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Costs of major complications in people with and without diabetes in Tasmania, Australia

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ABSTRACT

Objective. We set out to estimate healthcare costs of diabetes complications in the year of first occurrence and the second year, and to quantify the incremental costs of diabetes versus non-diabetes related to each complication. **Methods.** In this cohort study, people with diabetes ($n = 45\,378$) and their age/sex propensity score matched controls ($n = 90\,756$) were identified from a linked dataset in Tasmania, Australia between 2004 and 2017. Direct costs (including hospital, emergency room visits and pathology costs) were calculated from the healthcare system perspective and expressed in 2020 Australian dollars. The average-per-patient costs and the incremental costs in people with diabetes were calculated for each complication. **Results.** First-year costs when the complications occurred were: dialysis $78 152 (95% CI 71 095, 85 858), lower extremity amputations $63 575 (58 290, 68 688), kidney transplant $48 487 (33 862, 68 283), non-fatal myocardial infarction $30 827 (29 558, 32 197), foot ulcer/gangrene $29 803 (27 183, 32 675), ischaemic heart disease $29 160 (26 962, 31 457), non-fatal stroke $27 782 (26 285, 29 354), heart failure $27 379 (25 968, 28 966), kidney failure $24 904 (19 799, 32 557), angina pectoris $18 430 (17 147, 19 791), neuropathy $15 637 (14 265, 17 108), nephropathy $15 133 (12 285, 18 595), retinopathy $14 775 (11 798, 19 199), transient ischaemic attack $13 905 (12 529, 15 536), vitreous hemorrhage $13 405 (10 241, 17 321), and blindness/low vision $12 941 (8164, 19 080). The second-year costs ranged from 16% (ischaemic heart disease) to 74% (dialysis) of first-year costs. Complication costs were 109–275% higher than in people without diabetes. **Conclusions.** Diabetes complications are costly, and the costs are higher in people with diabetes than without diabetes. Our results can be used to populate diabetes simulation models and will support policy analyses to reduce the burden of diabetes.

Keywords: Australia, complications, cost of illness, data linkage, diabetes, excess cost, incremental costs, record linkage, Tasmania.

Introduction

Diabetes is a chronic disease that is considered to be an escalating problem in Australia.[1] In 2018, it was estimated that approximately 1.2 million people in Australia were living with diabetes.[2] It is predicted that there will be an increasing number of people with diabetes in Australia,[1,3] leading to an anticipated heavy burden on the healthcare system.

Most of the healthcare costs related to diabetes are due to management of complications.[4] Therefore, identifying complications that are the key drivers of the economic burden will help guide policy makers and practitioners in determining the main targets to reduce the burden of diabetes. Additionally, up-to-date diabetes complication costs are an essential ingredient in country-specific analyses of the cost-effectiveness of new diabetes interventions and are used by multiple international diabetes health economics simulation models.[5–8] Because diabetes complications have both immediate and

long-term impact,[9] cost estimates associated with each complication at different time points are needed. In Australia, there are few studies quantifying the costs of diabetes complications over time. Those that do exist were performed over a decade ago, were focused on a single complication or a limited number of them, did not have a matched cohort of people without diabetes to estimate the incremental costs due to diabetes of each complication, and were based on a relatively small dataset.[10–12]

The aims of this study were to:

1. Estimate the costs of diabetes-related complications in the year of first occurrence and the second year.
2. Quantify the incremental costs of complications in people with diabetes versus non-diabetes.

Methods

Data linkage

This was a matched retrospective cohort study using a linked dataset in Tasmania, Australia. The dataset used in this study was first linked to examine the burden of chronic kidney disease.[13] Any Tasmanian who had a serum creatinine test between 1 January 2004 and 31 December 2017; recorded in either Royal Hobart Hospital Pathology (RHHPATH) or Hobart Pathology (Diagnostic Services Pty Ltd [DSPL]) was identified at the first step. After that, the Tasmanian Data Linkage Unit linked these data to other administrative datasets: Tasmanian Public Hospital Admitted Patient Episodes (AP), Tasmanian Public Hospital Emergency Department Presentations (ED), Tasmanian Death Register and Tasmanian Coded Cause of Death (DEATH). Details related to the linkage process and data extraction have been published previously.[13,14] It was estimated that approximately 87% of the Tasmanian adult population was included in this dataset.[13]

Participant selection

From the linked dataset, people were identified as having diabetes if they had at least one of the following criteria, as per our previously-published costing study:[14]

1. ≥1 HbA1c test ≥ 48 mmol/mol (6.5%).
2. ≥1 fasting plasma glucose tests ≥ 7.0 mmol/L (126 mg/dL).
3. ≥1 random plasma glucose test ≥ 11.1 mmol/L (200 mg/dL).
4. International Statistical Classification of Diseases and Related Health problems 10th Revision Australian Modification (ICD-10-AM) diagnosis code (primary or other) in the E10—E14 ranges recorded in either AP or ED.
5. A cause of death code (primary or underlying) in the E10–E14 ranges recorded in DEATH (this was used primarily to ascertain whether diabetes identification was accurate).

People with diabetes were matched with people without diabetes (having none of the above criteria) sourced from the same dataset. Propensity score matching (1:2) was performed by age decile, sex, Statistical Areas Level 4 of residence, year of first serum creatine test and total time (years) in the datasets. Finally, 45 378 people with diabetes and 90 756 people without diabetes were identified (Fig. 1).

