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Use of hospital care among Dutch diabetes patients

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Abstract

Aim: To provide insight into healthcare resource utilization and hospital expenditure of patients treated for diabetes in Dutch hospitals.

Materials and methods: We conducted an observational cohort study of 193 840 patients aged ≥18 years and treated for diabetes mellitus in 65 Dutch hospitals in 2019 to 2020, using real-world reimbursement data. Consultations, hospitalizations, technology use, total hospital and diabetes care costs (encompassing all care for diabetes itself) were assessed during 1-year follow-up. In addition, expenditure was compared with that in the general Dutch population.

Results: Total hospital costs for all patients with diabetes were €1 352 690 257 (1.35 billion) per year, and 15.9% (€214 963 703) was associated with treatment of diabetes. Mean yearly costs per patient were €6978, with diabetes care costs of €1109. Mean hospital costs of patients exceeded that of the Dutch population three- to sixfold. Total hospital costs increased with age, whereas diabetes expenditure decreased with age (18-40 years, €1575; >70 years, €932). Of all patients with diabetes, 51.3% (n = 99 457) received care related to cardiovascular complications. Micro- and macrovascular complications, or a combination, increased hospital costs (1.4-5.3 times higher).

Conclusions: The hospital resource use of Dutch diabetes patients is high, with a large burden of cardiovascular complications. Resource use is rooted mainly in hospital care of diabetes-related complications, not in the treatment of diabetes. Early treatment and prevention of complications remain imperative to taper future healthcare expenditure on patients with diabetes.

KEYWORDS

cardiovascular disease, cohort study, diabetes complications, health economics, observational study, real-world evidence

1 | INTRODUCTION

Diabetes mellitus is a chronic illness that, in 2021, affected an estimated 10.5% of the global population.[1] Predictions show a steep growth in the prevalence of diabetes in the coming decades, which is driven by the aging population and the rise of obesity.[2] The lives of many of these diabetes patients will be burdened by an array of complications. Diabetes is in the top 10 conditions with the highest disease burden expressed in disability-adjusted life-years (DALYs), and it profoundly influences patients' quality of life.[2,3] These complications

and higher mortality rates in diabetes patients will also increasingly impact current healthcare practice. Moreover, growing populations of elderly people with diabetes will lead to more heterogeneous disease patterns, requiring more complex treatment strategies that cause changes in healthcare utilization.[4] In 2021, worldwide, diabetes-related expenditure was estimated by the International Diabetes Federation Diabetes Atlas at 966 billion USD. This number is expected to rise to a staggering 1.05 trillion USD by 2045.[1] The indirect costs of diabetes-related cardiovascular disease will add up to an even higher economic burden, resulting in worries about the financial sustainability of future diabetes care provision. Hospital care use by people with diabetes is far higher compared with people without diabetes.[5] The rates of hospitalization, length of hospital stay and readmission rates are higher.[6] In line with this, in-hospital and outpatient care are the main contributors to diabetes-related healthcare expenditure.[7] However, diabetes care costs are often left undiscussed.[7] Focusing on the Netherlands, the prevalence of diabetes is currently estimated at 1.2 million patients, with an economic burden of €1.6 billion due to healthcare costs in 2016. An additional €1.3 billion was caused by complications.[8] Following global trends, Dutch primary care data predict that diabetes prevalence will rise to nearly 1.5 million in 2040, of an estimated population of 19 million.[9] Recent studies have shown that medical specialist care services account for the largest share of expenditure in all Dutch type 2 diabetes patients.[10,11] However, hospital use by the whole diabetes population on a patient level is unknown. Further insight and understanding of healthcare utilization provide an opportunity to optimize patient care, contain concomitant costs, and reallocate healthcare resources efficiently.

We aimed to provide insight into healthcare resource utilization, hospital expenditure, and cost-driving factors among adult patients with diabetes mellitus treated in Dutch hospitals using real-world reimbursement data.

2 | MATERIALS AND METHODS

2.1 | Study setting

This nationwide, retrospective cohort study was conducted on healthcare reimbursement data of Dutch patients with diabetes mellitus. In the Netherlands, basic healthcare, including hospital care, is covered for all citizens by mandatory healthcare insurance. Insurance companies receive declarations based on a system of Diagnosis Treatment Combination (DBC) codes. DBCs are nationally predefined packages of healthcare activities and procedures based on a particular diagnosis and the associated treatment; therefore, DBC codes contain information on medical specialty, diagnosis and related treatment. Information on all claimed DBC codes is collected in the hospital information systems of individual Dutch hospitals.[12] Invoices with DBC codes are filed by each hospital and reimbursed by healthcare insurance companies. LOGEX (Amsterdam, the Netherlands) is a Dutch healthcare analytics company that services a database with benchmark information from 65 affiliated hospitals across the Netherlands, comprising approximately 88% of all Dutch hospitals in 2019. For this study, a dataset was obtained from the database with information on all claimed DBC codes. The authors selected the dataset's study population based on diabetes-related claims. Several studies have shown administrative data sources, such as the database used in this study, to be useful for quality assessment in different medical fields in the Netherlands.[13,14] All reimbursement data collected by hospitals were processed and validated by LOGEX using previous data deliveries. The current analysis comprised secondary and tertiary hospital care, thus excluding data from primary care and independent treatment clinics. National prevalence estimates show that nearly 100 000 Dutch adults live with type 1 diabetes, most of whom are treated in secondary and tertiary hospitals.[15] In addition, adults with type 2 diabetes are referred from primary care to outpatient hospital care when more intensive or complex disease management is required, for screening or treatment of diabetes-related complications, and in case of hospitalization.

