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Vries, S.A.G. de; Bak, J.C.G.; Mul, D.; Wouters, M.W.J.M.; Nieuwdorp, M.; Verheugt, C.L.; Sas, T.C.J.

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Does size matter? Hospital volume and resource use in paediatric diabetes care

Silvia A. G. de Vries[1,2] | **Jessica C. G. Bak**[1,2] | **Dick Mul**[3] | **Michel W. J. M. Wouters**[2,4] | **Max Nieuwdorp**[1] | **Carianne L. Verheugt**[1] | **Theo C. J. Sas**[3,5]

[1]Department of Vascular Medicine, Amsterdam University Medical Centers, Amsterdam, The Netherlands

[2]Dutch Institute for Clinical Auditing, Leiden, The Netherlands

[3]Diabeter, Center for Pediatric and Adult Diabetes Care and Research, Rotterdam, The Netherlands

[4]Department of Biomedical Data Sciences, Leiden University Medical Center, The Netherlands

[5]Department of Pediatrics, Division of Pediatric Endocrinology, Erasmus University Medical Center, Sophia Children's Hospital, Rotterdam, The Netherlands

Correspondence
Silvia A. G. de Vries, Department of Vascular Medicine, Amsterdam University Medical Centers, Amsterdam, The Netherlands.
Email: a.devries2@amsterdamumc.nl

Abstract

Aims: Paediatric diabetes care has become increasingly specialised due to the multidisciplinary approach and technological developments. Guidelines recommend sufficient experience of treatment teams. This study evaluates associations between hospital volume and resource use and hospital expenditure in Dutch children with diabetes.

Methods: Retrospective cohort study using hospital claims data of 5082 children treated across 44 Dutch hospitals (2019–2020). Hospitals were categorised into three categories; small (≥20–100 patients), medium (≥100–200 patients) and large (≥200 patients). All-cause hospitalisations, consultations, technology and hospital expenditure were analysed and adjusted for age, sex, socio-economic status (SES) and hospital of treatment.

Results: Fewer hospitalisations were observed in large hospitals compared to small hospitals (OR 0.48; [95% CI 0.32–0.72]; $p < 0.001$). Median number of yearly paediatrician visits was 7 in large and 6 in small hospitals, the significance of which was attenuated in multilevel analysis (OR ≥7 consultations: 1.89; [95%CI 0.74–4.83]; $p = 0.18$). Technology use varies between individual hospitals, whereas pump usage and real-time continuous glucose monitoring showed no significant differences between hospital volumes. Mean overall expenditure was highest in medium-sized centres with €6434 per patient (IQR €2555–7955); the difference in diabetes care costs was not significant between hospital patient volumes.

Conclusions: Care provision patterns vary by hospital patient volume. Large hospitals had the lowest hospitalisation rates. The use of diabetes technology was not different between hospital patient volumes. Medium-sized hospitals showed the highest overall expenditure, but diabetes care costs were similar across hospital volumes.

KEYWORDS

children, diabetes mellitus, health economics, healthcare utilization, quality of health care, real-world evidence, technology

1 | INTRODUCTION

Type 1 diabetes is one of the most common endocrine diseases in childhood, affecting more than a million children worldwide.[1] Individuals living with youth-onset type 1 diabetes face a decreased life expectancy and an elevated risk of cardiovascular disease in later years.[2] Awareness of the significance of early and appropriate treatment in the initial years after diagnosis is increasing, as stricter glycaemic targets improve cardiovascular outcomes.[3] With no current curative treatment on the horizon, optimal care provision remains pivotal in modern type 1 diabetes clinical practice.

Heterogeneity in paediatric diabetes care systems and patient outcomes has been described in Europe for over a decade.[4] In recent years, paediatric diabetes care has evolved towards a multidisciplinary approach, accompanied by technological advances. Similar to centralised care models in cardiovascular or oncological procedures, the developments in modern diabetes practice may also require more specialised care structures.[5] Centralised care enhances the quality of care through the availability of local resources, knowledge and expertise, leading to increased cost-effectiveness due to economy of scale.[6] Treatment guidelines recommend paediatric diabetes care be organised in specialised and multidisciplinary teams, preferably in regional centres of excellence. The International Society for Pediatric and Adolescent Diabetes (ISPAD) 2022 guideline emphasises the influence of demographic and geographical factors on the local care organisation though also advocates that diabetes teams should treat a minimum of 150 patients to acquire sufficient experience and expertise.[7] Moreover, they advise patients to consider travelling to a specialised team; otherwise, local healthcare providers should have readily available access to experts' knowledge. Similarly, the American Diabetes Association (ADA) 2022 guideline stresses the importance of expertise in managing age-specific challenges in children with diabetes.[8] Inter-institutional initiatives such as the international SWEET network strive to improve paediatric diabetes outcomes by creating centres of reference.[9] Similarly, in Dutch paediatric diabetes care, a trend towards collaborative initiatives or specialised value-based healthcare institutions has recently been observed.