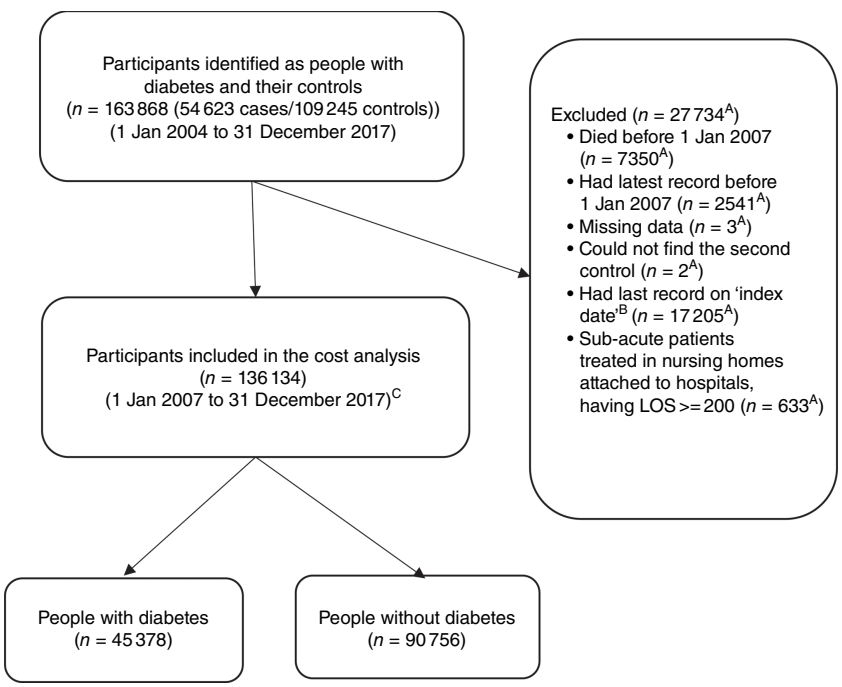

Fig. 1. Flow of participants into the study. LOS, Length of stay. [A]Total number of people with and without diabetes. If a participant was excluded, their corresponding case/controls were also excluded. [B]Date of first diagnosis as people with diabetes. [C]Because of the availability of data from the Tasmanian Public Hospital Admitted Patient Episodes (AP), the final analysis was from 1 January 2007 to 31 December 2017.

Identification of complications

People with diabetes complications were identified from hospital and ED records using primary diagnosis and primary procedure (Supplementary Table S1). Records before diabetes diagnosis were also checked to exclude participants who had already developed any complications. Definitions of complications and their hierarchical order of severity were based on the Diabetes Complications Severity Index.[15] To avoid double counting in cost estimates, participants with multiple complications belonging to one main group were assigned to the complications at the highest order of severity when estimating healthcare resource consumption. For instance, participants who developed kidney failure in 2008 and dialysis in 2009 would be assigned to dialysis group only. If participants had multiple complications belonging to different main groups (e.g. cardiovascular disease and cerebrovascular disease), when estimating costs due to the complication of interest, costs of the other complications were excluded.

Costing method

Our study was performed from the healthcare system perspective and considered the three cost components that could be estimated from the linked dataset: hospital, ED, and pathology costs. All costs were inflated to 2020 Australian dollars. Additional information regarding how these costs were calculated were described previously.[14]

All records from the first time diabetes was diagnosed (i.e. the index date) were extracted for people with diabetes. Records during the same period were extracted for the corresponding controls. We also identified the first time participants who were diagnosed with a complication to separate the costs in the year the complication occurred (event costs) and the second year (state costs) for all chronic complications.

Statistical analyses

For all health service use and cost data, we reported the arithmetic mean and its confidence interval. Although cost data tend to be right skewed due to outliers, the arithmetic mean is the most informative measure used by policy makers to predict the corresponding total budget required.[16,17] The confidence interval of the mean was derived by a bias-corrected bootstrapping method with 1000 resamples. The incremental costs for each complication in people with diabetes, in comparison with people without diabetes were defined as the differences in mean annual costs per person in these two groups.[18,19]

The matching was conducted in R version 4.0.3.[20] Stata version 17.0 was used for all statistical analyses.

Ethics approval

Ethics approval (with waiver of consent) for the study was granted by the Tasmanian Health and Medical Human Research Ethics Committee (reference number H0018548).

Results

Because people with diabetes and those without were matched on age, sex, and follow-up time, these characteristics were similar in both groups (Table 1). There were 55% men and 45% women, with the mean age of 59 years. They were both followed for over 5 years.

In general, the proportions of people with diabetes developing complications outweighed those without diabetes (Table 2). Macrovascular complications, including cardiovascular disease (CVD, 10 216 people) and cerebrovascular disease (2501 people) accounted for the highest proportions in people with diabetes, while metabolic complications were the least prevalent (2378 people).

In both groups, health service utilisation in the first year when the complications occurred was higher than the second year (Table 3). In people with diabetes, healthcare resource usage was highest for dialysis, transplant, and lower extremity amputations (LEA) (based on ranks of number of visits and length of stay (LOS)).

Table 1. Characteristics of participants.

