Self-monitoring of blood glucose in type 2 diabetes

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Article points

1. SMBG enables people to better manage their diabetes and, when used with structured education programmes, helps reduce the severity of potentially costly complications.
2. However, many studies have shown no benefit to HbA_{1c} following SMBG in people with type 2 diabetes being treated with diet or a combination of oral hypoglycaemic agents.
3. Guidelines are provided on the circumstances when each glucose-monitoring method should be used and how frequently.

Key words

- SMBG
- Treatment cost
- Guidelines

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Self-monitoring of blood glucose (SMBG) is advocated by many sources, including Diabetes UK (2007), the American Diabetes Association (ADA, 2002), International Diabetes Federation (IDF, 2005) and NICE (2002). The benefits of SMBG in type 1 diabetes are undisputed. In the management of insulin-treated type 2 diabetes, there is a similar agreement that the potential benefits of SMBG, especially when combined with a structured patient education programme, are immense, facilitating tighter glycaemic control (DAFNE study group, 2002; Nathan et al, 2005). A review of some of the publications surrounding blood glucose monitoring in type 2 diabetes is presented together with proposed recommendations for glucose monitoring in people with non-insulin-treated type 2 diabetes. These recommendations have been adopted recently by one local health community (Hereford PCT and Hereford Hospital), with a primary care prescribing review planned to promote this guidance in practice.

When used in conjunction with structured patient education programmes such as DAFNE, SMBG in type 1 diabetes brings proven benefits in terms of blood glucose management and control (DAFNE study group, 2002; Nathan et al, 2005). It enables people to better manage their diabetes and thereby help prevent or reduce the severity of devastating and potentially costly complications (DCCT, 1993). Furthermore, it provides the opportunity for individuals to take control of their diabetes management.

What is in dispute at the present time is the role and value of SMBG in the majority of people with type 2 diabetes being treated with diet and/or oral hypoglycaemic agents (OHAs). Figures reveal an alarming escalation of blood glucose testing reagent costs to the NHS, with £129.6 million spent on blood glucose testing strips in 2004 compared with £71.9 million in the year 2000 (DoH, 2007a).

A review of the literature reveals a striking lack of evidence for the use of SMBG in non-insulin-treated type 2 diabetes. It is not

recommended that people in the UK alter their OHA therapy in the light of SMBG results. Instead, they may alter their diet and lifestyle, but rely on their physician to up-titrate the dosage based on HbA_{1c} results. It is therefore questionable whether or not any such monitoring system that does not allow corrective action is of value. GPs and practice-based specialist nurses may, of course, find such monitoring useful when adjusting doses, or when contemplating the addition of OHAs in the first instance; however, most tend to rely on, or are guided by, HbA_{1c} measurements (ADA, 2006). Furthermore, some people with diabetes have meters from chemists purchased at a considerable discount and not provided by a member of the medical team caring for them. Pressure is then often exerted by the individual to be supplied with costly test strips without any discussion as to how SMBG might help the individual to improve their control or treatment.

SMBG can increase anxiety levels in some individuals and, in others, trigger the fabrication of results that can be misleading (Gallichan, 1997). Adequate training and education should always accompany commencement of SMBG, but it is the experience of the authors and their colleagues that this is often not the case. In the context of finite resources, perhaps some limitation of SMBG at this time is both appropriate and sensible.

Also worth consideration is urine glucose testing. Both the IDF and the ADA advocate urine glucose testing, but the disadvantages of urine glucose testing are such that it cannot form a reliable basis for long-term glucose management (Goldstein et al, 2004).

Current practice

In type 1 diabetes, a structured education programme imparts the skills necessary to use SMBG to adjust insulin; this can lead to sustained improvements in glycaemic control (NICE, 2002). The value of SMBG is difficult to assess in the setting of a complex intervention. Some people record but do not act on the results; others use results to adjust insulin and some simply fabricate the results (National Prescribing Centre, 2002). Undoubtedly, there is the potential to waste this resource or use it inappropriately, but SMBG should be made available to all individuals with type 1 diabetes.

