Frequency of blood glucose monitoring in relation to glycaemic control: observational study with diabetes database

Josie M M Evans, Ray W Newton, Danny A Ruta, Thomas M MacDonald, Richard J Stevenson, Andrew D Morris

Abstract

Objectives To investigate patterns of self monitoring of blood glucose concentration in diabetic patients who use insulin and to determine whether frequency of self monitoring is related to glycaemic control.
Setting Diabetes database, Tayside, Scotland.
Subjects Patients resident in Tayside in 1993-5 who were using insulin and were registered on the database and diagnosed with insulin dependent (type 1) or non-insulin dependent (type 2) diabetes before 1993.
Main outcome measures Number of glucose monitoring reagent strips dispensed (reagent strip uptake) derived from records of prescriptions. First recorded haemoglobin A_{1c} concentration in the study period, and reagent strips dispensed in the previous 6 months.
Results Among 807 patients with type 1 diabetes, 128 (16%) did not redeem any prescriptions for glucose monitoring reagent strips in the 3 year study period. Only 161 (20%) redeemed prescriptions for enough reagent strips to test glucose daily. The corresponding figures for the 790 patients with type 2 diabetes who used insulin were 162 (21%; no strips) and 131 (17%; daily tests). Reagent strip uptake was influenced both by age and by deprivation category. There was a direct relation between uptake and glycaemic control for 258 patients (with recorded haemoglobin A_{1c} concentrations) with type 1 diabetes. In a linear regression model the decrease in haemoglobin A_{1c} concentration for every extra 180 reagent strips dispensed was 0.7%. For the 290 patients with type 2 diabetes who used insulin there was no such relation.
Conclusions Self monitoring of blood glucose concentration is associated with improved glycaemic control in patients with type 1 diabetes. Regular self monitoring in patients with type 1 and type 2 diabetes is uncommon.

Introduction

The importance of normoglycaemia for the subsequent prevention of diabetic complications is now recognised.[1,2] Self monitoring of blood glucose has been recommended as a technique for improving control of blood glucose concentrations,[3] and a common view is that it should form part of an integrated treatment programme.[4] An American study in 1993, however, showed that over two thirds of diabetic patients carried out no self monitoring at all.[5]

In 1995 £42.6 million was spent on self monitoring of glucose concentrations in the United Kingdom,[6] despite increasing doubt about its benefits. Studies carried out in selected clinic populations (children,[7] young people,[8] elderly people[9]) or under experimental trial conditions,[10–13] or both, have shown that tests can be inaccurate and unreliable, may not be interpreted by patients correctly, and can cause psychological harm.[6] We studied patterns of self monitoring and its effect on glycaemic control in an unselected population of diabetic patients who use insulin in Tayside, Scotland, using data available through the DARTS/MEMO collaboration.[14,15] This was an observational outcomes study, enabling the non-interventional investigation of the effectiveness of glucose monitoring under real life, non-experimental conditions.

Methods

The DARTS/MEMO collaboration has pioneered the record linkage of healthcare data in the population of Tayside, Scotland (estimated mid-year resident population of 395 600 in 1995[16]). By record linking independent data sources with the community health index number (a unique patient identifier used for healthcare activity in Tayside) a population based register of patients with diabetes in Tayside, known as DARTS (diabetes audit and research in Tayside),[15] has been created and validated.[17–19]

This study was carried out among people who were resident in Tayside (or who died) during the study period (January 1993 to December 1995). Patients who were diagnosed with type 1 diabetes before January 1993 were identified from the register, as were those with type 2 diabetes who were using insulin during the first 6 months of 1993 (and were presumed to be using insulin thereafter).

Self monitoring of blood glucose

The number of blood glucose monitoring reagent strips dispensed to patients during the study period was determined from the MEMO dispensed prescribing database, a computerised record of all prescriptions dispensed in community pharmacies in Tayside since 1993.[14] Patterns of use were investigated by sex, age, and duration of diabetes. The Carstairs social deprivation categories of the study patients, ranging from category 1 (most affluent) to category 7 (least affluent) and based on four census variables, were also determined from details of the patients' postcodes.[20]

Blood glucose control

Patients who had at least one glycated haemoglobin (A_{1c}) concentration recorded between July 1993 and December 1995 were identified. The numbers of reagent strips that were dispensed to these patients during a 6 month period before their first haemoglobin A_{1c} measurements were calculated. Linear regression models for patients with type 1 and type 2 diabetes were constructed separately, with haemoglobin A_{1c} as the outcome and