Characteristics	People with diabetes	People without diabetes
Total	*N* = 45 378	*N* = 90 756
Sex		
Men	24 964 (55)	49 928 (55)
Women	20 414 (45)	40 828 (45)
Age (years)[A]	62.0 ± 15.1	61.5 ± 15.1
Age groups (years)[A]		
0–39	3272 (7.2)	6905 (7.6)
40–49	5022 (11)	10 338 (11)
50–59	9725 (21)	20 099 (22)
60–69	12 751 (28)	25 349 (28)
≥70	14 608 (32)	28 065 (31)
IRSD		
1 (most disadvantaged)	9376 (21)	14 113 (16)
2	8752 (19)	15 786 (17)
3	9444 (21)	18 454 (20)
4	8784 (19)	19 890 (22)
5 (least disadvantaged)	9022 (20)	22 513 (25)
Number of deaths	9420 (21)	10 571 (12)
Follow-up time (years)[B]	5.6 ± 3.5	6.0 ± 3.5

Data are presented as the total number (%), except for the follow up time, which is presented as mean ± standard deviation.
[A]Calculated from recorded age at index date (date of first diabetes diagnosis).
[B]Calculated from index date and date of last record.
IRSD, Index of Relative Socioeconomic Disadvantage, calculated using statistical area level 2 (SA2) of residence.

Table 2. Cumulative incidence of diabetes complications during the study period (2007–17).

Main groups	Subgroups	People with diabetes		People without diabetes	
		Number at risk[A]	*n* (%)	Number at risk[A]	*n* (%)
Cardiovascular disease	Fatal MI[B]	41 168	108 (0.3)	84 948	91 (0.1)
	Non-fatal MI	41 168	2133 (5.2)	84 948	2237 (2.6)
	Heart failure	41 168	2355 (5.7)	84 948	1709 (2.0)
	Ischaemic heart disease	41 168	1037 (2.5)	84 948	1005 (1.2)
	Angina pectoris	41 168	2348 (5.7)	84 948	2250 (2.6)
	Other cardiovascular complications	41 168	2235 (5.4)	84 948	3289 (3.9)
	Total		10 216		10 581
Cerebrovascular disease	Fatal stroke[B]	41 168	60 (0.15)	84 948	91 (0.11)
	Non-fatal stroke	41 168	1477 (3.6)	84 948	1724 (2.0)
	Transient ischaemic attack	41 168	964 (2.3)	84 948	1369 (1.6)
	Total		2501		3184
Peripheral vascular disease	Lower extremity amputations	41 168	452 (1.1)	84 948	67 (0.1)
	Foot ulcer/gangrene	41 168	999 (2.4)	84 948	379 (0.4)
	Other peripheral vascular complications	41 168	417 (1.0)	84 948	230 (0.3)
	Total		1868		676
Renal disease (nephropathy)	Transplant	41 168	25 (0.06)	84 948	6 (0.01)
	Dialysis	41 168	288 (0.7)	84 948	110 (0.1)
	Kidney failure	41 168	174 (0.4)	84 948	72 (0.1)
	Nephropathy	41 168	227 (0.6)	84 948	51 (0.1)
	Other kidney complications	41 168	245 (0.60)	84 948	37 (0.04)
	Total		959		276
Ophthalmic complications	Blindness and low vision	41 168	33 (0.08)	84 948	36 (0.04)
	Vitreous hemorrhage	41 168	72 (0.16)	84 948	22 (0.03)
	Retinopathy	41 168	148 (0.36)	84 948	6 (0.01)
	Other ophthalmic complications	41 168	830 (2.0)	84 948	185 (0.2)
	Total		1083		249
Neuropathy		41 168	1105 (2.7)	84 948	1151 (1.4)
Metabolic complication	Hyperglycaemia	41 168	928 (2.3)	84 948	n/a
	Hypoglycaemia	41 168	714 (1.7)	84 948	n/a
	Acidosis	41 168	736 (1.8)	84 948	n/a
	Total		2378		n/a

[A]The number of participants without prior history of any complications.
[B]An event was defined as fatal if the participant died within 28 days of its onset.
LEA, lower extremity amputations; MI, myocardial infarction; TIA, transient ischaemic attack.

People having at least one complication had substantially greater healthcare costs than people without complications (Table 4). The costs in the first year for the complications that occurred in people with diabetes were substantial, especially for dialysis $78 152 (95% CI 71 095, 85 858), LEA $63 575 (58 290, 68 688), kidney transplant $48 487 (33 862, 68 283), non-fatal myocardial infarction $30 827 (29 558, 32 197), and foot ulcer/gangrene $29 803 (27 183, 32 675). Second-year costs were less than the first-year costs, ranging from 16% of first-year costs (ischaemic heart disease) to 74% (dialysis) in people with diabetes.

Table 3. Annual health service utilisation per person with and without diabetes, by complications.