2.2 | Data collection

Patients aged ≥18 years treated for type 1 or type 2 diabetes mellitus, or secondary diabetes mellitus in 65 affiliated hospitals across the Netherlands were included. Treatment for diabetes was defined as a registered diabetes DBC claim between January 1, 2019 and December 31, 2019. All included individuals had a follow-up duration of 365 consecutive days following the date the DBC claim was recorded, which is the same date that the patient visited the hospital. Diabetes-related care trajectories within the following six hospital-based specialties were included (specialty and diabetes codes are shown in Table S1): internal medicine, paediatrics, ophthalmology (diabetic retinopathy and maculopathy diagnosis codes), gastroenterology, surgery, and orthopaedics (diabetic foot diagnosis code). Separate care activities within these trajectories were only used for a selection of prespecified outcomes (codes shown in Table S2). Patient data were de-identified before analysis to prevent traceability to individual patients or hospitals. Use of de-identified data for research purposes without individual informed consent or ethical approval is in accordance with Dutch law and regulations. Demographic data on sex, age within 5-year intervals, socioeconomic status (SES), survival status, and hospital of treatment were collected. Age was categorized into groups (18-40; 41-60; 61-70; >70 years). SES scores were divided into low, intermediate and high based on the zip codes of patients' residential areas.

2.3 | Cost definitions

In accordance with the Dutch manual for costing studies in healthcare, an activity-based costing approach was used by LOGEX to determine average costs per care activity. A benchmark price per activity was used to enable comparison among all Dutch hospitals, to minimize the influence of local price negotiations.[16] Total hospital and diabetes care

costs were available at individual patient levels. For every diabetes patient, total hospital costs were calculated by the number of care activities performed multiplied by the prespecified cost per care activity. Diabetes care costs, hereafter referred to as direct diabetes care costs, comprised all hospital care activities included in diabetes-related claim trajectories. Both total hospital costs and direct diabetes care costs were divided into cost subcategories: clinical (inpatient) costs, consultation costs (outpatient consultations by physicians and nurses, including emergency care or intercollegiate and multidisciplinary consultations), treatment costs (activities related to diabetes technology, minor interventions or surgery, supporting activities such as paramedical care, but not including medication or consumables such as test strips, needles, and pens), diagnostic costs (activities related to diagnostics such as imaging), and additional costs (travelling costs and medication within an add-on category for expensive medication). All costs were rounded to the nearest integer. Costs were not corrected for the Consumer Price Index (CPI), as insured healthcare is not included in the CPI calculation in the Netherlands.[17] Cost evaluation was performed from the hospital perspective, focusing on all reimbursed in-hospital expenses of the diabetes patients treated.

2.4 | Outcomes

The primary outcome measure was the healthcare resource utilization of adult patients treated in Dutch hospitals for diabetes during the 1-year follow-up period. Healthcare resource utilization comprised all consultations by medical specialty (including face-to-face, telephone and digital consultations), all-cause hospitalizations, and the use of diabetes technology. Technology use was based on one or more claimed care activities related to either insulin pumps or real-time continuous glucose monitoring. Secondary outcome measures were outpatients' total hospital and direct diabetes care costs during follow-up. The mean hospital costs of the general Dutch adult population in the year 2019 were obtained from publicly available Statline data of the Dutch Central Bureau of Statistics (https://opendata.cbs.nl/statline) and compared to the study population by age category. The percentage of the general population that used hospital care increased with age (48%-87.6%). Age categories of the study population were used, with a difference of 1 year for each age interval (e.g., 21-40 years in the study population instead of 20-39 years in the Statline data). Ages 18 to 20 years were not included in the comparison. In addition, microvascular complications, macrovascular complications, and related treatments were identified in all patients with at least one care activity related to a diagnosis or treatment. Microvascular complications comprised retinopathy, nephropathy, neuropathy, and diabetic foot. Treatments related to microvascular disease were dialysis, ocular laser treatment and intravitreal injections. Coronary artery disease, peripheral arterial disease, heart failure and cerebrovascular accident (including ischaemic stroke, haemorrhagic stroke and transient ischaemic attack) were classified as macrovascular complications, with related treatments including percutaneous coronary intervention, coronary artery bypass grafting, thrombolysis, percutaneous transluminal angioplasty or bypass, and limb or digit amputations (diagnosis codes in Table S2). Hospital expenditures for patients with any cardiovascular disease, microvascular complications and macrovascular complications were determined and expenditure per patient was derived by diagnosis.