Medicines Monitoring Unit, Department of Clinical Pharmacology, Ninewells Hospital and Medical School, Dundee DD1 9SY
Josie M M Evans, *Wellcome postdoctoral research fellow in health services research*
Thomas M MacDonald, *professor of pharmacoepidemiology*
Diabetes Centre, Ninewells Hospital and Medical School
Ray W Newton, *consultant diabetologist*
Department of Epidemiology and Public Health, Ninewells Hospital and Medical School
Danny A Ruta, *senior lecturer*
Department of Medicine, Ninewells Hospital and Medical School
Richard J Stevenson, *medical student*
Andrew D Morris, *senior lecturer*
Correspondence to: J M M Evans josie@memo.dundee.ac.uk

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Table 1 Age and sex of patients with diabetes in study of self monitoring of blood glucose concentration

Age (years)	Type 1 diabetes (n=807)		Type 2 diabetes (n=790)	
	Male	Female	Male	Female
0-14	29	42	—	—
15-24	70	65	—	—
25-44	252	157	22	16
45-64	90	74	163	152
⩾65	10	18	195	242
Total	451	356	380	410

age, sex, duration of diabetes, and deprivation category as covariates. The effect of body mass index (available for 70% and 75% of patients with type 1 and type 2 diabetes, respectively) was also investigated. The analyses were repeated in subgroups of patients who obtained at least one pack of strips.

Costs and analysis

The total cost of the blood glucose test strips dispensed was calculated with 1998 tariffs obtained from the *British National Formulary* (number 35)[21] (including the pharmacist's dispensing fee). All statistical analyses were carried out with SPSS.

Results

Self monitoring of blood glucose

Among 367 051 Tayside residents there were 807 (0.2%) patients with type 1 diabetes and 5601 (1.5%) with type 2 diabetes, 790 of whom were included in the study (table 1). In total, 13 382 prescriptions for blood glucose monitoring reagent strips were dispensed to 1307 of these patients during the 3 year period.

In those with type 1 diabetes, 128 (16%) of the 807 patients obtained no reagent strips at all. The 679 remaining patients obtained between 50 and 6220 strips (between 0.05 and 5.68 strips a day). One hundred and sixty one (20%) patients obtained more than 1095 strips (equivalent to one a day), and only eight (1%) patients obtained enough strips to measure at least four times daily. In those with type 2 diabetes, 162 (21%) of the 790 study patients obtained no strips. The 628 remaining patients obtained between 50 and 10 100 strips (that is, between 0.05 and 9.2 strips a day), with 131 patients (17%) obtaining more than 1095 strips.

Table 2 shows patterns of uptake of reagent strips by sex, age, duration of diabetes, and deprivation category. There was a particularly high uptake in children with type 1 diabetes, which then decreased sharply among young adults (15-24 years). Elderly people were another group with low uptake. Analysis by duration of diabetes showed a similar pattern, probably partly because of confounding by age. A pattern of decreasing uptake with increasing age was also evident among patients with type 2 diabetes. A trend of decreasing uptake with increasing deprivation was evident, particularly among patients with type 2 diabetes.

Table 2 Mean number of reagent strips dispensed (95% confidence intervals) and median (range) number by sex, age, duration of diabetes, and deprivation category

Detail	Type 1 diabetes		Type 2 diabetes	
	Mean (95% CI)	Median (range)	Mean (95% CI)	Median (range)
Total	659 (597 to 720)	300 (0-6220)	576 (519 to 634)	300 (0-10100)
Sex:				
Male	611 (531 to 691)	300 (0-6220)	621 (523 to 719)	250 (0-10100)
Female	719 (623 to 815)	350 (0-5300)	535 (470 to 559)	300 (0-4300)
Age (years):				
0-14	1148 (906 to 1390)	850 (0-5000)	—	—
15-24	444 (323 to 565)	200 (0-6220)	—	—
25-44	635 (548 to 721)	300 (0-6000)	1061 (593 to 1528)	300 (0-5400)
45-64	724 (581 to 866)	400 (0-4500)	687 (583 to 791)	400 (0-10100)
⩾65	419 (154 to 685)	50 (0-2450)	454 (396 to 513)	200 (0-4600)
Duration of diabetes (years):				
0-4	980 (779 to 1182)	500 (0-6220)	759 (605 to 913)	400 (0-4300)
5-9	481 (373 to 588)	250 (0-5450)	515 (414 to 615)	250 (0-5400)
10-14	615 (473 to 758)	300 (0-4700)	504 (411 to 598)	300 (0-4600)
15-19	614 (454 to 775)	300 (0-4850)	509 (394 to 623)	250 (0-2850)
⩾20	637 (537 to 736)	350 (0-4500)	635 (435 to 836)	200 (0-10100)
Carstairs deprivation category:				
1	706 (462 to 949)	375 (0-5000)	776 (525 to 1006)	400 (0-5400)
2	749 (592 to 906)	400 (0-6000)	660 (517 to 803)	350 (0-4600)
3	742 (613 to 872)	319 (0-6220)	578 (477 to 679)	300 (0-3550)
4	626 (480 to 772)	300 (0-5450)	497 (384 to 609)	250 (0-4500)
5	668 (494 to 842)	350 (0-4350)	587 (404 to 771)	250 (0-3800)
6 or 7	455 (334 to 575)	250 (0-5300)	520 (357 to 684)	200 (0-10100)