Complications	Number of hospital admissions		Length of hospital stay (days)		Number of ED presentations		Length of ED stay (minutes)	
	People with diabetes	People without diabetes	People with diabetes	People without diabetes	People with diabetes	People without diabetes	People with diabetes	People without diabetes
	Mean (95% CI)[A]	Mean (95% CI)[A]	Mean (95% CI)[A]	Mean (95% CI)[A]	Mean (95% CI)[A]	Mean (95% CI)[A]	Man (95% CI)[A]	Mean (95% CI)[A]
First year recorded[B]								
Cardiovascular disease								
Fatal MI	1.1 (1.0, 1.2)	1.2 (1.0, 1.3)	5.0 (3.9, 6.5)	4.7 (3.2, 6.9)	1.1 (1.0, 1.2)	1.1 (1.0, 1.3)	588 (424, 810)	436 (347, 561)
Non-fatal MI	2.6 (2.5, 2.7)	2.3 (2.2, 2.4)	13.4 (12.6, 14.3)	9.7 (9.1, 10.3)	2.5 (2.4, 2.6)	2.1 (2.1, 2.2)	1286 (1222, 1357)	1015 (967, 1069)
Heart failure	2.6 (2.4, 2.7)	2.3 (2.2, 2.4)	16.5 (15.6, 17.5)	16.0 (15.0, 17.2)	2.2 (2.1, 2.3)	2.0 (1.9, 2.1)	1327 (1256, 1402)	1171 (1094, 1245)
Ischaemic heart disease	2.2 (2.0, 2.6)	1.9 (1.8, 2.0)	9.0 (7.9, 10.2)	7.3 (6.5, 8.4)	0.9 (0.7, 1.0)	0.7 (0.7, 0.9)	394 (330, 479)	352 (303, 419)
Angina pectoris	1.9 (1.9, 2.0)	1.7 (1.6, 1.8)	6.5 (5.9, 7.1)	4.9 (4.4, 5.5)	1.8 (1.7, 1.9)	1.6 (1.5, 1.7)	825 (772, 881)	700 (661, 740)
Other cardiovascular complications	1.9 (1.7, 2.0)	1.5 (1.5, 1.6)	8.6 (7.7, 9.5)	6.7 (6.1, 7.4)	1.6 (1.5, 1.7)	1.6 (1.5, 1.6)	738 (682, 794)	674 (637, 711)
Cerebrovascular disease								
Fatal stroke	1.1 (1.0, 1.2)	1.2 (1.1, 1.3)	6.6 (4.6, 9.5)	5.8 (4.5, 7.3)	0.8 (0.7, 1.0)	0.8 (0.7, 0.9)	440 (309, 644)	472 (342, 643)
Non-fatal stroke	2.3 (2.2, 2.3)	2.1 (2.0, 2.3)	24.8 (23.2, 26.6)	21.7 (20.3, 23.2)	1.6 (1.6, 1.7)	1.6 (1.5, 1.7)	999 (940, 1064)	984 (932, 1041)
TIA	1.6 (1.5, 1.8)	1.3 (1.2, 1.4)	8.8 (7.5, 10.2)	6.0 (5.1, 7.3)	2.1 (1.9, 2.3)	1.7 (1.6, 1.8)	1011 (917, 1120)	793 (731, 851)
Peripheral vascular disease								
LEA	5.0 (4.3, 5.8)	2.4 (1.9, 3.2)	39.6 (35.8, 43.7)	24.0 (14.2, 36.2)	2.0 (1.7, 2.2)	1.3 (1.0, 1.8)	927 (812, 1062)	727 (473, 1089)
Foot ulcer/gangrene	4.6 (3.9, 5.3)	2.2 (1.7, 2.8)	19.9 (17.6, 22.2)	12.1 (9.9, 14.7)	2.3 (2.1, 2.5)	2.0 (1.8, 2.2)	964 (858, 1082)	592 (515, 685)
Other peripheral vascular complications	1.5 (1.2, 1.7)	0.9 (0.7, 1.1)	6.6 (5.0, 8.6)	4.6 (3.0, 6.8)	1.2 (1.0, 1.4)	1.3 (1.0, 1.7)	453 (359, 538)	493 (384, 640)
Renal disease								
Transplant	23.5 (12.0, 42.9)	29.2 (3.2, 80.7)	36.5 (21.7, 56.7)	33.3 (4.3, 89.8)	1.2 (0.6, 1.7)	1.2 (0.2, 2.7)	386 (180, 754)	144 (7, 326)
Dialysis	73.1 (65.5, 81.0)	61.9 (50.3, 74.4)	85.0 (77.4, 93.5)	73.4 (61.4, 87.5)	1.8 (1.6, 2.1)	1.7 (1.3, 2.3)	764 (647, 898)	855 (609, 1234)
Kidney failure	3.0 (2.1, 4.3)	2.4 (1.9, 3.2)	16.6 (12.2, 22.3)	14.3 (9.6, 20.6)	1.2 (0.9, 1.5)	1.0 (0.7, 1.4)	612 (477, 766)	672 (388, 959)
Nephropathy	2.3 (1.8, 2.9)	3.3 (2.3, 4.7)	11.5 (8.7, 14.7)	23.8 (11.7, 46.5)	1.1 (0.9, 1.3)	1.4 (0.9, 2.1)	495 (382, 629)	682 (419, 981)
Other kidney complications	2.7 (2.4, 3.1)	3.6 (2.8, 4.7)	22.1 (17.5, 27.3)	18.5 (9.9, 30.2)	2.2 (1.8, 2.6)	1.3 (0.8, 1.8)	1116 (928, 1325)	846 (497, 1406)

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Table 3. (*Continued*)