Several studies have shown an association between hospital features, particularly hospital size, and clinical patient outcomes such as glycaemic control.[10–12] In previous studies conducted in the Netherlands, unexpectedly higher diabetes expenditures were observed in larger hospitals and diabetes technology use was found to play an important role in the costs of paediatric diabetes care.[13,14] Nevertheless, it remains unknown whether an association exists between hospital volume and healthcare resource utilisation in paediatric diabetes care. Therefore, no information is available for policymakers and hospital management to facilitate evidence-based decisions on the effect of hospital volume on care patterns and the trend towards inter-institutional collaborations.

What's new

- Centre size is known to influence clinical outcomes in diabetes care, particularly glycaemic control.
- We studied hospital volumes and the association with resource use of Dutch children with diabetes. Large hospitals had fewer hospitalisations. RtCGM use, insulin pump use and diabetes expenditure were similar across hospital volumes when adjusted for patient characteristics and hospital of treatment. There was considerable variation between hospitals in the use of insulin pumps and rtCGM.
- The findings show that volume-related variation exists in hospital resource use. Further insight into these differences and the clinical implications are warranted.

Using nationwide data, this study aims to evaluate the association between hospital volume and hospital resource utilisation in Dutch children with diabetes mellitus, with a focus on hospitalisations, consultations, technology use and hospital expenditures.

2 | METHODS

2.1 | Study design

This retrospective, nationwide cohort study used administrative healthcare data of children with diabetes mellitus treated in Dutch hospitals across the country. In the Netherlands, healthcare insurance is mandatory for all citizens and is automatically covered for children. Most hospitals are privately owned, non-profit foundations or organizations and care is covered by insurance regardless of public or private organization, limiting insurance's influence on utilisation patterns. Dutch hospital care is organised and reimbursed through a Diagnose Treatment Combination (DBC) system. Information on diagnosis, the specialty of treatment and performed healthcare activities are registered within a DBC claim and collected in each hospital's information system. LOGEX (Amsterdam, the Netherlands) services a benchmark database with routinely collected reimbursement data and a data set

regarding patients with a diabetes DBC claim was provided. All data deliveries are validated after collection by comparison to previous data deliveries. Previous studies have shown that reimbursement data can be used for healthcare evaluation and research purposes in the Netherlands.[15,16] The benchmark database contains de-identified data that can not be traced back to hospitals or patients. The use of non-identifiable data is allowed for research purposes by Dutch law; therefore, no ethical approval nor informed consent was required. In the Netherlands, children with type 1 diabetes are treated by paediatricians in hospitals, diabetes-care collaborations between hospitals or independent treatment clinics. In concordance with national guidelines, paediatric diabetes services include a paediatrician or paediatric endocrinologist, a diabetes nurse, a dietician and access to a psychologist. Other diabetes types in children, including type 2 diabetes, are treated in all centres but are relatively rare in the Netherlands (estimated at 6.5%).[17] The benchmark database contained information on 65 secondary and tertiary hospitals (~88% of all Dutch hospitals), 44 (68%) of which treated ≥20 children with diabetes in 2019 (Figure 1). Only data from affiliated hospitals were available, leading to the absence of approximately 22% of paediatric patients.

2.2 | Patient selection

Children 0–17 years old with a DBC claim for diabetes mellitus from January to December 31, 2019 in one of the 65 hospitals in the Netherlands were selected. Diabetes claims include all diabetes types, such as type 1, type 2, MODY, neonatal and secondary diabetes (codes in Table S1). Patients had 365 consecutive days of follow-up from the date the DBC was recorded. For this study, only patients treated in the paediatrics department were included (see Figure 1). Children with no care trajectory in the paediatrics department, either due to a referral from a different institution or a transition to adult care, were excluded. In concordance with previous literature and based on expert opinion, hospitals treating less than 20 patients per year were excluded to guarantee that hospitals provided chronic outpatient treatment of children with diabetes.[13] Hospitals were categorised by the number of patients in a year: small (≥20–100 patients), medium (≥100–200 patients) and large (≥200 patients). The proportion of patients with new-onset diabetes or undergoing follow-up care is expected to be similar across hospital volumes since both typically occur within the same hospital. A limited number of patients may have attended more than one hospital in a year (e.g. in case of moving during the follow-up), but due to the anonymization of patients, cross-utilization could not be accounted for. Data contained information on hospital of treatment, age in 5-year intervals, sex, socio-economic status (SES) scores (previously derived from zip codes) and mortality.