2.5 | Statistical analysis

The baseline characteristics of the study population were assessed using descriptive statistics. Continuous data were presented as mean with standard deviation (SD) or median with interquartile range in case of skewed data distribution. Categorical variables were expressed as absolute numbers with corresponding proportions. Despite (right-) skewness of data, all costs were expressed as mean cost per patient in Euros (€), as this has been described earlier as the most informative measure in cost outcomes.[18] For clarity, median cost and interquartile ranges were also reported due to the skewed data distribution. The sum of the expenses of all patients was used to calculate the total costs and the costs within different cost subcategories of the study population. All costs were reported in Euros (exchange rate April 7, 2023: 1 euro = 1.09 US dollars). Differences between groups were tested for significance with Kruskal-Wallis tests, and Dunn's test was used for a pairwise comparison of costs between the subgroup without complications and the micro- and macrovascular complication subgroups. There were no missing data with the exception of unknown SES scores (1.3%). A two-sided P value <0.05 was taken to indicate statistical significance for all tests. Statistical analyses were performed using R Statistical Software (v4.0.3; R Core Team 2020).

3 | RESULTS

3.1 | Baseline characteristics

Table 1 shows the characteristics of 193 840 adult patients with diabetes mellitus treated in 65 hospitals across the Netherlands in 2019 and 2020. Of all patients, 92.7% were treated in secondary care hospitals, and 53.8% were male. The median (range) age was 65.0 (18.0-105.0) years, 67.3% of patients were aged between 55 and 85 years, and 88.9% were older than 40 years. SES was low in 37.6% and high in 27.6% of patients. Outpatient clinics in internal medicine treated 120 560 patients (62.2%) and ophthalmology departments treated 99 640 patients (51.4%) for a diabetes-related diagnosis, whereas 31 234 (16.1% of all patients) visited both internal medicine and ophthalmology departments during 1 year of follow-up.

3.2 | Healthcare utilization

The annual number of diabetes-related consultations is also shown in Table 1. A total of 117 415 patients (60.6%) with a diabetes-related

TABLE 1 Baseline characteristics of Dutch diabetes patients utilizing hospital care in 2019 (n = 193 840)

baseline characteristics		Patients, n	% of all patients
Sex	Male	104 347	53.8
	Female	89 493	46.2
Median age, years		65.0 [18.0-105.0]	
Age category	18-40 years	21 264	11.0
	41-60 years	53 144	27.4
	61-70 years	47 567	24.5
	>70 years	71 865	37.0
SES	Low	72 943	37.6
	Intermediate	64 840	33.5
	High	53 458	27.6
	Unknown	2599	1.3
Hospital	Secondary	179 674	92.7
	Tertiary	14 166	7.3
All-cause mortality		2042	1.1
Treating specialty[a]	Internal medicine	120 560	62.2
	Paediatrics	1357	0.7
	Ophthalmology	99 640	51.4
	Ophthalmology and Internal Medicine	31 234	16.1
	Gastroenterology	36	0
	Surgery	7312	3.8
	Orthopaedics	444	0.2
Diabetes-related consultations			
Internal medicine	Total	120 560	62.2
	1-3	51 933	26.8
	4-6	45 320	23.4
	≥7	20 160	10.4
	Per patient, median	4.0 (2.0-5.0)	
Paediatrics	Total	1334	0.7
	Per patient, median	3.0 (2.0-6.0)	
Ophthalmology	Total	99 374	51.3
	1	39 607	20.4
	2	26 540	13.7
	≥3	33 227	17.1
	Per patient, median	2.0 (1.0-3.0)	
Surgery	Total	7081	3.7
	Per patient, median	4.0 (2.0-9.0)	
Cardiology	Total	46 190	23.8
Hospitalizations			
	Total	49 313	25.4
	1 hospitalization	29 335	15.1
	2 hospitalizations	10 493	5.4
	≥3 hospitalizations	9485	4.9
Diabetes technology			
Insulin pump use		9353	4.8
	Number of care activities per patient	2.0 (1.0-4.0)	

(Continues)

TABLE 1 (Continued)

baseline characteristics	Patients, n	% of all patients
rtCGM care use	8691	4.5
Number of care activities per patient	2.0 (1.0-4.0)	
Insulin pump and rtCGM care activities	3756	1.9

Note: Numbers are presented as median with (IQR) or [range], and the number of patients with percentage. Hospitalizations comprise all causes.
Abbreviations: DBC, diagnosis treatment combination; rtCGM, real-time continuous glucose monitoring; SES, socioeconomic status.
[a]Diabetes-related is determined by DBC code per specialty. The number of consultations was only available for treating specialties.