Complications	Number of hospital admissions		Length of hospital stay (days)		Number of ED presentations		Length of ED stay (minutes)	
	People with diabetes	People without diabetes	People with diabetes	People without diabetes	People with diabetes	People without diabetes	People with diabetes	People without diabetes
	Mean (95% CI)[A]	Mean (95% CI)[A]	Mean (95% CI)[A]	Mean (95% CI)[A]	Mean (95% CI)[A]	Mean (95% CI)[A]	Man (95% CI)[A]	Mean (95% CI)[A]
Ophthalmic complications								
Blindness and low vision	1.7 (1.2, 2.3)	2.6 (1.6, 3.8)	12.3 (4.7, 25.4)	12.7 (6.2, 21.1)	2.0 (1.5, 2.6)	2.4 (1.8, 3.1)	722 (414, 1150)	1157 (773, 1664)
Vitreous hemorrhage	2.6 (1.9, 4.0)	1.4 (1.0, 1.9)	5.0 (3.3, 7.4)	2.1 (1.2, 3.7)	0.9 (0.7, 1.3)	1.0 (0.4, 1.6)	518 (293, 875)	230 (70, 462)
Retinopathy	2.4 (2.1, 3.0)	2.6 (0.8, 6.2)	7.2 (5.0, 10.4)	8.6 (0.4, 23.8)	1.0 (0.8, 1.4)	1.4 (0.6, 2.6)	393 (279, 545)	466 (59, 1094)
Other ophthalmic complications	1.9 (1.8, 2.1)	1.4 (1.2, 1.7)	5.0 (4.3, 5.9)	3.1 (2.0 (4.7)	0.7 (0.6, 0.8)	1.1 (0.9, 1.2)	245 (208, 282)	270 (206, 353)
Neuropathy	2.2 (2.0, 2.3)	1.8 (1.6, 1.9)	9.5 (8.4, 10.6)	7.7 (6.9, 8.9)	1.7 (1.5, 1.8)	1.4 (1.3, 1.6)	834 (750, 923)	617 (555, 680)
Metabolic complication								
Hyperglycaemia	2.4 (2.3, 2.6)		15.4 (13.9, 17.2)		2.1 (1.9, 2.3)		937 (838, 1065)	
Hypoglycaemia	2.6 (2.3, 2.8)		16.4 (14.3, 18.8)		2.3 (2.1, 2.5)		1205 (1082, 1361)	
Acidosis	2.2 (2, 2.4)		10.7 (9.3, 12.3)		2.3 (2.1, 2.6)		999 (900, 1135)	
No complication	0.5 (0.5, 0.5)	0.2 (0.2, 0.2)	2.5 (2.4, 2.6)	0.8 (0.7, 0.8)	0.3 (0.3, 0.3)	0.2 (0.2, 0.2)	117 (112, 122)	54 (53, 56)
Second year[C]								
Cardiovascular disease								
Non-fatal MI	0.9 (0.8, 1.0)	0.6 (0.5, 0.6)	4.9 (4.2, 5.5)	2.5 (2.1, 2.9)	1.0 (0.9, 1.1)	0.6 (0.5, 0.6)	459 (409, 515)	266 (229, 306)
Heart failure	1.1 (0.9, 1.2)	0.8 (0.7, 0.9)	6.6 (5.8, 7.7)	5.0 (4.2, 5.9)	0.9 (0.8, 1.0)	0.8 (0.7, 0.9)	506 (451, 576)	397 (341, 450)
Ischaemic heart disease	0.6 (0.5, 0.8)	0.5 (0.4, 0.6)	2.0 (1.5, 2.6)	2.1 (1.4, 3.0)	0.5 (0.4, 0.6)	0.4 (0.3, 0.5)	185 (144, 240)	177 (128, 227)
Angina pectoris	0.7 (0.6, 0.7)	0.6 (0.5, 0.6)	2.6 (2.2, 3.0)	2.2 (1.8, 2.7)	0.8 (0.7, 0.9)	0.6 (0.5, 0.7)	304 (262, 359)	220 (184, 256)
Other cardiovascular complications	0.8 (0.7, 1.0)	0.5 (0.4, 0.6)	3.8 (3.1, 4.6)	2.2 (1.8, 2.6)	0.6 (0.5, 0.7)	0.5 (0.5, 0.6)	280 (241, 325)	210 (182, 238)
Cerebrovascular disease								
Non-fatal stroke	0.6 (0.5, 0.7)	0.5 (0.4, 0.6)	4.2 (3.3, 5.0)	3.3 (2.7, 4.0)	0.6 (0.5, 0.7)	0.5 (0.4, 0.6)	293 (248, 340)	245 (204, 307)
TIA	0.7 (0.6, 0.8)	0.4 (0.4, 0.5)	3.5 (2.7, 4.3)	2.5 (1.9, 3.4)	0.9 (0.7, 1.1)	0.5 (0.5, 0.7)	365 (281, 490)	238 (194, 294)

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Table 3. (*Continued*)

