Achieved levels of HbA1c and likelihood of hospital admission in people with type 1 diabetes in the Scottish population

Achieved Levels of HbA_{1c} and Likelihood of Hospital Admission in People With Type 1 Diabetes in the Scottish Population

A study from the Scottish Diabetes Research Network Epidemiology Group

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OBJECTIVE—People with type 1 diabetes have increased risk of hospital admission compared with those without diabetes. We hypothesized that HbA_{1c} would be an important indicator of risk of hospital admission.

RESEARCH DESIGN AND METHODS—The Scottish Care Information–Diabetes Collaboration, a dynamic national register of diagnosed cases of diabetes in Scotland, was linked to national data on admissions. We identified 24,750 people with type 1 diabetes during January 2005 to December 2007. We assessed the relationship between deciles of mean HbA_{1c} and hospital admissions in people with type 1 diabetes adjusting for patient characteristics.

RESULTS—There were 3,229 hospital admissions. Of the admissions, 8.1% of people had mean HbA_{1c} <7.0% (53 mmol/mol) and 16.3% had HbA_{1c} <7.5% (58 mmol/mol). The lowest odds of admission were associated with HbA_{1c} 7.7–8.7% (61–72 mmol/mol). When compared with this decile, a J-shaped relationship existed between HbA_{1c} and admission. The highest HbA_{1c} decile (10.8–18.4%/95–178 mmol/mol) showed significantly higher odds ratio (95% CI) for any admission (2.80, 2.51–3.12); the lowest HbA_{1c} decile (4.4–7.1%/25–54 mmol/mol) showed an increase in odds of admission of 1.29 (1.10–1.51). The highest HbA_{1c} decile experienced significantly higher odds of diabetes-related (3.31, 2.94–3.72) and diabetes ketoacidosis admissions (10.18, 7.96–13.01).

CONCLUSIONS—People with type 1 diabetes with highest and lowest mean HbA_{1c} values were associated with increased odds of admission. People with high HbA_{1c} (>10.8%/95 mmol/mol) were at particularly high risk. There is the need to develop effective interventions to reduce this risk.

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People with type 1 diabetes are at increased risk of hospital admission compared with the general population (1–3). A previous study in Tayside, Scotland found that 25% of people with type 1 diabetes had had at least one hospital admission in 1995, 2.89-fold higher than the general population (2). Hospital admissions are key drivers of the increased costs of diabetes born by health care systems as well as reflecting preventable morbidity suffered by patients.

HbA_{1c} has a central clinical role in counseling patients regarding risks of hypoglycemia, vascular, and other complications of diabetes (4). National guidelines promote targets for glycemic control based on HbA_{1c} and attempt to minimize both risk of complications as well as risk of hypoglycemia (5).

We hypothesized that HbA_{1c} would be an important indicator of risk of hospital admission and might be useful in defining that part of the population likely to suffer morbidity and incur an increase in hospital costs in the short and medium term. Such information could inform design of interventional programs promoting reduction in morbidity and costs of diabetes; prioritizing health policies; and identifying which subgroup of patients, determined by HbA_{1c}, would benefit most.

We examined the association between HbA_{1c} levels and risk of hospital admission in the Scottish type 1 diabetic population.

RESEARCH DESIGN AND METHODS

Datasets

The Scottish Care Information–Diabetes Collaboration (SCI-DC) is a dynamic national register of diagnosed cases of diabetes in Scotland (www.diabetesinscotland.org.uk). SCI-DC contains records for over 99% of diagnosed cases of diabetes (6) with

Table 1—*Baseline characteristics of patients, stratified by HbA_{1c} decile group*