There is much variation in the use of SMBG in type 2 diabetes nationwide. In a study of 11 688 people with type 2 diabetes in 262 general practices in the UK, between 1993 and 1998, there was wide variation in glucose testing methods and this variation remains (*Table 1*; Gulliford and Latinovic, 2004).

Costs of glucose monitoring agents

The cost of SMBG is considerable and still increasing. *Table 2* shows the escalating cost to the NHS, in England alone, of glucose-monitoring agents compared with oral hypoglycaemic agents and lipid-lowering drugs (DoH, 2007a).

Table 3 demonstrates the national patterns of prescribing for glucose-testing reagents: SMBG is increasing and urine testing is in slow decline. Local data show that Herefordshire PCT has the lowest prescribing rate for SMBG supplies in the West Midlands region, spending more on oral hypoglycaemic agents than glucose-monitoring agents, contrary to the national picture (DoH, 2007a). Nonetheless, the cost of blood glucose testing is still escalating at

Table 1. Trends in utilisation of glucose-monitoring agents in type 2 diabetes (Gulliford and Latinovic, 2004).

	1993 (%)	1998 (%)
No testing	24	30
Blood glucose testing	19	32
Urine glucose testing	45	27
Urine and blood glucose testing	12	11

Table 2. Net ingredient costs in England (£ thousands). Adapted from DoH, 2007a.

Year	Blood glucose testing	Oral hypoglycaemic agents	Lipid-lowering drugs
2000	71 997	53 041	326 110
2001	87 250	64 106	438 845
2002	106 675	81 972	570 973
2003	119 778	98 348	715 002
2004	129 627	120 270	769 236

Table 3. Comparative prescribing costs (£) for Herefordshire and England (DoH, 2007a).

Year	Actual cost per 1000 patients			
	Glucose blood-testing reagents		Urine-testing reagents	
	Herefordshire	England	Herefordshire	England
2001/2002	968.28	1559.06	168.20	69.70
2002/2003	1171.47	1848.97	171.38	60.75
2003/2004	1370.92	2029.15	165.62	53.35
2004/2005	1637.70	2148.54	151.95	45.91
2005/2006	2045.96	2364.24	127.83	39.26

approximately 20 % per year while use of urine glucose testing is gradually reducing (National Prescribing Centre, 2002).

SMBG in type 2 diabetes

There is much evidence for and against self-monitoring of blood glucose. Below, we discuss some key trials that argue for and against the use of SMBG in people with insulin- and non-insulin-treated type 2 diabetes.

The argument against

The DCCT identified SMBG as one of the key components in a landmark study that, in the authors' opinion, proved beyond doubt that intensive insulin treatment can result in lower HbA_{1c} and lower the risk of microvascular complications (DCCT group, 1993). However, the UKPDS essentially achieved the same clinical goal of improved glycaemic control (as reflected by lower HbA_{1c}) and better long-term microvascular outcomes, without SMBG being a required element in overweight people with type 2 diabetes who manage their condition by diet, or by diet plus OHAs (UKPDS Group, 1998a; UKPDS Group, 1998b).

The ADA admits that the optimal frequency of SMBG for people with type 2 diabetes is unknown (ADA, 2002). Data from the third National Health and Nutrition Examination Survey (NHANES III) between 1988 and 1994 showed that the vast majority of people with type 2 diabetes on OHAs or diet rarely test their blood: approximately 5–6 % of people with type 2 diabetes test at least once daily; 80 % of diet-treated individuals never test or test less than once a month. Of those treated with OHAs, 65 % never tested or tested less than once a month (Harris and NHANES III, 2001). Moreover, the data in NHANES III showed no correlation between the frequency of blood glucose monitoring and HbA_{1c} levels in any of the therapeutic categories.