Complications	Number of hospital admissions		Length of hospital stay (days)		Number of ED presentations		Length of ED stay (minutes)	
	People with diabetes	People without diabetes	People with diabetes	People without diabetes	People with diabetes	People without diabetes	People with diabetes	People without diabetes
	Mean (95% CI)[A]	Mean (95% CI)[A]	Mean (95% CI)[A]	Mean (95% CI)[A]	Mean (95% CI)[A]	Mean (95% CI)[A]	Man (95% CI)[A]	Mean (95% CI)[A]
Peripheral vascular disease								
LEA	2.1 (1.5, 2.8)	0.6 (0.3, 1.0)	9.3 (7.1, 11.8)	6.8 (2.0, 14.5)	1.0 (0.8, 1.3)	0.7 (0.3, 1.2)	470 (377, 579)	227 (109, 377)
Foot ulcer/gangrene	1.3 (0.9, 1.7)	0.6 (0.4, 0.7)	6.4 (4.9, 8.4)	3.1 (2.0, 4.6)	1.0 (0.8, 1.2)	0.7 (0.5, 0.9)	415 (338, 509)	212 (162, 277)
Other peripheral vascular complications	0.8 (0.6, 1.0)	0.5 (0.4, 0.7)	5.2 (3.0, 8.2)	2.7 (1.8, 4.2)	0.6 (0.5, 0.8)	0.5 (0.4, 0.7)	303 (225, 411)	251 (149, 408)
Renal disease								
Transplant	20.7 (6.8, 47.3)	47.2 (0.0, 94.3)	25.9 (8.4, 54.2)	53.8 (0.0, 135.3)	0.5 (0.2, 0.8)	0.2 (0.0, 0.3)	256 (89, 480)	68 (0, 136)
Dialysis	58.1 (49.6, 66.8)	47.4 (35.2, 61.2)	65.6 (56.9, 74.3)	51.6 (39.0, 65.6)	1.6 (1.3, 1.9)	1.2 (0.9, 1.6)	701 (542, 861)	499 (332, 713)
Kidney failure	1.2 (0.7, 1.8)	1.1 (0.6, 1.7)	9.2 (3.5, 18.8)	8.0 (2.9, 18.9)	0.8 (0.3, 1.5)	0.8 (0.4, 1.3)	302 (97, 586)	678 (235, 1294)
Nephropathy	1.3 (1, 1.7)	0.7 (0.2, 1.4)	7.6 (5.0, 11.0)	2.2 (0.7, 4.7)	1.0 (0.7, 1.3)	0.8 (0.3, 1.6)	404 (296, 566)	545 (135, 1397)
Other kidney complications	0.8 (0.5, 1.1)	0.8 (0.3, 1.5)	4.4 (2.5, 6.3)	2.9 (0.6, 6.1)	0.9 (0.6, 1.4)	0.8 (0.2, 1.8)	465 (301, 681)	319 (81, 678)
Ophthalmic complications								
Blindness and low vision	0.6 (0.3, 1.0)	1.8 (0.6, 3.8)	2.8 (1.0, 5.8)	6.5 (2.5, 12.7)	0.6 (0.2, 1.1)	0.8 (0.3, 1.7)	391 (132, 736)	393 (117, 848)
Vitreous hemorrhage	0.9 (0.6, 1.2)	0.4 (0.0, 1.0)	3.3 (1.6, 6.1)	3.4 (0.1, 11.2)	0.9 (0.4, 1.6)	0.7 (0.0, 1.8)	275 (133, 502)	204 (4.5, 737)
Retinopathy	0.8 (0.5, 1.0)	1.3 (0.3, 3.3)	2.7 (0.9, 4.6)	1.3 (0.3, 3.3)	0.6 (0.4, 0.8)	0.8 (0.3, 1.8)	227 (148, 324)	355 (84, 897)
Other ophthalmic complications	0.8 (0.7, 0.9)	0.6 (0.3, 1.3)	3.8 (3.0, 4.8)	1.6 (0.8, 2.8)	0.6 (0.5, 0.6)	0.3 (0.2, 0.5)	257 (216, 312)	124 (63, 208)
Neuropathy	0.9 (0.8, 1.1)	0.7 (0.6, 0.8)	5.0 (4.1, 6.1)	3.2 (2.6, 4.0)	0.9 (0.8, 1.1)	0.6 (0.5, 0.7)	397 (316, 483)	215 (183, 256)
No complication	0.3 (0.3, 0.3)	0.2 (0.2, 0.2)	1.3 (1.2, 1.4)	0.8 (0.8, 0.8)	0.2 (0.2, 0.3)	0.2 (0.2, 0.2)	82 (77, 88)	59 (57, 61)

[A]Derived using bootstrapping method.
[B]Within 12 months from the first time diagnosed with the complications.
[C]Within 12 months from the end of the first year when the complications occurred.
ED, Emergency Department; LEA, lower extremity amputations; MI, myocardial infarction; TIA, transient ischaemic attack.

Table 4. Annual healthcare costs per person with and without diabetes, by complications.