	1	2	3	4	5	6	7	8	9	10	All
n	2,476	2,474	2,513	2,446	2,591	2,350	2,476	2,475	2,475	2,474	24,750
Mean HbA_{1c}, % (range)	6.5 (4.4–7.1)	7.4 (7.1–7.7)	7.9 (7.7–8.1)	8.2 (8.1–8.4)	8.6 (8.4–8.7)	8.9 (8.7–9.0)	9.2 (9.0–9.4)	9.7 (9.4–9.9)	10.3 (9.9–10.8)	12.0 (10.8–18.4)	8.9 (4.4–18.4)
Male (%)	1,449 (59)	1,453 (59)	1,428 (57)	1,393 (57)	1,452 (56)	1,330 (57)	1,362 (55)	1,383 (56)	1,353 (55)	1,289 (52)	13,892 (56)
Age, years (SD)	41 (17)	41 (17)	40 (17)	39 (17)	39 (17)	37 (17)	37 (18)	38 (17)	38 (16)	33 (14)	38 (17)
Previous vascular disease (%)	140 (6)	171 (7)	155 (6)	140 (6)	195 (8)	155 (7)	166 (7)	174 (7)	179 (7)	145 (6)	1,620 (7)
Mean creatinine, μmol/L (SD)	104 (82)	105 (88)	99 (70)	99 (67)	100 (75)	97 (63)	103 (75)	103 (75)	102 (63)	99 (63)	101 (73)
Mean BMI* (SD)	28 (6)	27 (5)	27 (5)	27 (5)	27 (5)	27 (5)	27 (5)	27 (5)	27 (6)	26 (6)	27 (5)
Median diabetes duration, years (IQR)	11 (2–23)	14 (5–26)	14 (5–24)	14 (5–26)	13 (5–24)	13 (5–24)	14 (6–25)	14 (7–24)	13 (6–22)	10 (4–17)	13 (5–24)
Admitted (%)	1,070 (43)	1,021 (41)	1,071 (43)	1,065 (44)	1,162 (45)	1,192 (51)	1,282 (52)	1,239 (52)	1,385 (56)	1,569 (63)	12,058 (49)
Total admissions† (per patient)	3,229 (3.0)	2,647 (2.6)	2,566 (2.4)	2,814 (2.6)	2,953 (2.5)	3,157 (2.7)	3,303 (2.6)	3,475 (2.8)	3,891 (2.8)	5,481 (3.5)	33,516 (2.8)
Diabetes related‡	1,890 (59)	1,745 (66)	1,846 (72)	1,898 (67)	2,068 (70)	2,150 (68)	2,523 (76)	2,570 (74)	3,108 (80)	4,605 (84)	24,403 (73)
Hypoglycemic‡	88 (2.7)	98 (3.7)	141 (5.5)	121 (4.3)	150 (5.1)	142 (4.5)	191 (5.8)	166 (4.8)	151 (3.9)	172 (3.1)	1,420 (4.2)
DKA‡§	118 (3.7)	127 (4.8)	196 (7.6)	149 (5.3)	302 (10.2)	358 (11.3)	429 (13.0)	514 (14.8)	807 (20.7)	1,812 (33.1)	4,812 (14.4)
Dysglycemia‖	226 (7.0)	243 (9.2)	350 (13.6)	277 (9.8)	468 (15.8)	529 (16.8)	636 (19.3)	700 (20.1)	1,005 (25.8)	2,008 (36.6)	6,442 (19.2)
Vascular‡	56 (1.7)	67 (2.5)	50 (2.0)	59 (2.1)	69 (2.3)	61 (1.9)	86 (2.6)	62 (1.8)	90 (2.3)	56 (1.0)	656 (2.0)
Cancer‡	382 (11.8)	213 (8.1)	130 (5.1)	391 (13.9)	284 (9.6)	165 (5.2)	138 (4.2)	79 (2.3)	89 (2.3)	66 (1.2)	1,937 (5.8)

HbA_{1c}, creatinine, and BMI were the mean of any values recorded between January 2005/date of diagnosis and December 2007/date of death. *BMI, kg/m^2; †total admissions over the period 2005–2007 and number of admissions per patient if they had at least one admission; ‡percentage of total admissions; §DKA; ‖coma, DKA, or hypoglycemia.

detailed clinical information including BMI, creatinine, age, sex, and HbA_{1c}. Type 1 diabetes was identified using an algorithm that incorporated age, drug prescription, and clinical description of the type of diabetes. Cross referencing of diabetes coded in routine hospital discharge information (SMR01) found that a diagnosis of diabetes was present in Scottish Morbidity Records (SMR01) in people absent from the SCI-DC register in 0.6% of cases (H. Anwar, personal communication).

Information on hospital admissions was obtained using SMR01, national data on hospital admissions from Information Services Division (ISD) of NHS National Services, Scotland. The SMR01 records contain over 95% of Scotland's hospital admissions and include administrative data and demographic information such as age, sex, and postcode of the patient. Details of individual episodes of care are recorded within each admission with up to six International Classification of Diseases (ICD-10) diagnosis codes and up to four procedure codes per episode.