In their systematic literature search, Faas and colleagues found six prospective randomised trials addressing SMBG in people with non-insulin-treated type 2 diabetes; five of the trials lasted between 12 and 62 weeks. Analysis showed that SMBG had no significant impact on either HbA_{1c} or fructosamine level. Only one of these five trials showed significant improvement in glycaemic control in those who were using SMBG after 12 months. In addition, a therapy decision scheme that would have improved glycaemic control was applied only to self-monitoring groups; thus, casting doubt on the demonstrated impact of SMBG (Faas et al, 1997).

An observational study in Tayside between 1993 and 1995 concluded: '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' (Evans et al, 1999). Furthermore, Franciosi and colleagues concluded that in people not treated with insulin, SMBG is associated with higher levels of HbA_{1c} and higher psychological burden and therefore, SMBG should not be offered to this group (Franciosi et al, 2001). A 6-month randomised trial of people with type 2 diabetes showed a rate of adherence with monitoring of 45 %. There was no significant difference between the self-monitoring and non-self-monitoring group in reduction in HbA_{1c}; 0.8 % and 0.6 %, respectively (Davidson et al, 2005).

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1. A study by the ROSSO Study Group looked at long-term outcomes in people with type 2 diabetes who self-monitor. After 6.5 years, it was concluded that SMBG was associated with a decrease in diabetes-related morbidity and all-cause mortality.
2. The DIGEM Study, which commenced in 2002, will hopefully provide much needed further information on this topic. It is set to be published by 2008 and consists of a randomised, controlled trial to determine the effect of blood glucose self-monitoring in people with type 2 diabetes.

A recent observational community-based study from Australia (Davis et al, 2006), in which 70 % of people with type 2 diabetes performed SMBG with a median of four tests per day, concluded that HbA_{1c} was not significantly different between SMBG users and non-users, either overall or within diabetes treatment groups (diet, OHAs, insulin with or without OHAs). The average annual cost of a 4-times daily testing regimen excluding glucometers was AUS$162 (GBP£71) per type 2 diabetes equivalent to AUS$51 000 000 (GBP£22 420 161) when projected to the entire Australian type 2 population.

A randomised trial involving non-insulin-treated people with type 2 diabetes assessed whether or not provision of free test strips would improve glycaemic control. It involved 262 people during the course of 6 months. It concluded that while there was more blood glucose testing in those given free strips, HbA_{1c} did not differ between the two groups (Johnson et al, 2006).

The argument for

An observational cohort of the Northern California Kaiser Permanente registry looked at 24 312 people with type 1 and type 2 diabetes in the US (Karter et al, 2001). Utilisation of SMBG was measured indirectly using average daily glucometer strip utilisation. HbA_{1c} in people with type 2 diabetes treated with insulin and/or OHAs was 0.75 % lower in those who monitored blood glucose frequently (at least daily) than in those who did so less frequently. The study did not separate people with type 2 diabetes into those on insulin and those taking OHAs. As an observational study, it cannot determine whether or not the association between self-monitoring and glycaemic control is causal.

Karter et al (2006) looked at SMBG in the Northern California Kaiser Permanente Health Service over a 4-year period in new and prevalent users of SMBG. The 16 091 new users were found to have marked improvement in HbA_{1c} after initiation of SMBG in the following three therapy groups: diet-controlled, treatment with OHAs only, and treatment with insulin (use of insulin or any regimen that includes insulin). This benefit showed a dose–response relationship for up to three tests per day. The more frequent the testing the greater the decrease in HbA_{1c}. In the prevalent user cohort, changes in frequency of SMBG were not associated with significant changes in HbA_{1c}. For people on OHAs and insulin, increases in frequency of monitoring above three times per day had minimal effect on HbA_{1c}. Causal interpretation of this data is limited by lack of randomisation. The role of education is unstated in those undertaking SMBG in this study. Those who were recommended to use SMBG may also have received intensification of diabetes therapy simultaneously.