2.3 | Outcome measures

The outcome measures involved the evaluation of three resource utilisation parameters over a 1-year follow-up period across various hospital sizes: (1) all-cause hospitalisations, (2) consultations in the paediatrics outpatient clinic (face-to-face, telephone and digital) and (3) diabetes technology. The data did not allow for identifying whether hospitalisations and consultations were diabetes-related. Technology use was defined as

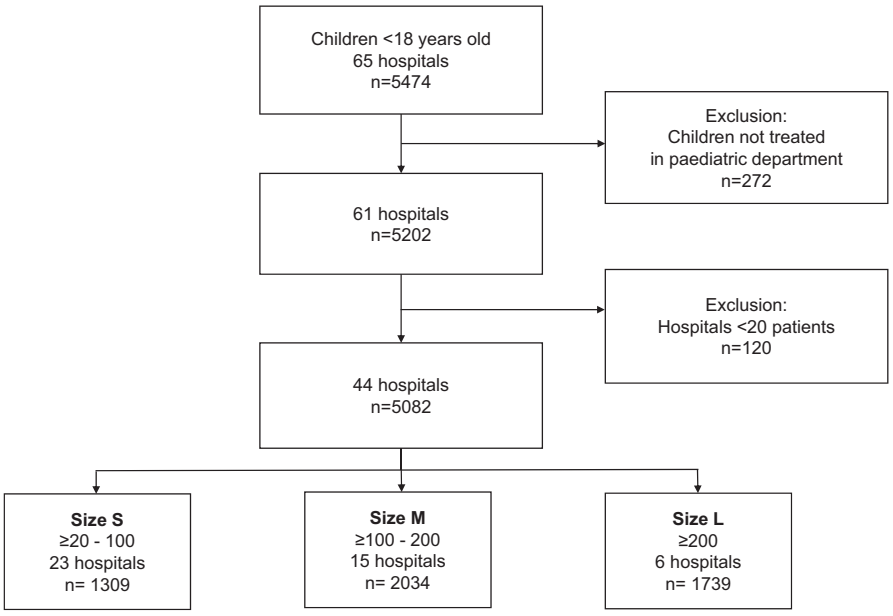

FIGURE 1 Flow chart of study selection.

≥1 registered healthcare activity for insulin pumps or real-time continuous glucose monitoring (rtCGM). Information on the use of flash glucose monitoring is unavailable in the Dutch DBC system. Total hospital costs and direct diabetes care costs were collected for each included patient. Cost evaluation was done from a hospital perspective. Total hospital costs per patient were calculated by the number of registered inpatient and outpatient hospital care activities multiplied by the cost per care activity. Uniform costs per care activity were applied to facilitate comparison between hospitals. These costs were established using an activity-based approach and taken from the LOGEX benchmark.[18] Direct diabetes care costs were part of the total hospital costs and comprised all care activities registered within a diabetes care trajectory.

2.4 | Statistical analysis

Patient and care characteristics were described by hospital category using frequencies and percentages. Continuous outcomes were reported as mean with standard deviation or median with interquartile ranges, depending on the data distribution. As commonly observed in cost outcomes, the data was highly right-skewed. Regardless, cost outcomes were reported as mean costs, as this has been described as the most informative outcome measure.[19] The associations between hospital volume categories and hospitalisations, consultations and technology were analysed using multilevel univariable and multivariable logistic regression, with adjustment for sex, age categories and SES. A random intercept for hospital of treatment was included, to adjust for clustering in hospitals. Size small was further stratified into size XS (≥20–50 patients) and size S (≥50–100 patients) and analysed accordingly. Size XS was not included in the models to ensure similar and sufficient group sizes. Variables with <10 patients per category (age 0 and unknown SES) were excluded from regression analyses. Multilevel linear regression was used to study the influence of hospital volume on diabetes care costs. Because of skewed distribution, non-parametric bootstrapping was performed with 5500 replications and bias-corrected and accelerated (BCa) confidence intervals were estimated. BCa confidence intervals are more accurate as they better adjust for bias and skewed distributions of the estimates.[20] All costs were reported in euros (exchange rate 25 July 2023: 1 euro = 1.10 US dollars). There was no missing data because complete data are required for reimbursement, and only claimed care trajectories were included. The exception was 0.3% of unknown SES scores due to individuals having no permanent residence in the Netherlands. Two-sided p-values <0.05 were considered significant. All analyses were performed in R Statistical Software (v4.2.1; R Core Team 2021).