Data were linked within the NHS using a unique patient identifier, the Community Health Index (CHI) number, where available. Where CHI was not available linkage was obtained using probabilistic methods based on name, sex, date of birth, and postcode, as previously described (7). No personal identifiers were released to researchers, and all subsequent analyses were conducted on anonymized datasets.

Individuals were excluded from the analysis where there were inconsistencies in date of birth or sex between SCI-DC and SMR01 (379 patients), no date of diagnosis (103 patients), or no clinical and no hospital admission data existing for the years 2005–2007 (345 patients). All patients with type 1 diabetes register with a general practitioner to obtain supplies of insulin. Thus the population includes people with type 1 diabetes who attend specialist clinics, their general practitioner for routine care, and those who may not attend for regular follow-up but have had a measurement of HbA_{1c} during the study period. HbA_{1c} was measured using a variety of clinical methods, all of which were Diabetes Control and Complications Trial (DCCT) aligned. In this retrospective cohort study, we identified 24,750 people with type 1 diabetes during January 2005 to December 2007.

Outcomes

The primary outcome of the study was any admission to hospital, with secondary

analysis of subgroups of ICD-10 codes for hospital admissions. Secondary analysis admissions were defined as a composite of all admissions because of diabetes or diabetes complications (excluding vascular disease), hypoglycemia, diabetes with ketoacidosis (DKA; without coma), vascular causes, and cancer. The ICD-10 codes for each type of outcome are listed in the Supplementary Data. Where coma is present ("Diabetes mellitus with coma": E 16.0), coding does not allow differentiation between coma with associated hypoglycemia, ketoacidosis, or hyperglycemia. Therefore, this coding was not included in either the hypoglycemic or hyperglycemic groups but was considered a composite group of hypoglycemia, diabetic ketoacidosis, and diabetes with coma under the heading "dysglycemia."

For the purposes of this analysis the vascular and cancer admissions were coded using the principal diagnostic position of the first episode, and diabetes-related admissions, hypoglycemia, DKA, and dysglycemia were identified using any diagnostic position.

Statistical methods

Of all the variables, only 4% of datapoints were missing. Imputation of missing data (mean HbA$_{1c}$, BMI, and serum creatinine) was performed using standard regression techniques. Deciles of mean levels of all HbA$_{1c}$ measurements over the study period were estimated. Individual patient HbA$_{1c}$ was summarized as the mean of all observations per year and assigned a decile. Association between deciles of HbA$_{1c}$ and all-cause admission was assessed using logistic regression models clustered by person. Parametric relationships between continuous variables and outcomes were examined using the grouped smoothing and fractional polynomial methods (8). Only linear relationships were included in final models since higher order relationships did not improve model fit. The referent decile was chosen to be the decile that provided the lowest odds of admission in univariate analyses (decile 3, mean HbA$_{1c}$ 7.9, range 7.7–8.1%). Outcomes were expressed as odds ratio (OR) of admission with corresponding 95% CIs for each decile compared with the reference category. Models were adjusted for potential confounding factors including age, sex, presence of previous vascular disease (ICD-9: 410–414, 430–438, 443; ICD-10: I20–25, I60–69, I73), mean serum creatinine, mean BMI, and diabetes duration at hospital admission. Sensitivity analysis was performed by excluding measurements taken within 6 months of diagnosis, those patients with suspected renal failure, and patients under 18 years of age. Annual number of days in hospital for those who were admitted was calculated by taking the median of the total days in hospital divided by the length of time exposed to diabetes over the study period.

RESULTS

Patient characteristics

Baseline mean HbA$_{1c}$ for all people with type 1 diabetes was 8.9% (SD 1.5). On average, there were 8.6 HbA$_{1c}$ measurements per person during the study period (SD 5.7). Female sex, younger age, and shorter duration of diabetes were associated with higher HbA$_{1c}$ (Table 1).