An epidemiological cohort study by the ROSSO (RetrOlective Study: Self-monitoring of blood glucose and Outcomes in patients with type 2 diabetes) study group looked at long-term outcomes in people with type 2 diabetes who self-monitor. After 6.5 years, it was concluded that SMBG was associated with a decrease in diabetes-related morbidity and all-cause mortality. This association was true of people with insulin- and non-insulin-treated type 2 diabetes (Martin et al, 2006).

The DIGEM (DIabetes Glycaemic Education and Monitoring) study, which commenced in 2002, will hopefully provide much-needed further information on this topic. It is set to be published by 2008 and consists of a randomised, controlled trial to determine the effect of blood glucose self-monitoring in people with type 2 diabetes. In total, 450 people with type 2 diabetes managed with lifestyle or OHAs will participate. Over a 12-month period, the effectiveness of three trial strategies will be studied: a control group with 3-monthly HbA_{1c} interpreted by a nurse practitioner; a self-testing group with a nurse practitioner interpreting the results and informing adjustment of drug dosage; and a self-monitoring group who will interpret their own results in relation to lifestyle changes. The main outcome will be HbA_{1c} levels, plus

Page points

1. The DIGEM Study will inform practice about the extent of effectiveness of SMBG and identify individuals who might derive the greatest benefit from different forms of blood glucose monitoring.
2. The use of urine glucose testing to estimate blood glucose concentration is undesirable.
3. A supporting information leaflet has been produced for use within the local health economy (primary and secondary care) to explain any changes in current recommended practice to patients.
4. A series of training events are being held to update all relevant healthcare professionals, along with a county-wide primary care-prescribing review that will support integrating these guidelines into current practice.

additional measurements of other risk factors for cardiovascular disease, satisfaction with care, quality of life and cost of care (DoH, 2007b). It will inform practice about the extent of effectiveness of SMBG and identify individuals who might derive the greatest benefit from different forms of blood glucose monitoring. [This trial has been published. See Farmer et al, 2007 for details].

Evidence for self-monitoring of urine glucose in diabetes

The use of urine glucose testing to estimate blood glucose concentration is undesirable for the following reasons (Goldstein et al, 2004).

- There is a wide variation in renal threshold even in healthy individuals, that averages 10 mmol/l. The renal threshold rises in longstanding diabetes and, hence, urine glucose underestimates blood glucose. Children and pregnant women have low or variable renal threshold.
- Fluid intake and urine concentration affect results.
- The urine glucose value reflects an average level of blood glucose during the interval since the last voiding and not the level at the time of the test.
- A negative urine glucose test does not distinguish between hypoglycaemia and euglycaemia and mild or moderate hyperglycaemia.
- Urine glucose testing is of no value in recognising or preventing hypoglycaemia and hyperglycaemia. Negative tests in people with a high renal threshold may provide a false sense of security (Lawton et al, 2004).
- Drug interference, such as ascorbic acid, levodopa or phenothiazines, interfere with urine glucose determinations.
- People often perceive urine testing as less convenient, messy and unhygienic, and recognise that it provides very limited information that can be misleading.

Urine glucose testing on the other hand is cheaper and preferred by some patients, no finger pricks being necessary. Urine glucose testing could also be considered for people who are unable or unwilling to perform SMBG.

Most people assume that blood glucose meters are given to those with a more advanced or serious form of diabetes. This attitude has implications for how they think about their diabetes.

New local guidance for SMBG

Based on the above discussion of the evidence and a recent consensus statement, the authors formulated their own local guidelines for blood glucose testing (Owens et al, 2004; 2005) proposed guidelines for blood glucose testing in type 2 diabetes in Herefordshire. These are summarised in *Table 4*. Additionally:

- All blood glucose testing should be in conjunction with a structured diabetes education programme.
- Urine testing serves no useful purpose in glucose monitoring in type 2 diabetes.

The above recommendations aim to ensure the best use of finite resources within a healthcare setting.