Complications	Total costs		Incremental costs (95% CI)[A]
	People with diabetes Mean (95% CI)[A]	People without diabetes Mean (95% CI)[A]	
First year recorded[B]			
Cardiovascular disease			
Fatal MI	15 513 (11 598, 20 361)	12 586 (10 095, 16 928)	2927 (−1858, 9414)
Non-fatal MI	30 827 (29 558, 32 197)	24 322 (23 448, 25 255)	6505 (4899, 8085)
Heart failure	27 379 (25 968, 28 966)	23 489 (22 246, 24 826)	3890 (1770, 5715)
Ischaemic heart disease	29 160 (26 962, 31 457)	26 662 (24 795, 28 844)	2497 (−193, 5549)
Angina pectoris	18 430 (17 147, 19 791)	13 878 (12 980, 14 820)	4551 (3103, 6077)
Other cardiovascular complications	17 708 (16 222, 19 198)	14 791 (13 666, 15 877)	2916 (1174, 4939)
Cerebrovascular disease			
Fatal stroke	13 227 (10 668, 17 442)	11 532 (9824, 13 253)	1694 (−1369, 5447)
Non-fatal stroke	27 782 (26 285, 29 354)	24 103 (23 056, 25 206)	3680 (1889, 5515)
TIA	13 905 (12 529, 15 536)	9845 (8954, 10 914)	4060 (2404, 5861)
Peripheral vascular disease			
LEA	63 575 (58 290, 68 688)	31 150 (21 927, 41 653)	32 425 (20 119, 42 688)
Foot ulcer/gangrene	29 803 (27 183, 32 675)	15 024 (12 924, 17 519)	14 779 (11 390, 18 550)
Other peripheral vascular complications	13 240 (10 904, 15 527)	8276 (6525, 10 816)	4965 (1649, 8074)
Renal disease			
Transplant	48 487 (33 862, 68 283)	36 634 (10 549, 83 754)	11 853 (−46 527, 45 898)
Dialysis	78 152 (71 095, 85 858)	66 282 (56 207, 79 239)	11 870 (−1771, 25 265)
Kidney failure	24 904 (19 799, 32 557)	18 205 (13 840, 23 716)	6699 (−886, 14 758)
Nephropathy	15 133 (12 285, 18 595)	25 879 (17 105, 38 323)	−10 746 (−24 137, −1081)
Other kidney complications	26 844 (22 824, 31 155)	21 838 (16 022, 28 797)	5006 (−2474, 13 088)
Ophthalmic complications			
Blindness and low vision	12 941 (8164, 19 080)	17 138 (10 363, 27 030)	−4197 (−14 791, 5665)
Vitreous hemorrhage	13 405 (10 241, 17 321)	9052 (5045, 16 345)	4353 (−2487, 10 618)
Retinopathy	14 775 (11 798, 19 199)	7850 (1998, 16 936)	6924 (−4641, 14 547)
Other ophthalmic complications	10 505 (9363, 12 146)	7659 (6019, 9702)	2846 (396, 5259)
Neuropathy	15 637 (14 265, 17 108)	11 620 (10 571, 12 872)	4017 (2129, 6024)
Metabolic complication			
Hyperglycaemia	23 911 (21 811, 26 233)		
Hypoglycaemia	24 862 (22 597, 27 220)		
Acidosis	22 343 (20 201, 25 022)		
No complication	4322 (4132, 4496)	1394 (1342, 1440)	2928 (2739, 3121)
Second year[C]			
Cardiovascular disease			
Non-fatal MI	8784 (7807, 9905)	4716 (4157, 5303)	4068 (2961, 5383)
Heart failure	10 295 (9136, 11 585)	7310 (6476, 8246)	2985 (1589, 4676)
Ischaemic heart disease	4555 (3607, 5704)	3568 (2756, 4462)	987 (−209, 2509)

(*Continued on next page*)

Table 4. (*Continued*)

Complications	Total costs		Incremental costs (95% CI)[A]
	People with diabetes Mean (95% CI)[A]	People without diabetes Mean (95% CI)[A]	
Angina pectoris	5431 (4741, 6192)	4194 (3557, 4873)	1237 (289, 2170)
Other cardiovascular complications	6367 (5396, 7496)	3654 (3264, 4099)	2713 (1569, 3891)
Cerebrovascular disease			
Non-fatal stroke	5989 (5193, 6994)	4465 (3769, 5200)	1524 (303, 2681)
TIA	5877 (4927, 7070)	3754 (3147, 4493)	2123 (832, 3492)
Peripheral vascular disease			
LEA	15 814 (12 851, 19 076)	5759 (2719, 10 538)	10 055 (4489, 14 765)
Foot ulcer/gangrene	9744 (7975, 12 152)	4751 (3295, 6415)	4993 (2768, 7476)
Other peripheral vascular complications	6945 (4977, 9139)	4567 (3230, 6315)	2377 (−77, 4961)
Renal disease			
Transplant	19 985 (8252, 37 219)	46 207 (995, 104 372)	−26 223 (−92 581, 24 238)
Dialysis	57 828 (49 840, 69 152)	41 933 (32 383, 51 969)	15 895 (2968, 29 775)
Kidney failure	13 722 (7254, 25 532)	9226 (3619, 19 179)	4496 (−5427, 16 806)
Nephropathy	10 079 (7192, 13 982)	5137 (1984, 10 109)	4941 (−553, 10 124)
Other kidney complications	8049 (4747, 13 482)	9229 (2590, 19 879)	−1180 (−13 740, 7412)
Ophthalmic complications			
Blindness and low vision	4810 (2055, 8956)	11 303 (3813, 24 472)	−6494 (−23 551, 1639)
Vitreous hemorrhage	5701 (3593, 8310)	5236 (83, 14 682)	465 (−9571, 5974)
Retinopathy	6935 (3968, 12 846)	3957 (55, 8757)	2977 (−3202, 9325)
Other ophthalmic complications	5880 (5011, 6842)	3174 (1879, 4740)	2705 (937, 4224)
Neuropathy	8309 (7028, 9921)	5115 (4301, 6030)	3194 (1603, 4950)
No complication	2254 (2147, 2396)	1450 (1393, 1508)	803 (670, 943)

[A]Derived using bootstrapping method.
[B]Within 12 months from the first time diagnosed with the complications.
[C]Within 12 months from the end of the first year when the complications occurred.
LEA, lower extremity amputations; MI, myocardial infarction; TIA, transient ischaemic attack.

In comparison to their non-diabetic counterparts, the incremental costs were substantial in people with diabetes having macrovascular complications and foot complications. Complications with considerably high incremental costs included LEA (1st year: $32 425 [20 119, 42 688]; 2nd year: $10 055 [4489, 14 765]), foot ulcer/gangrene (1st: $14 779 [11 390, 18 550]; 2nd: $4993 [2768, 7476]), and non-fatal MI (1st: $6505 [4899, 8085]; 2nd: $4068 [2961, 5383]). Costs for hospital admissions, ED visits and pathology tests are presented separately in Supplementary Table S2.