HbA$_{1c}$ and hospital admission

Over the 3 years, 49% of people with type 1 diabetes were admitted at least once accounting for 33,516 hospital admissions (2.8 hospital admissions per person on average if admitted at least once). The number of admissions was markedly higher in the highest HbA$_{1c}$ decile (10.8–18.4%) with 5,481 admissions in the 3-year period compared with 2,566 in the reference decile (decile 3, HbA$_{1c}$ 7.7–8.1%). Despite younger age and shorter duration of diabetes, decile 10 accounted for 16% of all admissions and deciles 8–10 accounted for 38% of admissions. The proportion of admissions because of cancer (5.8%) decreased with HbA$_{1c}$ decile (11.8% in lowest, 1.2% in highest decile). The proportion of admissions as a result of ketoacidosis (14.4%) increased with HbA$_{1c}$ decile (3.7% in lowest, 33.1% in highest decile), as did the proportion of dysglycemia admissions (7.0% in lowest, 36.6% in highest decile). The number of admissions for diabetes

Table 2—*Unadjusted and adjusted analysis of HbA$_{1c}$ and all-cause admission to hospital*

	Unadjusted		Adjusted†	
	OR (95% CI)	SE	OR (95% CI)	SE
Male	0.867 (0.812–0.926)	0.029	0.746 (0.697–0.798)	0.026
Age (years)*	1.007 (1.005–1.009)	0.001	1.002 (1.000–1.005)	0.001
Previous vascular admission	3.772 (3.392–4.194)	0.204	3.111 (2.782–3.479)	0.177
Creatinine (μmol/L)*†	1.009 (1.008–1.010)	0.000	1.009 (1.008–1.010)	0.000
BMI (kg/m^2)*†	0.996 (0.991–1.002)	0.003	0.989 (0.983–0.995)	0.003
Diabetes duration (years)*	1.005 (1.003–1.008)	0.001	0.989 (0.986–0.992)	0.002
HbA$_{1c}$ (mean of decile values)‡				
Decile 1 (mean 6.5)	1.382 (1.219–1.567)	0.089	1.306 (1.145–1.489)	0.088
Decile 2 (mean 7.4)	1.183 (1.048–1.336)	0.073	1.149 (1.022–1.291)	0.068
Decile 3 (mean 7.8)	Reference	Reference	Reference	Reference
Decile 4 (mean 8.2)	1.382 (0.965–1.328)	0.096	1.401 (1.218–1.611)	0.099
Decile 5 (mean 8.5)	1.438 (1.295–1.596)	0.077	1.423 (1.289–1.567)	0.076
Decile 6 (mean 8.9)	1.622 (1.452–1.812)	0.092	1.664 (1.489–1.861)	0.095
Decile 7 (mean 9.2)	2.074 (1.862–2.310)	0.114	2.116 (1.904–2.351)	0.114
Decile 8 (mean 9.7)	1.514 (1.358–1.688)	0.084	1.506 (1.350–1.679)	0.084
Decile 9 (mean 10.4)	1.801 (1.613–2.011)	0.101	1.836 (1.644–2.050)	0.103
Decile 10 (mean 12.0)	2.796 (2.505–3.120)	0.156	2.905 (2.599–3.247)	0.165

*Per 1 unit increase; †mean of any values recorded between January 2005/date of diagnosis and December 2007/date of death; ‡multivariate analysis results for model including all factors in table.

with coma (E10.0) was quite low: 287 compared with 6,422 under the general dysglycemia heading.

Odds of admission increased with higher serum creatinine, age, female sex, previous vascular admission, and lower BMI (Table 2). In univariate analysis there was a J-shaped relationship of HbA_{1c} with an increased likelihood of admission in the lowest decile and significantly higher (and increasing) likelihood of admission in deciles 5 through 10. The relationship of HbA_{1c} to admission did not substantially change after inclusion of sex, age, previous vascular admission, and BMI in a multivariate model (Table 2), where likelihood of hospital admission was greatest in decile 10 (adjusted OR 2.80 [95% CI 2.51–3.12]). However, the lowest decile was also associated with higher odds of all-cause admission (1.38 [1.22–1.57]). The increased odds of admission in the lowest decile persisted even after exclusion of admissions as a result of hypoglycemia and cancer (Fig. 1*A*) and all diabetes-related admissions (Fig. 1*B*).

Within the subgroup of causes of admission, there was an inverse relationship between HbA_{1c} and likelihood of cancer (Table 3) and positive relationships between HbA_{1c} and likelihood of ketoacidotic, vascular, and all other diabetes admissions. The relationship of HbA_{1c} to all diabetes-related admissions was particularly strong with almost a fourfold increase in likelihood of admission in the highest decile compared with the referent decile.