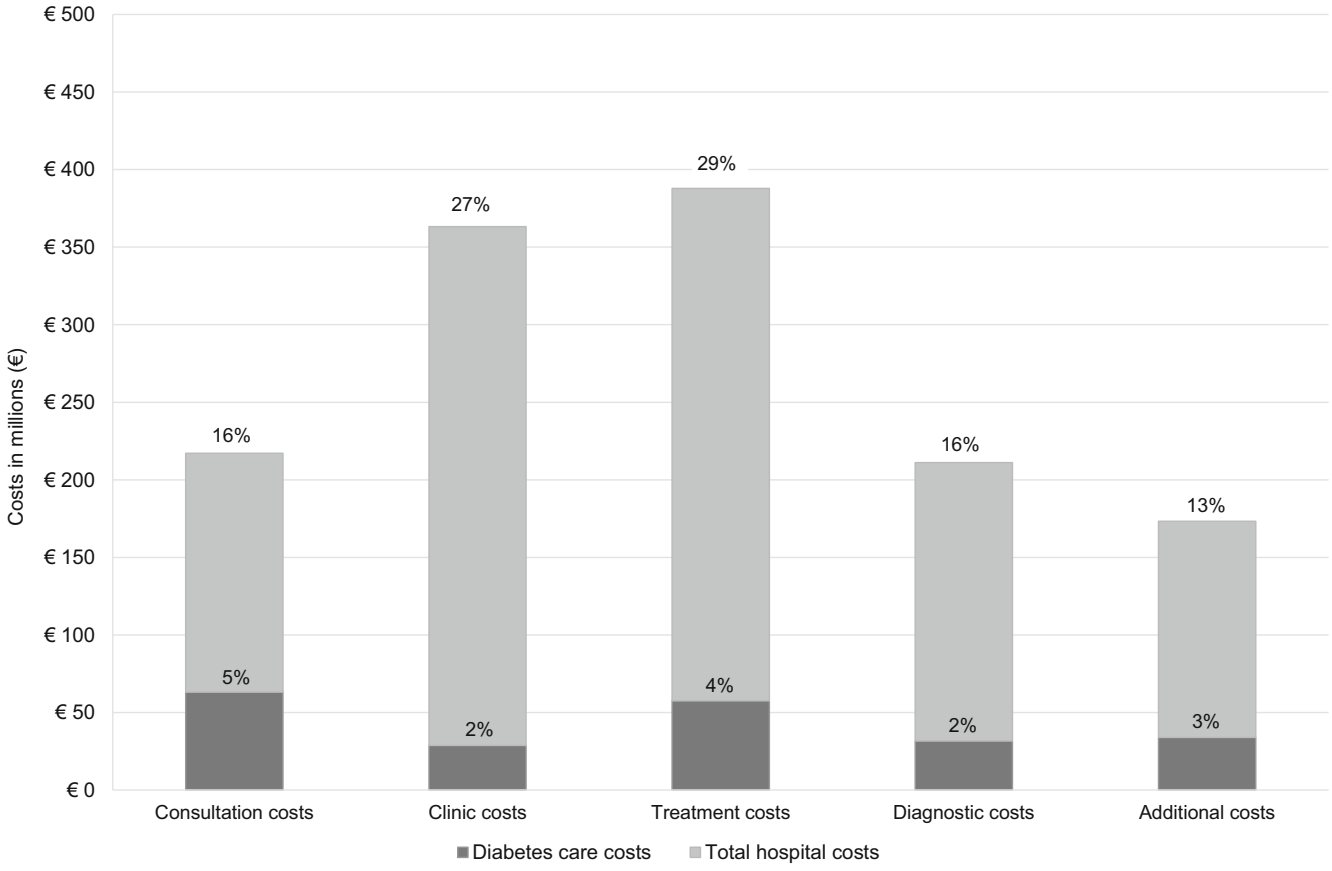


FIGURE 1 Total annual hospital costs for Dutch diabetes patients in 2019 to 2020 by care category (n = 193 840)

diagnosis had one or more consultations at the internal medicine outpatient clinic during 1 year. Patients treated in the internal medicine department had a median of 4 consultations during 1 year of follow-up, 17.2% of whom had ≥7 consultations with a care provider in this department. Patients who frequented the ophthalmologist had a median number of 2 visits in a year, which was similar for the groups with and without concurrent treatment in the internal medicine department. Surgery consultations took place in 7081 patients (3.7%), whose median (range) number of consultations was 4 (1-73). Consultations in cardiology took place in 23.8% of all included diabetes patients during 1 year of follow-up. Hospitalization was observed in 49 313 patients (25.4%) during a 1-year time span with a median (range) number of hospitalizations of 1 (1-30), and 19 978 patients (10.3%) were hospitalized at least twice. The hospitalization rate in the study population was 46.7 per 100 person-years. Regarding diabetes technology, 9353 patients (4.8%) used an insulin pump, 8691 (4.5%) had registered real-time continuous glucose monitoring care activities, and 3756 patients used both modalities (1.9%).