Blood glucose control

There were 258 patients with type 1 diabetes who had at least one valid haemoglobin A_{1c} concentration recorded (ranging from 4.2% to 17.4% of total haemoglobin), of whom 152 had obtained at least one pack of reagent strips in the previous 6 months. In a linear regression model the total number of reagent strips dispensed was a predictor of haemoglobin A_{1c} concentration ($P<0.001$; table 3), with a decrease in haemoglobin A_{1c} concentration for every extra 180 test strips dispensed (equivalent to one a day) of 0.7%. Sex was the only other independent predictor of haemoglobin A_{1c} concentration ($P=0.002$), with higher values in female patients (table 3). In the subgroup of 152 patients (those who obtained at least one pack of strips in the 6 month period) the relation between strip uptake and haemoglobin A_{1c} concentration was still strong (regression coefficient -0.672, $P<0.001$).

There were 290 insulin users with type 2 diabetes who had at least one valid haemoblobin A_{1c} concentration recorded (ranging from 4.2% to 14.3%). In a linear regression model none of the covariates, including the number of strips dispensed ($P=0.357$), were independent predictors of haemoglobin A_{1c} concentration (table 4). Similarly, there were no associations in the 171 patients who obtained at least one pack of strips.

Cost

The total cost of the 7002 prescriptions for glucose monitoring test strips dispensed to patients with type 1 diabetes was £155 912 (an average of £64.40 per patient per year). The 6381 prescriptions for reagent strips dispensed to patients with type 2 diabetes who used insulin cost £134 907 (£56.92 per patient per year).

Discussion

Self monitoring of blood glucose

This study provides an insight into blood glucose monitoring habits in all diabetic patients in Tayside who used insulin and shows that many patients with either type of diabetes did no testing at all. Less than one fifth tested daily.

It is encouraging to note that large numbers of strips were dispensed to children who are learning to

Table 3 Linear regression models in 258 patients with type 1 diabetes with haemoglobin A_{1c} concentration as outcome variable

Variable	Regression coefficient	P value
Univariate analysis		
Age (+10 years)	–0.097	0.156
Total strips dispensed (+180)	–0.613	<0.001
Duration (+1 year)	–0.006	0.539
Deprivation score (+1 category)	0.008	0.951
Sex (female *v* male)	0.474	0.025
Body mass index (+1 SD)	–0.001	0.996
Adjusted analysis		
Sex (female *v* male)	0.637	0.002
Total strips dispensed (+180)	–0.661	<0.001

Table 4 Linear regression models in 290 patients with type 2 diabetes who were using insulin, with haemoglobin A_{1c} concentration as outcome variable

Factors in univariate analysis	Regression coefficient	P value
Age (+10 years)	–0.0003	0.997
Total strips dispensed (+180)	–0.108	0.357
Duration (+1 year)	0.007	0.616
Deprivation score (+1 category)	–0.018	0.796
Sex (female *v* male)	0.217	0.283
Body mass index (+1 SD)	0.145	0.216

adjust to type 1 diabetes. The decline in teenagers and young adults, for whom parental control is presumably less influential, however, is worrying and backs up previous work which showed that some are not even compliant with insulin treatment.[17] The Carstairs score is a crude measure of social deprivation, but a link with strip uptake was still evident, as has been documented elsewhere for income and education level.[5] Diabetic patients do not pay for their prescriptions in the United Kingdom so it is not that they cannot afford them. The decline in self monitoring with age in patients with type 1 and type 2 diabetes has also been reported elsewhere.[5]

We believe that these results are reliable. Data from the DARTS/MEMO collaboration are well validated.[14 15] The dispensing of reagent strips was used as a proxy measure for self monitoring, and, although patients may not actually have used them (resulting in overestimation of use), the misclassification effect of primary non-compliance is eliminated,[22] and the method is probably more objective than direct questioning of patients.[23] We had no information on strips dispensed to patients in hospitals, however, or on glucose measurements performed by a third party (for example, by district nurses).