CONCLUSIONS—People with type 1 diabetes experience a large number of hospital admissions. In 1995, people with type 1 diabetes in the Tayside region of Scotland had an ~25% chance of hospitalization and the 864 people in the study accounted for some 2,261 days in hospital (2). Since that time the estimated prevalence of type 1 diabetes has increased from 0.24% of the Scottish population to 0.4%, an increase that reflects increasing incidence and possibly improved survival (9) but also more complete ascertainment. Data are now available for the entire Scottish population. Each year, people with type 1 diabetes in Scotland had an ~24% chance of hospitalization and the 24,750 people in the study accounted for 71,330 days in hospital, with an annual median of 2 days in the hospital for those admitted, a figure comparable with previous data (2).

We investigated risk factors for admission and in particular HbA_{1c}. Our analysis shows that low (4.4–7.1%/25–54 mmol/mol) and high (10.8–18.4%/95–178 mmol/mol) mean HbA_{1c} values were associated with increased odds of admission compared with HbA_{1c} levels of between 7.7 and 8.1% (61–65 mmol/mol). This J-shaped relationship does not appear to be accounted for by hospitalization around the time of diagnosis since the relationship between HbA_{1c} and all-cause admission is maintained even after excluding those patients who had diabetes for less than 180 days, and excluding measurements taken within the first 6 months of diagnosis and those under the age of 18 years (data not shown). A recent study has shown a similar J-shaped relationship between HbA_{1c} and mortality (10) in patients with type 2 diabetes.

We observe higher odds of hospitalization for those in the lowest decile of HbA_{1c}. Although lower HbA_{1c} is associated