3 | RESULTS

3.1 | Patient characteristics

In total, 5082 patients <18 years old treated for diabetes were included from 44 hospitals across the Netherlands (Figure 1). Median age was 15.0 years (range 0–15), and 52% was male. The number of patients per hospital varied from 30 to 402 (median 146), and 98% ($n = 4966$) of patients were treated in secondary care hospitals. Table 1 shows that large hospitals had more children in young age categories (0–10 years: 28% vs 27% in medium and 25% in small hospitals), whereas small hospitals treated more adolescents (11–17 years: 75% vs. 73% in medium and 72% in large hospitals). Low SES occurred in 41% of children in small hospitals, 32.9% in medium-sized and 28% in large hospitals ($p < 0.001$ for SES score across hospital volumes).

3.2 | Consultations, admissions and technology use

Table 1 shows that in small hospitals patients had fewer annual pediatrician consultations than the other sizes. Hospitalisation rates and the percentage of hospitalised patients were lowest in large hospitals (10% difference with small hospitals). Use of insulin pumps did not significantly differ between small (58%), medium-sized (60%) and large hospitals (61%). RtCGM use was highest in medium-sized hospitals (35% vs. 29% in small and large centres). Patients in large hospitals had less variation in median consultations compared to the total study population (median ≥7 consultations, Figure 2a). Figure 2b shows an inverse relationship between hospitalisation rate and hospital size, with a higher rate in small hospitals. Regarding technology, the variation in all technology use (pump, rtCGM or both) was most prominent in small hospitals (Figure 2c). In 10 of 15 medium-sized hospitals, usage was above the study population average of 62% (horizontal dashed line). When adjusted for age, sex and SES and hospital of treatment, patients in large hospitals no longer had a significant difference to have an above-median (≥7) number of consultations compared to small hospitals, with an an adjusted odds ratio (OR) of 1.89 (95% CI 0.74–4.83; $p = 0.18$). Table 2 shows that hospitalisation OR was significantly lower in large hospitals compared to small hospitals (adjusted OR 0.48

TABLE 1 Characteristics of Dutch children with diabetes mellitus using hospital care in 2019 by hospital volume category ($n = 5082$).

	Annual hospital volume			
	Small	**Medium**	**Large**	
	***n* = 1309**	***n* = 2034**	***n* = 1739**	***p*-value**
Hospital size	≥20–100	≥100–200	≥200	
Number of hospitals	23	15	6	
Patient				
Sex				
Male (%)	676 (52)	1087 (53)	894 (51)	0.398
Female (%)	633 (48)	947 (47)	845 (49)	
Age categories (years)				
0	0 (0.0)	0 (0.0)	1 (0.1)	0.241
1–5	61 (4.7)	113 (5.6)	114 (6.6)	
6–10	260 (20)	429 (21)	372 (21)	
11–15	614 (47)	961 (47)	787 (45)	
16–17	374 (29)	531 (26)	465 (27)	
SES				
High	309 (24)	718 (35)	741 (43)	<0.001
Middle	461 (35)	640 (31)	513 (29)	
Low	535 (41)	669 (33)	481 (28)	
Unknown	4 (0.3)	7 (0.3)	4 (0.2)	
Care characteristics				
Number of visits paediatrician	6.0 [0.0, 34.0]	7.0 [0.0, 45.0]	7.0 [0.0, 31.0]	<0.001
Ophthalmology visit (≥1)	266 (20)	337 (17)	267 (15)	0.001
Hospitalisations				
Hospitalised patients (%)	301 (23)	409 (20)	218 (13)	<0.001
1 hospitalisation	247 (19)	334 (16)	175 (10)	<0.001
2 hospitalisations	40 (3.1)	51 (2.5)	32 (1.8)	0.092
≥3 hospitalisations	14 (1.1)	24 (1.2)	11 (0.6)	0.207
Hospitalisation rate (per 100 PY)	29	26	16	0.030
Diabetes technology				
Insulin pump care activities	760 (58)	1222 (60)	1067 (61)	0.183
Number of insulin pump care activities	6.0 [1.0, 41.0]	7.0 [1.0, 180.0]	7.0 [1.0, 67.0]	<0.001
RtCGM care activities	374 (29)	720 (35)	498 (29)	<0.001
Number of rtCGM care activities	5.0 [1.0, 173.0]	4.0 [1.0, 59.0]	6.0 [1.0, 44.0]	<0.001
Insulin pump & rtCGM care activities (%)	339 (26)	671 (33)	472 (27)	<0.001