3.3 | Healthcare costs

Total hospital costs for all adult diabetes patients combined were €1 352 690 257 per year, with mean costs of €6978 per patient per year (cost details in Table S3). Direct diabetes care costs were €214 963 703 (15.9% of total hospital costs), with mean costs of

€1109 per patient per year. As illustrated in Figure 1, the largest fractions of total healthcare costs were attributed to treatment (28.7%) and clinic (26.9%) costs. The cost distribution remained similar after excluding patients who only attended the ophthalmology department for their diabetes (remaining study population n = 126 249); 29.2% was attributed to clinic and 29.0% to treatment costs. Focusing on direct diabetes care costs, the largest proportion was due to treatment (4.3% of total hospital treatment costs and 29.4% of all diabetes care costs) and consultation costs (4.7% of total costs and 26.8% of diabetes care costs). Among patients who only had ophthalmology as a treating specialty for diabetes (n = 67 591; 34.9%), total hospital costs (mean €5542 vs. €6978 in the total study population) and especially direct diabetes care costs were lower (mean €748 vs. €1109). All cost categories were lower than in the total study population, except additional costs, which were 40% higher in this patient group (22.6% of total hospital costs instead of 12.8%).

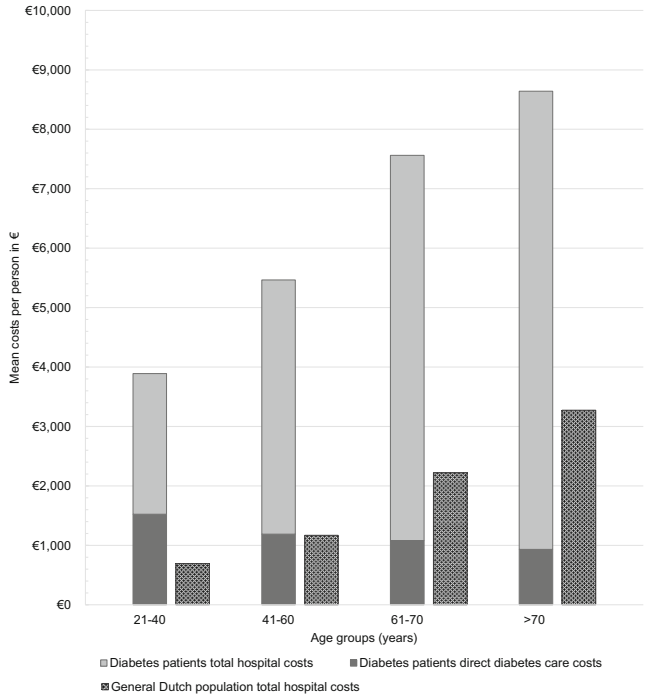
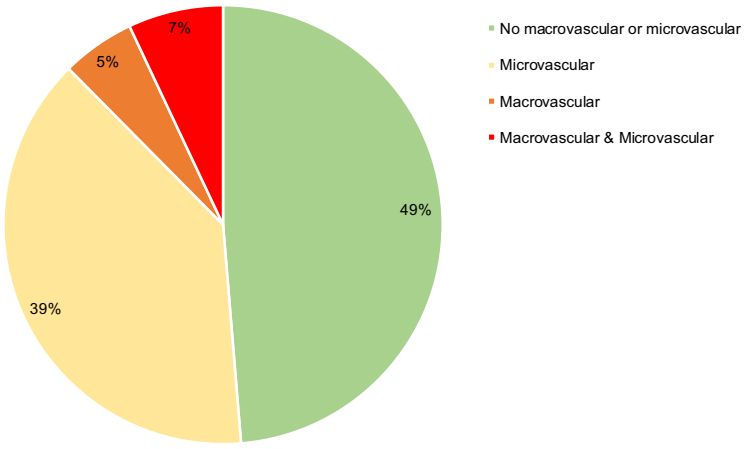


FIGURE 2 Mean total and direct diabetes care costs per patient per year by age group (n = 193 840) compared to the general Dutch population. *Direct diabetes care costs were part of the total hospital costs and are therefore illustrated in the same bar

3.4 | Costs by age and comparison

The total and direct diabetes care hospital costs stratified in several age groups are shown in Figure 2, versus healthcare costs across comparable age groups in the general Dutch population. Total hospital costs per year increased per age category in patients. In contrast, mean direct diabetes care costs, comprising costs related to the diabetes care trajectory only, decrease with age, from €1575 per patient in the age group 18 to 40 years to €932 in patients aged over 70 years (cost details in Table S4). The relative contribution of direct diabetes care costs to the total hospital costs decreases as diabetes patients become older, from 41.1% in the age group 18 to 40 years to 10.8% in those older than 70 years. Total hospital costs of diabetes patients exceed those of the general