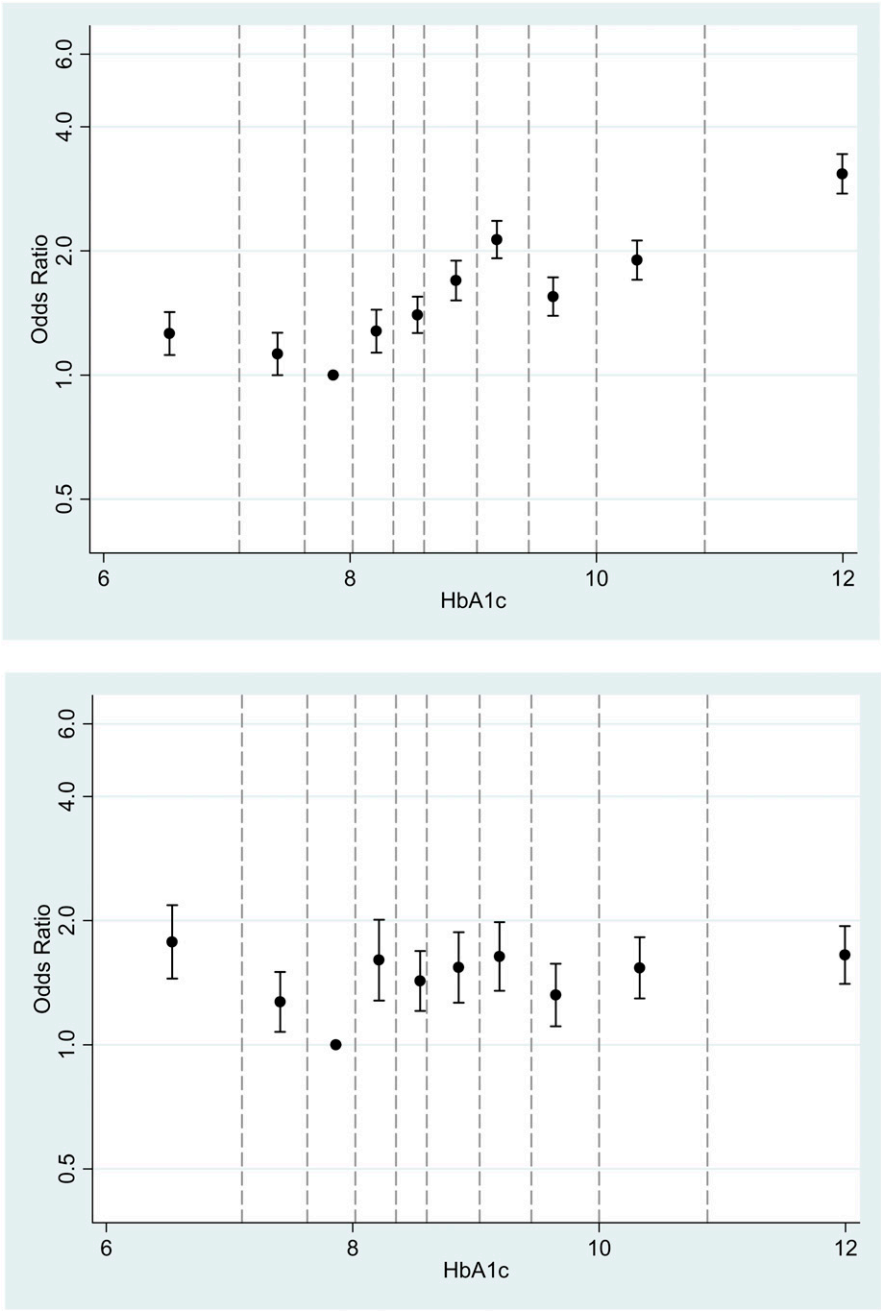

Figure 1—*Adjusted OR (and 95% CI) of types of admission to hospital (reference decile = 3) by HbA_{1c} decile: all-cause excluding hypoglycemia and cancer* (A) *and all-cause excluding diabetes related* (B). *Dashed vertical lines represent the HbA_{1c} range of each decile. (A high-quality color representation of this figure is available in the online issue.)*

Table 3—*Adjusted analysis (OR and 95% CI) of HbA_{1c} and admission to hospital for various recorded diagnoses*

Decile	Diabetes related*	Hypoglycemia	DKA	Coma, DKA, or hypoglycemia†	Cancer	Vascular
1	1.073 (0.948–1.215)	0.661 (0.463–0.944)	0.687 (0.505–0.934)	0.735 (0.578–0.935)	2.311 (1.203–4.438)	1.059 (0.671–1.670)
2	1.080 (0.946–1.232)	0.911 (0.655–1.267)	0.882 (0.638–1.219)	0.966 (0.759–1.230)	1.649 (0.964–2.822)	0.853 (0.528–1.376)
3	Reference	Reference	Reference	Reference	Reference	Reference
4	1.296 (1.126–1.492)	0.977 (0.700–1.364)	1.463 (1.100–1.944)	1.280 (1.025–1.598)	3.704 (1.835–7.480)	1.127 (0.704–1.805)
5	1.432 (1.127–1.604)	1.204 (0.881–1.646)	2.148 (1.649–2.797)	1.754 (1.420–2.167)	2.508 (1.407–4.470)	1.640 (1.080–2.489)
6	1.695 (1.506–1.909)	1.243 (0.901–1.714)	3.260 (2.514–4.227)	2.416 (1.955–2.985)	1.343 (0.718–2.514)	1.416 (0.883–2.269)
7	2.259 (2.020–2.526)	1.788 (1.316–2.429)	3.821 (2.981–4.897)	2.994 (2.451–3.658)	1.470 (0.799–2.707)	1.843 (1.206–2.819)
8	1.571 (1.398–1.767)	1.129 (0.811–1.571)	3.322 (2.559–4.313)	2.340 (1.886–2.904)	1.090 (0.560–2.121)	1.626 (1.041–2.539)
9	1.938 (1.717–2.187)	1.127 (0.810–1.570)	4.819 (3.698–6.281)	3.150 (2.535–3.914)	1.373 (0.710–2.656)	1.677 (1.052–2.673)
10	3.307 (2.935–3.725)	1.436 (1.044–1.973)	10.181 (7.964–13.015)	6.299 (5.145–7.712)	0.582 (0.296–1.143)	1.749 (1.073–2.850)

*Includes ketoacidosis and hypoglycemia; †DKA.

with an increase in risk of hypoglycemia (4) this does not obviously account for the increase in admissions we observe since there is no increase in hypoglycemic admissions. Clearly most hypoglycemic episodes will not result in hospital admission. We cannot exclude some failure to detect admissions complicated by hypoglycemia because of failure to code for this at hospital discharge. A further potential explanation would be reverse causality with HbA_{1c} falling in response to major illness, although given the observational nature of the dataset we cannot exclude other possibilities.