Note: Numbers are presented as mean ± SD, median [range] or number of patients with percentage (%).

Abbreviations: PY, person-years; rtCGM, real time continuous glucose monitoring; SES = socio-economic status.

[95%CI 0.32–0.72]; $p < 0.001$). Insulin pump use did not significantly differ, yet there was between-hospital variation [variance: 0.75, standard deviation (SD): 0.87]. No significant difference in rtCGM use was present in the multilevel model after accounting for patient characteristics and hospital of treatment. However, considerable between-hospital variation was present (variance: 1.78, SD: 1.33).

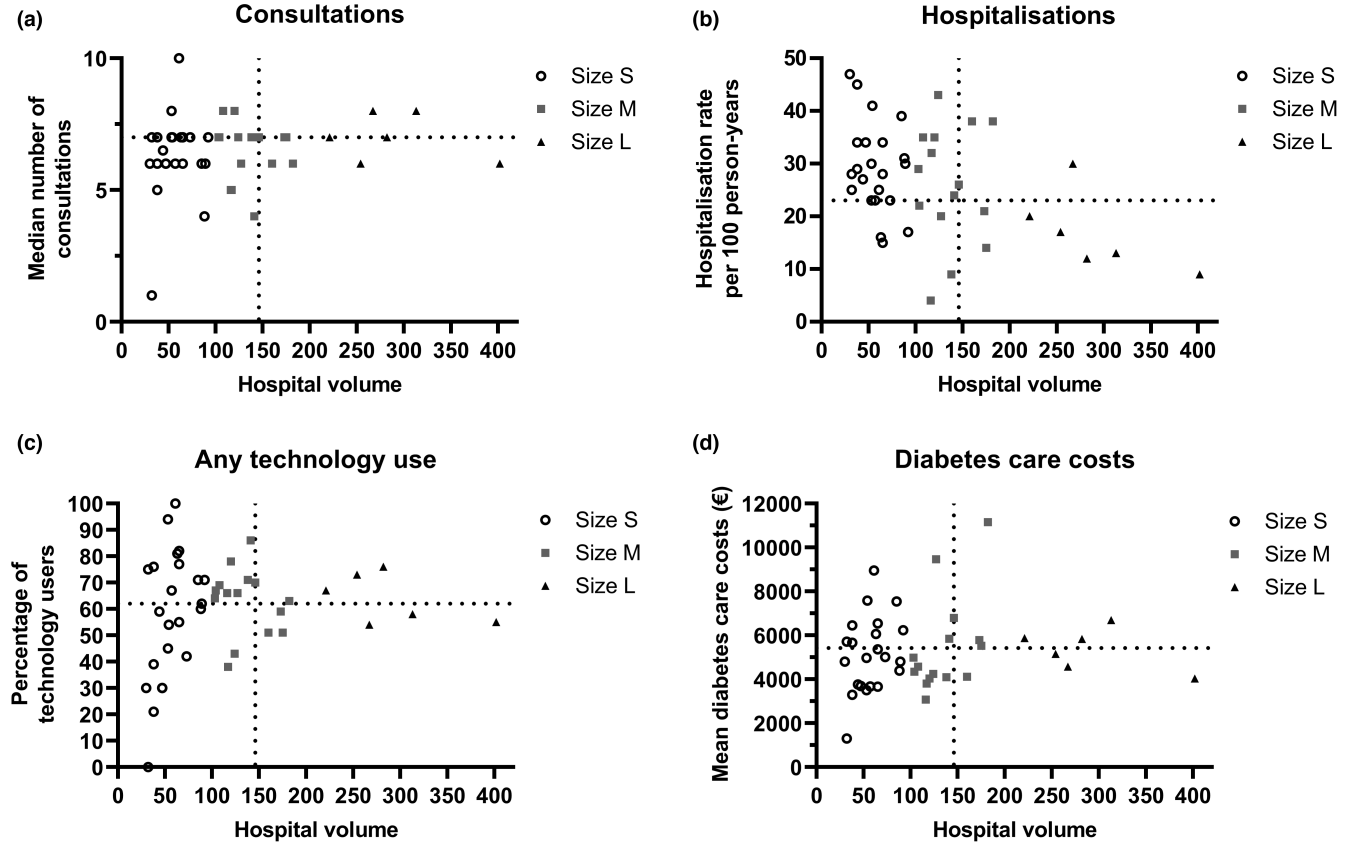

FIGURE 2 Care characteristics and diabetes care costs per hospital in 2019–2020, arranged by hospital volume category (Size S (small) = ≥20 – 100; Size M (medium) = ≥100 – 200; Size L (large) ≥200 patients per centre). *The vertical dashed lines represent the median hospital volume ($n = 146$), and the horizontal dashed lines show the outcome for the study population as a whole.

3.3 | Costs

Figure 2d shows a wide variation in mean diabetes care costs between hospitals within different volume categories. Mean diabetes care costs per patient ($n = 5082$) were €5249 [interquartile range (IQR) €1859–7065] in small hospitals, €5658 (IQR €1930–6967) in medium-sized and €5287 (IQR €1735–7234) in large hospitals. Medium-sized hospitals had the most variation in mean expenditure (€8076 difference in mean expenditure). Table 3 shows that mean total hospital costs were highest in medium-sized hospitals, with a significant difference between small- and medium-sized centres only (mean difference €487 [95% CI €113–827]). A significant difference remained after adjustment for patient characteristics and hospital of treatment (mean difference €386 [95% CI €22–724]). Focusing on diabetes care costs per se, unadjusted and adjusted diabetes care costs were lowest in small hospitals, yet a significant difference across the hospital volume sizes was absent. Medium-sized hospitals had the highest percentage of rtCGM users ($n = 720$, 35%); most were combined pump and rtCGM users ($n = 671$, 33%). When patients of medium-sized hospitals were stratified by rtCGM use, mean diabetes care costs were 2.4 times higher compared to no users (rtCGM €9005 vs €3825). For pump use, this was also 2.4 times higher (€7366 vs. €3089).

