1,055)	14,012 (12,894–15,183)	12,287 (11,673–12,926)	855 (811–903)	13,142 (12,525–13,800)
Ischemic heart disease	11,316 (10,777–11,867)	1,261 (1,221–1,305)	12,577 (12,026–13,123)	12,392 (11,804–12,983)	1,119 (1,070–1,175)	13,511 (12,918–14,126)
Heart failure	14,256 (12,713–15,739)	1,274 (1,175–1,374)	15,530 (13,965–17,009)	11,861 (11,152–12,604)	1,089 (1,027–1,142)	12,950 (12,212–13,699)
Amputation	19,606 (17,873–21,506)	810 (723–906)	20,416 (18,670–22,411)	22,991 (21,200–24,881)	802 (717–882)	23,793 (21,987–25,705)
Renal failure	27,820 (22,136–33,283)	841 (632–1,082)	28,661 (22,989–34,202)	27,011 (22,454–32,175)	958 (788–1,148)	27,969 (23,336–33,218)
Blindness	8,126 (5,678–11,829)	754 (574–975)	8,880 (6,374–12,646)	7,904 (6,146–9,782)	757 (644–879)	8,661 (6,903–10,573)
Ulcer	14,447 (12,121–17,135)	967 (819–1,122)	15,413 (13,089–18,123)	17,357 (14,985–19,636)	889 (782–1,001)	18,246 (15,861–20,554)
Estimates for subsequent years						
Nonfatal MI	1,061 (917–1,214)	620 (570–670)	1,681 (1,524–1,850)	2,036 (1,761–2,330)	665 (613–718)	2,701 (2,422–3,003)
Nonfatal stroke	2,924 (2,465–3,483)	767 (675–861)	3,691 (3,226–4,230)	2,614 (2,330–2,899)	742 (700–789)	3,356 (3,058–3,653)
Ischemic heart disease	1,246 (1,010–1,496)	883 (809–960)	2,130 (1,868–2,399)	3,441 (3,189–3,733)	871 (833–913)	4,312 (4,042–4,614)
Heart failure	5,550 (4,204–7,351)	948 (863–1,038)	6,498 (5,154–8,262)	4,498 (4,052–4,978)	873 (810–937)	5,371 (4,905–5,862)
Amputation	3,296 (2,447–4,296)	735 (629–846)	4,031 (3,163–5,023)	5,313 (4,181–6,804)	751 (650–861)	6,065 (4,898–7,574)
Renal failure	29,847 (2,1712–37,345)	614 (382–943)	30,462 (22,438–37,864)	29,952 (19,944–40,707)	660 (429–892)	30,612 (20,630–41,266)
Blindness	2,425 (986–3,950)	615 (409–875)	3,039 (1,588–4,662)	2,379 (1,522–3,327)	513 (401–636)	2,892 (2,025–3,875)
Ulcer	3,338 (2,039–5,072)	728 (584–869)	4,066 (2,717–5,827)	4,077 (3,198–5,011)	684 (587–794)	4,761 (3,877–5,704)

Estimates and based equations reported in the appendix and in supplementary material.
MI, myocardial infarction.

information was available), these costs could be adjusted to reflect more recent changes in inflation through the use of a suitable price index.

An important feature of this study has been its use of linked administrative health data (including hospital and Medical Benefits and Pharmaceutical Benefits Data) and death registry data. This is the first time such data have been available at the population level in Australia and the use of these data has enhanced the study in several ways. First, the administrative data cover most of the Australian population because it combines Medicare claims data and the WA hospital admissions data also include both public and private hospital admissions within the State. Although the former is based on insurance claims rather than actual use, there are strong financial incentives for those covered by Medicare to file claims. Second, the use of multiple criteria for identifying people with diabetes, including HbA_{1c} tests and drugs primarily used for treating diabetes (e.g., Metformin), is likely to produce a larger more representative sample than studies which have had access to only one of these sources such as hospital or medical records. The access to Medicare data has facilitated the quantification of nonhospital costs for those patients with and without complications and in this regard it extends the findings of a previous Australian study that only reported hospital costs for some of these complications [22]. Finally, the use of administrative data is likely to provide more accurate estimates of health-care costs than studies based on self-report health service use information which can suffer from errors in recall [23].

Although practical and privacy issues restrict the linkage of these data with other clinical data to determine the accuracy of ascertainment, it is worth noting that the number of individuals included in the sample accords with a previous estimate of the prevalence of diabetes in WA from the AUSDIAB study [24]. Third, the sample size is larger than many comparable costing studies and contains individuals over the full age range. This has facilitated the separation of costs of complications for younger (35–65 years) and older (more than 65 years) patients. Although there are differences in resource use between these groups for some complications (e.g., ulcers appear to be more costly in the older age groups), for most complications are not significantly different across these age groups.

It is important to emphasize that overall health-care costs are considerably higher than DRG cost weights associated with a single admission for most of these types of complications. For example, DRG cost weights associated with treating cerebrovascular disease ranged from $3609 to $6632 [15] compared with $14,012 (12,894, 15,183) in event costs and $3691 (3226, 4230) in state costs for a man aged 60 years reported here. This difference in event costs is mainly due to multiple admissions in the year the event was first recorded. This does have important implications for economic evaluations of therapies that prevent or treat complications which based estimates of future costs on DRG cost weights because these are likely to significantly underestimate the lifetime cost of many complications.

This study also shows that nonhospital costs also contribute mainly to state costs. For example, in the case of MI, around 30% of ongoing health-care costs are due to costs incurred outside of hospital. Although these estimates pertain to Australia, this does suggest a need to also estimate the nonhospital costs associated with complications in other countries. This would allow health economic models to capture more of the potential savings in future health-care costs arising from prevention, or the better management of diabetes.

Finally, a number of limitations of the data should be acknowledged. First, the data linkage is confined to those residents in WA which is only one of Australia's States. There is a considerable international literature [25] showing variations in medical practice across regions. Nevertheless, international evidence suggests these pertain more to discretionary health care that the treatment of serious events such as MIs. It would be useful to undertake comparisons with costing from studies from other regions to determine the extent of variation within Australia. Second, these costs do not include several important categories of health-care expenditure most notably the cost of pharmaceuticals and rehabilitation costs which may be important in treating some types of complication such as stroke. Third, the reported costs for some complications may change over time because advances in technology and new treatments may impact on the relative cost of treating various complications over time. In regard to the latter, it may be possible to account for these changes by adjusting the probability of hospitalization, when there is evidence that a new intervention impacts on the hospitalization rate. The increasing availability of linked administrative data in Australia covering medical, hospital, and nursing home care should allow future studies to overcome limitations and lead to further refinement of complication-specific costs for diabetes.

In conclusion, the results of this study illustrate how complication specific costs can be estimated using administrative data. This approach may also be useful in deriving cost that can be used in health economic models in other chronic disease areas. On a practical level, they provide a set of health-care costs of diabetes-related complications that can be used for economic evaluation in the Australian setting based on the best available data. They should be of interest to economists, policymakers, and health service researchers, particularly those interested in forecasting future health-care costs of people with diabetes, or wishing to model the cost-effectiveness of interventions aimed at reducing the rates of complications.

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