	All patients (n= 193 840)	No complications (n= 94 383)	Microvascular only (n= 75 401)	Macrovascular only (n=10 482)	Micro & Macrovascular (n= 13 574)	p†
Total hospital costs	6978 (659-6241)	4416 (576-3789)	6022*** (583-5043)	15 452*** (4224-19 395)	23 564*** (5661-26 949)	<0.001
Diabetes care costs	1109 (157-817)	939 (224-792)	1111*** (135-790)	973* (224-854)	2388*** (156-1384)	<0.001

FIGURE 3 All patients of the Dutch study population (n = 193 840) stratified by cardiovascular complication groups, with total and diabetes care hospital costs in 2019 to 2020. Data are presented as mean (interquartile range) costs per patient in Euros (€) between 2019 and 2020. Patients were included in the stratified groups when ≥1 related care activity was registered. †Difference between all complication groups. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$, compared with no vascular complication group

population at all ages with a three- to sixfold difference, and this difference attenuates with increasing age. Hospital costs show a steep increase with age in both groups. The eldest age group of >70 years had the highest total hospital costs, with mean costs of €8641 per patient in our study population versus €3247 per patient from the general Dutch population.

3.5 | Vascular complications and related costs

Figure 3 shows that 99 457 patients (51.3%) received care related to cardiovascular complications during 1 year of follow-up. Among cardiovascular patients, 75 401 (75.8% within the cardiovascular group, 38.9% of the study population) had only microvascular complications. The occurrence of both microvascular and macrovascular complications increased with age, and the proportion was highest in patients aged over 70 years. Patients with cardiovascular complications had significantly higher mean total hospital costs per year than those without complications. Expenditure was 1.4 times higher in patients with microvascular complications only, 3.5 higher in patients with macrovascular complications only, and 5.3 times higher in patients with both micro- and macrovascular complications compared with patients without complications, as seen in Figure 3. Table 2 shows hospital costs per patient by cardiovascular complication during 1 year of follow-up. The group of patients with cardiovascular complications comprised 51.3% of all patients and contributed 69.2% to total hospital costs. Patients with microvascular complications contributed 57.2% to total costs and mean annual costs per patient were €8698 (interquartile range €723-7814). Patients with macrovascular complications had a mean expenditure of €20 030 (interquartile range €4946-23 521), contributing 35.6% to total costs due to a smaller patient group (12.4% of the study population, n = 24 056). Treatments with the highest annual costs per patient were dialysis (mean €99 945), percutaneous transluminal angioplasty/bypass (mean €56 539), and amputations (mean €40 483). Complications with the highest expenditure per patient per year were nephropathy (mean

TABLE 2 Hospital costs per patient by cardiovascular complication during 1 year of follow-up

			Total hospital costs	
		Patients, n	% total costs[a]	Mean, € per patient
Macrovascular				
CVA		6007	7.3	16 347 (4323-19 129)
	Thrombolysis/ thrombectomy	534	0.8	20 243 (7868-26 025)
Coronary artery disease		2647	4.9	24 852 (8122-26 428)
	PCI	1916	3.6	25 272 (8942-26 988)
	CABG	535	1.7	42 230 (23 094-48 548)
	Heart failure	9336	14.3	20 780 (5057-25 568)
Peripheral arterial disease		6954	12.8	24 926 (4788-30 887)
	PTA or bypass	502	2.1	56 539 (23 303-80 207)
	Leg amputations	2685	8.0	40 483 (15 456-50 498)
Total macrovascular complications		24 056	35.6	20 030 (4946-23 521)
Microvascular				
Retinopathy		75 668	38.7	6926 (599-6177)
	Laser	6059	5.1	11 370 (1966-11 414)
	Injection	12 978	12.5	13 059 (2971-14 261)
Nephropathy		9520	20.6	29 209 (3681-32 424)
	Dialysis	1476	10.9	99 945 (54 902-136 598)
Neuropathy		2546	2.6	13 673 (2386-13 684)
Diabetic foot		9052	10.7	16 028 (2715-18 523)
Total microvascular complications		88 975	57.2	8698 (723-7814)
Total cardiovascular complications		99 457	69.2	9410 (840-9170)
Total all patients		193 840	100.0	6978 (659-6241)

Note: Data are presented as the number of patients with ≥1 registered care activity related to the comorbidity or complications. The percentage of the total cost was derived from the sum of all hospital costs divided by the total costs of the specific patient group. Costs are presented as mean (interquartile range) per patient in Euros (€).

Abbreviations: CABG, coronary artery bypass grafting; CVA, cerebral vascular accident; Injection, intravitreal injection; PCI, percutaneous coronary intervention; PTA, percutaneous transluminal angioplasty.

[a]Percentages do not add up to 100%, as patients can be included in multiple categories.