3.4 | XS hospitals

Small-sized hospitals were further stratified into nine extra small hospitals (XS, ≥20–50 patients, $n = 346$) and 14 small hospitals (S, ≥50–100 patients, n = 963). Hospitalisation rates were highest in size XS, with 34 per 100 person-years (PY) vs. 27 per 100 PY in size S, with 27% vs. 21% of patients hospitalised at least once during follow-up, respectively (Table S2). The median of yearly paediatrician consultations was 6 (range 0–21) in size XS versus 7 (range 0–34) in size S. Technology use was lowest in size XS, with 39% pump use and rtCGM in 16% of patients. Mean total hospital costs (€4765, IQR €1595–6117) and mean diabetes care costs (€4243, IQR €1289–5740) were lowest in XS hospitals.

4 | DISCUSSION

This nationwide study observed differences in hospitalisations, consultations, technology use and diabetes

TABLE 2 Multilevel logistic regression of care characteristics of children with diabetes, compared between hospital volume categories (S, M, L) ($n = 5066$).

Hospital volume	Outcome (%)	OR	95% CI	*p*-value	aOR[a]	95% CI	*p*-value
All-cause hospitalisation (yes)							
S	301 (23)	Ref	–		Ref	–	
M	406 (20)	0.79	(0.58, 1.07)	0.13	0.80	(0.59, 1.09)	0.16
L	218 (13)	0.48	(0.32, 0.71)	<0.001	0.48	(0.32, 0.72)	<0.001
Consultations (≥7)							
S	638 (49)	Ref	–		Ref	–	
M	1034 (51)	1.14	(0.58, 2.24)	0.72	1.12	(0.56, 2.23)	0.75
L	1057 (61)	1.90	(0.75, 4.81)	0.17	1.89	(0.74, 4.83)	0.18
Insulin pump usage (yes)							
S	759 (58)	Ref	–		Ref	–	
M	1220 (60)	1.18	(0.66, 2.10)	0.58	1.11	(0.62, 2.01)	0.72
L	1066 (61)	1.26	(0.58, 2.77)	0.56	1.17	(0.52, 2.59)	0.71
rtCGM use (yes)							
S	374 (29)	Ref	–		Ref	–	
M	718 (35)	2.15	(0.95, 4.86)	0.07	2.10	(0.85, 5.16)	0.11
L	496 (29)	1.76	(0.58, 5.33)	0.32	1.62	(0.48, 5.51)	0.44

Abbreviations: CI, confidence interval; rtCGM, real-time continuous glucose monitoring; Size S (small), ≥20 – 100 patients; size M (medium), ≥100 – 200 patients; size L (large), ≥200 patients.