Discussion

Our study is the first Australian study comparing healthcare costs of individual complications between people with and without diabetes. Compared to their non-diabetic counterparts, people with diabetes had considerably greater costs of complications. It might be because managing complications in people with diabetes is more challenging due to the complexity of diabetes complication pathogenesis that leads to more severe manifestations, resulting in a higher number of hospital and ED visits, as well as longer LOS.

In the first year of occurrence, managing diabetes complications required substantially high levels of healthcare resource utilisation. Although there were some reductions, both health service utilisation and costs were still relatively high in the second year, especially when compared with people without any complications. The main reason for that might be because of the recurrence of diabetes complications or the indirect impact of the complications on other health conditions.

We also identified complications that are key cost drivers. Using a matched control method, our study not only investigated event and state costs of complications in people with

diabetes, but also compared these costs with people without diabetes to provide another perspective to assess the impact of diabetes complications. While the event and state costs highlight the extent of the problem, the incremental costs reveal the attributable impact of diabetes complications by excluding either fixed medical costs (in case of dialysis) or the costs due to general medical conditions. If only event and state costs were considered, the results indicated that dialysis, transplant, LEA, non-fatal MI, and foot ulcer/gangrene were the complications responsible for considerable costs. If the incremental costs were considered, the huge impact of LEA, non-fatal MI and foot ulcer/gangrene on costs were strongly demonstrated. The incremental costs also showed that people with diabetes having macrovascular complications imposes a heavy economic burden, especially when the incidence of CVD was the highest among complications reported in our study.

Previous studies focusing on the immediate and long-term impact of diabetes complications showed a similar pattern to our results, which suggests that although state costs decreased, they still contributed to a large burden of diabetes.[9–12,21] To compare these previous results with ours, we used the Campbell–Cochrane Converter based on the International Monetary Fund gross domestic product deflator to convert the original currency and price to 2020 Australian dollars.[22] In general, their cost estimates were comparable to our results, although there were some variations most likely due to the differing cost components included and also to changes in medical technology and treatment over time. In 2005, a systematic review in Australia found that the complications with considerable annual costs included dialysis (peritoneal dialysis: $64 676; haemodialysis: $40 348 [hospital event costs]), LEA ($43 538 [hospital event costs]), and transplant (event cost: $38 136; state costs: $1857 [only medication costs]).[11] However, costs for blindness (event costs: $49 071) were substantially higher than our estimate, most likely because of the inclusion of nursing home costs and pension payments in that study.[11] A study published in 2008 that included hospital and Medicare Benefits Schedule data also confirmed the key cost drivers among diabetes complications, namely renal failure (event costs: $51 222; state costs: $54 440); amputation (event costs: $36 487; state costs: $7204); and heart failure (event costs: $27 755; state costs: $11 613).[12] The differences in cost estimates for renal failure between this study and our study might be because this study did not distinguish between patients presenting with renal failure with or without transplant and dialysis, resulting in much higher costs, especially state costs.

The large sample size and long-term follow-up of our dataset enabled us to assess not only the immediate but also the second-year impact of a wide range of diabetes complications. Additionally, our inclusion criteria of people with diabetes were based on both diagnosis codes and pathology test results. However, our study had some limitations. First, we assumed that all costs in the first and second years the complication occurred were attributable to that complication, as has been done previously.[9,12] This might not be accurate in some cases, leading to a potential overestimation of the true costs. However, published literature suggested that estimating costs of diabetes complications based solely on events labelled to particular complications could result in underestimation, especially for incremental costs.[9,23] Additionally, as our results were comparable to other robust estimates from previous studies, we believe that the risk of overestimation is low. Second, in our dataset, only pathology tests performed on the same day as the serum creatinine test were provided. This likely contributed to an underestimate of pathology costs. As we also did not have data related to private hospitals in Tasmania, costs of admissions in private hospitals were not included. Another limitation is that because our dataset did not include Medicare Benefits Schedule or Pharmaceutical Benefits Scheme data, our direct cost did not contain general practitioner and specialist visits, patient out-of-pocket costs, and medication costs. However, previous studies demonstrated that hospital costs are the main driver of costs in people with diabetes,[24,25] and our study has captured public hospital costs thoroughly. Finally, we could not report results for type 1 and type 2 diabetes separately due to data unavailability.

Findings from our study will be useful for researchers and decision makers in Tasmania as well as Australia where the information regarding costs of a wide range of diabetes complications under similar settings is lacking. Compared with previous studies estimating the geometric mean of event and state costs based on the total medical costs during calendar years, our event and state costs were calculated from the first time being diagnosed with the complication (s). We believe that this approach allowed us to quantify the costs that accurately reflect the impact of onset complications on costs. However, because this study focused on multiple complications and each complication had different starting points in different patients, within the scope of this study, we did not calculate costs for further subsequent years beyond the second year after onset. Although there was evidence reporting a slightly downward trend in diabetes complication costs in subsequent years,[26] there was also other evidence suggesting that costs of individual complication are relatively stable after the year of first occurrence.[27]

In conclusion, our study provides a comprehensive analysis of diabetes complications by comparing the medical costs in the first year the complications occurred and the second year after occurrence and determining how much of these costs were specifically attributable to diabetes. Our findings are essential input information for economic evaluations and contribute to supporting policy analyses aiming at reducing the economic burden of diabetes.

Supplementary material

Supplementary material is available online.

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Data availability. Due to ethical and privacy concerns, the data from which the findings of this study were generated cannot be made available openly.

Conflicts of interest. MJ is a member of the Australia and New Zealand Dialysis and Transplant Registry (ANZDATA).

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