€29 209), peripheral artery disease (mean €24 926) and coronary artery disease (mean €24 852). Overall, the patient groups with retinopathy, nephropathy and heart failure contributed the most to total annual hospital costs (38.7%, 20.6% and 14.3%, respectively) due to the combination of group size and high mean expenditure per patient. Focusing on direct diabetes care costs, patients with retinopathy (6.3% of total costs), intravitreal injections (3.6%) and diabetic foot (2.3%) were the highest contributors to yearly expenditure.

4 | DISCUSSION

This study was the first to investigate in detail the use of hospital resources among patients with type 1 or type 2 diabetes mellitus, or secondary diabetes mellitus treated in secondary and tertiary hospitals in the Netherlands. Total hospital costs were €1.35 billion per year, and 16% was directly associated with the treatment of diabetes, with the remaining share of hospital expenditure attributable to diabetes-related complications or diabetes-unrelated care. Hospital costs of these diabetes patients exceed the hospital costs of the general population three- to sixfold. Hospital costs, including care for diabetes-related complications, showed a steep increase with age, but expenditure directly related to the treatment of diabetes itself decreased as patients became older. Slightly over half of the study population (51%) had microvascular or macrovascular complications, and these complications led to a major increase in yearly expenditure. Microvascular complications occurred frequently and contributed most to the total economic burden, while patients with macrovascular complications had the highest yearly expenditure per patient. Patient groups with retinopathy, nephropathy and heart failure were top contributors to total hospital costs during 2019 to 2020.

Our study population had similar demographics and healthcare utilization patterns to that of a recent Dutch study.[11] Regarding costs, mean annual expenditure of €6978 per patient was within the range of previously reported outcomes in economically developed countries (US$220-$7600). However, these analyses only included type 2 diabetes patients, while type 1 diabetes is known to have a larger impact on healthcare expenditure.[5,19] Similarly, a previous Dutch study with type 2 diabetes patients showed a lower mean annual expenditure in specialist care of €3893.[11] Overall, our data show that the direct annual costs of diabetes patients far exceed the general population, and other studies have shown comparable results.[20] Interestingly, our findings show a relatively low fraction of direct diabetes care costs within total hospital costs. In line with this, (inter)national studies observed that most costs seem to be caused by care indirectly related to diabetes.[8,10] In fact, it has been observed previously that complications and cardiovascular disease increase the total direct costs of diabetes treatment up to ninefold.[21,22] The disease complexity and comorbidity of the study population are further substantiated by the high number of patients hospitalized at least once during follow-up. Over half of our patients were treated for cardiovascular complications during 1 year of follow-up. Macrovascular complications drastically increased the expenditure per patient. Conversely, microvascular complications were most common and thus contributed most to total hospital costs, yet did not have a large impact on direct annual expenditure per patient. For instance, more patients than expected received care for retinopathy (39%) and the mean expenditure of this subgroup was similar to the overall study population, therefore, possibly also comprising screening. Patients visiting only the ophthalmology department also had lower expenditure in almost all cost categories. It is plausible that many of these patients only received hospital care related to retinopathy screening since the majority of Dutch patients with type 2 diabetes are treated by their general practitioner and are referred to the hospital for retinopathy screening according to national guidelines. Given the high screening costs and the need for healthcare cost control, our results raise the question of whether more efficient screening strategies are warranted, particularly in diabetes patients treated in primary care. Furthermore, patients receiving intravitreal injections may be the reason for increased additional costs in patients visiting ophthalmologists, as these injections are part of an expensive medication category. Retinopathy, chronic kidney disease and diabetic foot are all known to influence healthcare expenditure.[23–25] Similarly, related treatments such as dialysis and amputation are known to increase healthcare expenditure per patient vastly.[26] The role of patients with heart failure was unexpectedly large in the current study population. In line with this, an international comparison across 12 countries observed that the highest percentage of hospital costs in type 2 diabetes was caused by cardiovascular and renal disease, specifically heart failure and chronic kidney disease.[24] The frequent occurrence of heart failure in diabetes is explained by the increased awareness of heart failure with preserved ejection fraction and the risk that type 2 diabetes poses for the development of cardiovascular events and ischaemic cardiomyopathy. Previous Dutch results also showed a frequent occurrence and financial burden of diabetic eye complications and heart failure in the type 2 diabetes population.[10]

We observed that cardiovascular complications increase in the elderly, and consequently, expenditure will rise along with age. Of note, direct diabetes care costs decrease with increasing age. This suggests that, over time, the focus shifts to treating diabetes care complications instead of treating the disease itself. Patients may also become more experienced in the self-management of their disease or gain extra motivation to meet treatment goals when complications occur. Moreover, the focus of care for elderly patients may also become less strict on outcome targets, as patients may be transferred to primary care more often, or mortality may be higher among elderly patients with high direct diabetes costs.