[a]Adjusted for sex, age categories and socio-economic status (SES) and a random intercept for hospital of treatment. Patients of age 0 and unknown SES were excluded from regression analysis ($n = 16$). Full multilevel logistic regression results are in Table S3.

TABLE 3 Mean annual total hospital and diabetes care costs by hospital volume category ($n = 5066$).

Hospital volume	Expenditure in € mean (median, IQR)	Difference unadjusted in € mean (95% CI)	*p*-value	Difference adjusted[a] in € mean (95% CI)	*p*-value
Total hospital costs					
S	5897 (4525, 2393–7621)	Ref		Ref	
M	6434 (4786, 2555–7955)	487 (113, 827)	<0.05	386 (22, 724)	<0.05
L	5948 (4346, 2155–8036)	305 (−75, 664)	≥0.05	143 (−232, 491)	≥0.05
Diabetes care costs					
S	5263 (3904, 1883–7067)	Ref		Ref	
M	5642 (4119, 1947–6944)	330 (−17, 650)	≥0.05	224 (−100, 556)	≥0.05
L	5295 (3792, 1749–7244)	252 (−114, 592)	≥0.05	86 (−262, 407)	≥0.05

Note: Full multilevel linear regression results are in Table S4.

Abbreviations: Size S (small), ≥20 – 100 patients; Size M (medium), ≥100–200 patients; Size L (large), ≥200 patients.

[a]Adjusted for sex, age categories and socio-economic status (SES) with a random intercept for hospital of treatment. Patients of age 0 and unknown SES were excluded from regression analysis ($n = 16$). 95% confidence intervals (CI) were estimated with bias-corrected and accelerated bootstrapping with 5500 replications.

expenditures among hospitals with different volumes of diabetes care in a high-income country with basic healthcare insurance for all children. The lowest all-cause hospitalisation rates were observed in large hospitals of ≥200 patients and the highest in small hospitals of 20–100 patients. In contrast, the number of yearly consultations with a paediatrician was highest in large hospitals, with a median of 7 compared to 6 in small hospitals, although not significant. Concerning technology use, there was between-hospital variation, but there were no significant differences in rtCGM or insulin pump use among hospitals of different volumes. Mean total hospital expenditure and diabetes care costs exhibited considerable variation across hospital volumes. The highest costs and variation in mean diabetes care costs were observed in medium-sized hospitals. However, after adjustment for patient characteristics and hospital of treatment only the difference in total hospital costs

was significant, suggesting that diabetes care costs did not significantly differ based on hospital volumes.

Our results are in concordance with a previous study from the national DPV Registry in Germany and Austria, showing the lowest number of consultations in the smallest hospitals.[10] All-cause hospitalisation in relation to hospital volume has not been studied previously. However, the previous study revealed that diabetic ketoacidosis (DKA) occurred most in extra-small centres (<20 patients), while DKA and hypoglycaemia rates were lowest in extra-large centres (≥200 patients).[10] This indicates a similar hospitalisation pattern that aligns with our results. Furthermore, the DPV study reported no differences in pump therapy between volume categories, yet they did find that the use of sensor-augmented pumps increases with centre size. Similarly, our results showed that rtCGM use was lowest in XS hospitals (≥20–50 patients). RtCGM use was highest in medium-sized centres, but the difference did not persist after accounting for clustering in hospitals. It seems that variation is present between individual hospitals rather than across hospital volumes. Most Dutch hospitals strive towards early initiation of technology, yet no specific guidelines are in place. Diabetes technology is reimbursed for all children <18 years old and no technology-related referral patterns are expected. Moreover, the absence of flash glucose monitoring in our results may also play a role in the observed variation. Regarding costs, a previous Dutch study observed contrasting results, suggesting that hospitals with larger volumes had the highest mean costs. Notably, the largest hospital category in that study had a range of 88–248 patients.[13] In contrast, we observed that the total hospital costs increase was particularly prominent in medium-sized hospitals. These medium-sized hospitals may have more specialised paediatric care or perform more procedures in children besides diabetes. Surprisingly, the adjusted costs in smaller clinics were slightly lower but not significantly different from large clinics, despite a higher number of hospitalisations. It seems that other unmeasured care forms even out the admission costs. One may speculate that the availability of 24-h services dedicated to diabetes care in larger institutions or the presence of larger multidisciplinary care teams may potentially explain the reduction of hospitalisations. Hospitalisations also may be relatively brief or for educational purposes. In the Netherlands, hospitalisation of children with new-onset diabetes is not standard practice unless clinically necessary and may depend on local hospital policy or treatment team preferences.