A supporting information leaflet has been produced for use within the local health economy (primary and secondary care) to explain any changes in current recommended practice to those affected. This leaflet can be obtained through Maggie Arter at the DSN Office, Hereford County Hospital HR1 2ER (Tel: 01432 355 444 Ext. 4066).

A series of training events are being held to update all relevant healthcare professionals, along with a county-wide primary care-prescribing review that will support integrating these guidelines into current practice. A community pharmacy intervention scheme currently in place has included relevant review points around test strips to help reinforce guidance. Early indications show a large prescribing variation in practice and encouraging changes towards this local guidance.

Conclusion

With the rising cost of diabetes; for example, more people diagnosed and the increasing use of insulin and new oral agents, saving from reducing blood glucose monitoring will

Table 4. Guidelines for blood glucose self-monitoring in diabetes, as produced by Hereford PCT.

Diabetes type	Treatment group	Testing recommendations	Frequency of prescription
Type 2	● Diet controlled ● Metformin ● Metformin plus thiazolidinediones	Not essential but HbA_{1c} minimum twice annually (NICE recommends 2–6 monthly	Not applicable
	● Sulphonylurea or sulphonylurea plus other oral hypoglycaemic agent	Blood test three-times a week ● at various times ● and/or when suspecting hypoglycaemia	50 per 4 months (12 per 28 days)
	● Oral hypoglycaemic agents plus steroids or during changes in treatment	Blood test at least once daily ● pre-lunch, pre-supper and/or post-meal	50 per 1–2 months (28 per 28 days)
	● Pre-insulin initiation	● once daily at various times (28 per 28 days)	50 per 1–2 months
	● Once-daily basal insulin ± oral hypoglycaemic agent	● during titration phase: once-daily fasting blood test (pre-breakfast) ● when stable: once-daily blood test at different times to detect high/low levels	50 per month (56 per 28 days)
	● During intercurrent illness	If not already blood testing, may be introduced if/when considered appropriate	50 per year
Type 1 or type 2	● Twice-daily insulin injections	Up to twice-daily blood testing ● at varying times	50 per month 56 per 28 days)
	● Multiple daily insulin injections	Up to four times daily blood testing ● pre- and/or post-meals	2 x 50 per month (112 per 28 days)
Type 1	● During intercurrent illness	Four-times-daily blood testing and testing for ketones, particularly if blood glucose raised	2 x 50 per month (112 per 28 days) and ketones test
	● Insulin pump therapy	Four–eight-times-daily blood tests ● varying times	2–4 x 50 per month (112–224 per 28 days
	● Loss of, or impaired, hypoglycaemia awareness	Four–eight-times-daily blood tests ● varying times	2–4 x 50 per month (112–224 per 28 days
Gestational	● Diet controlled	Blood tests once every 2 days ● before and after meals ● more frequently as results dictate	50 per month (56 per 28 days)
	● Insulin	Four-times-daily blood tests ● include some post-meal tests	2 x 50 per month (112 per 28 days)

HbA_{1c} test recommended for everyone with diabetes twice annually, minimum (NICE recommends 2–6 monthly; NICE, 2002).
Urine testing for glucose is an unreliable means of monitoring blood glucose and is not recommended.
Structured patient education is central to effective self-monitoring – patient information leaflet available.
Test strips are packaged in 50s and therefore must be prescribed in multiples of 50.
Avoid adding test strips to regular repeat list. Add to acute list unless regular insulin user.
Add normal directions for use to prescription to enable better compliance checks by staff.

be comparatively small but, nonetheless, it is important to use resources appropriately.

SMBG in people with type 2 diabetes treated with insulin is appropriate when used in conjunction with a structured educational programme. For those on sulphonylurea or non-sulphonylurea secretagogues, SMBG pre- or postprandially is useful and can detect hypoglycaemia. Where steroid use or intercurrent illness is likely to cause deterioration in glycaemic control, SMBG is advocated to help with uptitration of medication. For those not treated with sulphonylurea or insulin, there is insufficient evidence to advocate widespread blood glucose testing. ■

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