Blood glucose control

The regression analysis suggested a direct association between haemoglobin A_{1c} concentration and the number of strips obtained in a previous 6 month period in patients with type 1 diabetes. This result indicates either that self monitoring is important for maintaining good diabetic control or that it is a proxy measure of good health behaviour and practice that is associated with good control. In other words, patients who self monitor are also likely to be compliant with their diabetic regimen, with confounding by factors such as diet and exercise. When the analysis was restricted to patients who obtained at least some strips and could be regarded as partially compliant (providing some control for confounding), however, the association was still evident. Even if it is non-causal, self monitoring might improve quality of life by giving patients more control over their disease.[4]

The analysis could be carried out only for patients who had haemoglobin A_{1c} concentrations recorded (predominately those residing in the geographical area served by the main teaching hospital). This was not dependent on the clinical characteristics of the patient and is therefore unlikely to distort the results of the study, and indeed the age and sex distributions of patients with and without haemoglobin A_{1c} concentrations recorded were similar. Only one value was analysed per patient as more regular readings might be taken in patients judged to have poor control. Haemoglobin A_{1c} concentration is a biological correlate of diabetic control in the previous 3 months. The 6 month period for obtaining strips was chosen to allow for patients collecting them "in bulk" at infrequent intervals.

No association was found between haemoglobin A_{1c} concentration and self monitoring in patients with type 2 diabetes who used insulin, as reported elsewhere.[12] It may be that blood glucose monitoring is more effective in true insulin deficiency as opposed to the insulin resistant state. Or patients with type 2 diabetes might be less familiar with insulin use, more anxious about the risks of hypoglycaemia, and hence less likely to act on the results of tests. It is also important to note that patients with type 2 diabetes are a heterogeneous group, particularly in terms of pancreatic β cell reserve. An alternative explanation for the study findings is that self monitoring may be recommended particularly in those patients who are the most difficult to control.

Cost

The average cost of glucose monitoring per patient was relatively low when compared with other costs associated with diabetes care.[24] Even for a patient who is self monitoring four times daily, the approximate cost per year is only £409. We therefore suggest that self monitoring of blood glucose should be further encouraged, particularly in those subgroups of patients who do not monitor their blood glucose concentrations regularly—for example, young deprived men with type 1 diabetes.

Key messages

- Several studies have indicated the importance of self monitoring of blood glucose concentration for prevention of complications in patients with diabetes
- Uptake of reagent strips for self monitoring of blood glucose among diabetic patients who used insulin was low, with only 20% of patients with type 1 diabetes and 17% of those with type 2 diabetes obtaining enough strips to test blood glucose concentration once daily
- Reagent strip uptake depends on characteristics such as age and social deprivation category, and patient groups with low uptake should be identified and targeted
- There was a direct association between strip uptake in the previous 6 months and glycaemic control in patients with type 1 diabetes but not in those with type 2 diabetes

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A memorable patient

"Thank you for ending 40 years of misery"

Mary, who is 85, has been my patient for about six years. In 1957 she had had a gastroenterostomy and vagotomy for a peptic ulcer. Shortly afterwards, she had developed diarrhoea, which became chronic—she had been referred to many clinics and had been extensively investigated. No formal diagnosis seemed to have been made although malabsorption, bile acid reflux, postvagotomy diarrhoea, and dumping syndrome had been considered at one time or another.

She had trials of a fat free diet, pancreatic supplements, antibiotics, codeine, and bulking agents, but her bowels never improved. She was told that diarrhoea was something she would have to "put up with." In 1995 she developed prolapsing piles for which I referred her to hospital where she had a haemorrhoidectomy. In 1996 I had written in the records "chronic diarrhoea, for decades, recent faecal incontinence" and had rereferred her—she ended up having a colonoscopy, which was negative, and so she was discharged.

The diarrhoea was having a devastating impact on her life. In a letter she subsequently sent me she wrote: "My bowels had gone from bad to sheer hell. Not being able to go out without spending a lot of time on the toilet before going out, having to find toilets while out (very quickly) and in some cases having some very embarrassing accidents while out. I must say it's got to point where I did not want to go out … even at home I had accidents—going six times a day. Having mentioned this to so many doctors in the past who said sorry but this is something that I would have to put up with."

During one consultation I thought that she might have postvagotomy diarrhoea and suggested a trial of cholestyramine.[1 2] Within four weeks she had returned and stated that she had had a good response to the treatment. I suggested further referral and investigation, which she duly declined. At review at 12 months and 18 months, her diarrhoea is still well controlled.

She wrote about the impact of her new treatment: "Thank you for ending 40 years of misery. I am only going to the toilet once a day, I feel a lot better now in myself and I am now confident and can go out when I want to. Without the worry, I feel 20 years younger."

In a busy surgery, faced with a patient with chronic problems, it is easy to fall into the trap of thinking that a patient has been fully investigated and that nothing more can be done. But it is important to step back and reconsider. This is probably one of the most important duties of a GP, who must remain responsible for orchestrating the care of the patient and not be party to "collusion of anonymity."[3] Things that might help to recognise the problem earlier include good record keeping and medical summaries, unhurried consultations, and being constantly receptive to the patient's concerns.

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Mayur Lakhani, *lecturer in clinical audit, Leicester*