The variation in care profiles across hospital volume categories may indicate differences in the care provided, yet it does not necessarily imply differences in patient outcomes. Future research should assess whether these volume-related differences translate into different clinical outcomes, such as glycemic control and short- or long-term complications. Between-hospital variation underlines the importance of hospital-level audits and feedback to study differences and use these insights to improve diabetes care further. The implementation of the national diabetes registry DPARD within Dutch diabetes care will serve as a valuable tool for gaining insights into healthcare provision and quality of care in the foreseeable future.[21] Furthermore, additional research is needed to study the origins of the differences in patients' characteristics, such as socio-economic status, within different hospitals. Disparities are known to influence treatment outcomes like glycemic control, technology prescription and complications in diabetes patients, and these results suggest that hospital of treatment may play a role.[22–24] The current outcomes were corrected for the uneven distribution of SES across hospital patient volumes. However, measures should be taken to guarantee that all patients have equal knowledge and access to an optimal treatment setting tailored to their needs. For policymakers, these results underscore the importance of appropriately documenting modern technology to monitor care patterns within different hospitals. Moreover, it is reassuring to find that costs of diabetes treatment costs are comparable when considering the optimal hospital care setting.

This study was the first to study the association between hospital volume and resource use in a nationwide cohort while also considering patient characteristics and accounting for clustering in hospitals. Furthermore, using similar volume categories compared to prior studies allows for comparison and increases the generalizability of the findings. The exclusion of hospitals treating less than 20 patients minimises the risk of including patients who are only treated shortly after diagnosis, while no diabetes outpatient care is provided afterwards. Random variation may influence outcomes of smaller hospitals, but this effect was minimised by categorizing hospitals into volume groups. Furthermore, the financial setting of the data guarantees a high level of accuracy of care provided, however, registration errors in hospitals could not be omitted. Moreover, using a benchmark price based on an activity-based costing method provides a fair comparison between hospital volume categories. Despite the advantages of these prices, the influence of local price negotiations between hospitals and insurance companies on cost profiles remains unknown.

Our study also had several limitations. First, information on diabetes type, disease duration and clinical outcomes such as glycaemic control and complications was unavailable. This limits conclusions from a quality of care perspective since several important outcomes and possible confounders could not be included in the

analyses, leading to bias, despite adjustment for patient demographics. Unfortunately, more detailed data on technology use, specifically sensor types, is lacking in the registration system. Finally, data on independent treatment clinics was not included, possibly leading to selection bias.

Population characteristics in Dutch paediatric diabetes care vary depending on hospital volume categories. There is considerable variation in resource use across different hospital volumes, which persists despite adjustment for dissimilarities in target populations and hospital of treatment. Treatment approaches in small hospitals seem to focus more on in-patient care. Diabetes technology varies between hospitals but not between hospital volume categories. Total hospital expenditure for pediatric diabetes patients is highest in medium-sized hospitals, although diabetes care costs remain similar across hospital volumes. Whether these differences in care profile translate into variation in clinical outcomes remains to be evaluated.

AUTHOR CONTRIBUTIONS

SAGdV, TCSJ and CLV designed the study. JCGB was involved in the data collection. SAGdV, CLV, TCSJ, JCGB and MWJM were involved in the methodology. SAGdV performed the analysis and wrote the original draft of the manuscript. SAGdV, CLV, TCSJ and DM interpreted the results. MN and MWJM advised on timelines and supervised the work. All authors reviewed, revised and approved the manuscript. SAGdV is responsible for the integrity of the work as a whole.

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CONFLICT OF INTEREST STATEMENT

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

DATA AVAILABILITY STATEMENT

The dataset that supports the findings of this study is not available due to the sensitive nature (licence restrictions, privacy regulations and commercial reasons) of the data. The data set used is available only to other researchers, based on valid and reasonable requests and with permission granted by hospitals participating in the benchmark and LOGEX.

ORCID

Silvia A. G. de Vries https://orcid.org/0000-0002-2415-1239

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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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