For deciles 6–10 (8.7–18.4%/72–178 mmol/mol), the likelihood of admission increases markedly with HbA_{1c} and the highest levels mark out a group with high odds of admission and potential associated hospital costs. Decile 10 experience 16% of all hospital admissions and 19% of all diabetes-related admissions despite being younger. There is an increase in diabetes-related and vascular admissions in the highest HbA_{1c} decile compared with the reference group. For diabetes-related admissions this increase persists even after exclusion of admissions in the first 6 months after diagnosis. For cancer admissions, there was a slight decrease in odds of admission as HbA_{1c} increased. However, because of the wide CIs, there was a lack of significance in most deciles. More detailed analysis of cancer admission and mortality will be of interest.

One of the aims of this study was to determine whether HbA_{1c} could identify a group with high rates of admission that might be amenable to programs supporting patients and reducing admission. Some admissions may represent the longer term effects of higher blood glucose leading to complications (4,11) and would require long-term improvements in glycemic control to reduce the likelihood of admission. Nevertheless, it is notable that HbA_{1c} above 8.4% (68 mmol/mol) is associated with increased risk of hospital admission and particularly high levels of admission in the highest HbA_{1c} decile. Raised HbA_{1c} identifies a vulnerable part of the diabetic population at high risk of hospital admission resulting in substantial health care costs, a group for whom interventions might usefully be targeted. When comparing HbA_{1c} decile 10 to the reference decile there were an extra 2,915 hospital admissions over the 3-year period, the great majority of which were in our diabetes-related group (2,759), the majority of these with dysglycemia coded as a cause of admission (1,658), and the great majority of those coded under diabetic ketoacidosis (1,616). Given an average cost of admissions in people with diabetes of around £2,424 (12), this crudely suggests an extra cost for those with HbA_{1c} >10.8% of up to £2.4m per annum for all admissions, £1.3m per annum for admissions complicated by ketoacidosis, and £4m per annum for the dysglycemia outcome. Although it is acknowledged that not all of these admissions may be prevented, programs directed to prevention of hospital admissions would appear to have extensive scope to be cost effective.

One of the striking features of this dataset is the overall level of HbA_{1c} achieved in our population. National clinical guidance in 2001 suggested an aim of an HbA_{1c} below 7% in keeping with other national and international bodies. Notably, only 8% of our population in 2005–2007 were achieving HbA_{1c} <7% (53 mmol/mol) and only 16% with mean HbA_{1c} under 7.5% (58 mmol/mol). This is higher than national figures for adolescents (11–14 years of age) in our population (9.7% below 7.5% with mean HbA_{1c} 9.2%). Other contemporary series have shown similar results (proportion <7% in Australia 13%) (13).

We take advantage of linked data for both hospital admissions (SMR01) and clinical information (SCI-DC). These data provide almost 100% coverage for people with type 1 diabetes in Scotland during 2005–2007, avoiding problems of underreporting of diabetes in hospital discharge information or selected patient groups in previous studies. Some limitations are identified. First, we used an algorithm to determine type of diabetes. As with nearly every other cohort study of this scale and type, there is a potential for misclassification of diabetes type. However, it is believed that this will be an extremely small percentage. Second, we have used the annual average level of HbA_{1c}. This was chosen as the best measure of prevailing HbA_{1c} for each person. It does not capture variability of HbA_{1c}, which would merit further examination. For some outcomes (for example hyper- and hypoglycemic admissions) HbA_{1c} before admission could be argued to be more appropriate. These types of admissions were also analyzed using last available HbA_{1c}, and interestingly this made no difference to the conclusions (data not shown). Third, only those admitted into hospitals were included as admitted. Often, glycemic patients are treated in accident and emergency or as an outpatient, neither of which were

accounted for in this analysis. Finally, in determining the reason for admission we rely on hospital admission data to detect each type of admission. These data are dependent on the accuracy of ICD coding, which is around 90% in general (see http://www.isdscotland.org/isd/2737.html). More detailed confirmation of the codes related to diabetes, particularly the group of codes around admission for hypoglycemia and ketoacidosis, is necessary to confirm the nature of admissions. Further work is also required to determine whether these admissions could be prevented.

Our data suggest HbA_{1c} is an effective way of identifying patients at higher risk of hospital admission. Targeting these patients may be an effective strategy for lowering risk of admission and health care costs. Higher levels of HbA_{1c} is a strong predictor of hospital admissions, suggesting that effective interventions to lower HbA_{1c} in this group could result in considerably lower hospital admissions and associated costs for the care of people with type 1 diabetes.

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