Some findings may also be explained by the organization of Dutch healthcare, where primary care plays an essential role in the accessibility of care. An example is the smaller portion of patients treated in both the internal medicine and the ophthalmology departments (16.1%), while screening every 1 to 2 years is advised by national and international guidelines for all diabetes patients.[27] This suggests either screening barriers or that at least a fraction of the patients were treated at the general practitioners' office or in independent ophthalmology clinics.

Our outcomes may have several implications for policymakers and clinicians. First, the expenditure related to complications and

comorbidity highlights once again the urgency of preventing cardiovascular complications. With the aging of the diabetes population and the increasing expenditure with age, preventative measures should focus on healthy vascular aging. Moreover, the increased risk of developing heart failure and concomitant expenditure in this patient group should not be underestimated, and early cardiological screening and prevention deserve specific attention.[28,29] The number of elderly diabetes patients with multiple vascular comorbidities is expected to rise considerably in the future, and these patient will probably have care patterns characterized by multimorbidity and a high economic burden. Strategies for personalized and cost-efficient care provision for this complex patient group are warranted. Moreover, future research should focus on the influence of individual clinical patient profiles on the quality of care, costs and benefits. In this way, policymakers can create targeted interventions for high-risk patient groups to mitigate the increasing economic burden while ensuring high-quality care for lower-risk patients with lower financial means. It also highlights the importance of national diabetes registries with detailed, long-term patient data.[30] Furthermore, it is important to identify the high-needs and high-cost patients, as it was observed that the current data were highly skewed. This indicates that a small group of patients make an important contribution to overall expenditure and may be an interesting starting point for future interventions. As mentioned, the patient group visiting the ophthalmology departments for retinopathy screening only or intravitreal injections may be of specific interest.This study showed insight into the specialist care of a large diabetes mellitus cohort on a nationwide scale in a heterogeneous group of patients. Patient-level data provided information on different age groups, regions and socioeconomic backgrounds, creating a detailed picture of care patterns, costs and complications for the included patients. It also facilitated a distinction between total hospital costs and costs directly related to the treatment of diabetes. The administrative, financially bound nature of these real-world data guarantees a high level of completeness and accuracy of actual care provided. In addition, there was no influence of local price negotiations between hospitals and insurance companies on cost estimations because an activity cost methodology was used in the outcomes.

The study also had several limitations. First, the Dutch setting and national regulations may limit the generalizability of the findings, although the included population was a heterogeneous and realistic group of patients that will be similar to those in other Western countries. Because the data used were registered in real-world hospital settings, registration errors such as in technology usage could not be omitted, and only selective data were available. Furthermore, distinction between diabetes types and between incidence or prevalence of comorbidities was not possible, since Dutch hospital reimbursement claims do not specify diabetes type or provide additional clinical information on patients. It is known that glycaemic control, insulin use and disease duration may influence care use and concomitant costs.[31,32] Because individuals with type 2 diabetes are often treated in primary care, the data on hospital patients provide a selected overview of the total Dutch diabetes population of 1.2 million.[15] However, previous studies have shown that up to 97% of type 2 diabetes patients are referred to medical specialist care.[10] In addition, the current population is of special interest because hospital care is one of the most important contributors to the healthcare expenditure of diabetes patients.[10] The comparison with the general population provides additional context to the costs results but does not have the properties of a formal control group, therefore, the findings may be biased. Finally, the influence of the COVID-19 pandemic and other unmeasured confounders cannot be ruled out. Regardless, we believe the current results provide accurate insights into the hospital care patterns and expenditure of a nationwide diabetes population.

This study provides a detailed overview of healthcare resource use and expenditure for patients with diabetes mellitus treated in Dutch hospitals using real-world reimbursement data. The patients in this nationwide population are characterized by high resource use, with substantial economic impact and a large burden of cardiovascular complications. This is reflected by hospital costs that greatly exceed those for the general population, despite the limited financial contribution of direct diabetes treatment. This contrast becomes even more evident in the older population. With a predicted increase in elderly diabetes patients, preventative measures for cardiovascular disease remain imperative to keep healthcare for all diabetes patients sustainable in the future.

AUTHOR CONTRIBUTIONS

Silvia de Vries, Jessica Bak and Carianne Verheugt conceptualized the study. Jessica Bak and Vincent Stangenberger were involved in the data collection and the methodology of the study. Silvia de Vries performed the analysis. Silvia de Vries and Carianne Verheugt interpreted the results. Silvia de Vries wrote the original draft of the manuscript and all authors reviewed, revised and approved the final manuscript. Carianne Verheugt and Theo Sas were involved with the project administration. Michel Wouters and Max Nieuwdorp advised on timelines and supervised the work.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest relevant to this work to declare.

PEER REVIEW

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DATA AVAILABILITY STATEMENT

The dataset that supports the findings of this study are not available due to the sensitive nature (licence restrictions, privacy regulations and commercial reasons) of the data. Data are however available from the authors upon reasonable request and with permission of LOGEX.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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