

When and how should patients with diabetes mellitus test blood glucose?

The incidence of diabetes mellitus is increasing in all age groups. About 1.3 million people in the United Kingdom (UK) have diagnosed diabetes, 85 to 90% of whom suffer from type II disease.^{1,2} However, it is likely that hundreds of thousands of people have undiagnosed type II diabetes.¹

Prolonged exposure to raised blood glucose levels damages tissues throughout the body. Initially, this damage is reversible but, ultimately, it can lead to microvascular complications (e.g. retinopathy, renal failure and neuropathy) and macrovascular complications (e.g. stroke, lower limb ischaemia and coronary heart disease).^{1,3}

Many people with diabetes monitor their blood glucose levels at home (self-monitoring) but current evidence suggests that this might not be essential for all patients.³

This *Bulletin* summarises the evidence for monitoring of blood glucose by patients with diabetes (excluding people with asymptomatic hypoglycaemia and pregnant women). It compares blood testing with urine testing, and explores the evidence for frequency of monitoring.

Introduction

The care of people with diabetes accounts for about 5% of total NHS resources and for up to 10% of hospital inpatient resources. One in 20 people with the condition will require support from social services, the average

SUMMARY

- ❑ The NHS spends about 40% more on blood glucose testing materials for people with diabetes mellitus than it does on oral hypoglycaemic drugs (£90m vs. £64m in 2001).
- ❑ Strict control of blood glucose levels improves outcomes in patients with either type I or type II diabetes. However, it is not clear whether self-monitoring contributes to this improvement.
- ❑ For self-monitoring of blood glucose to be most useful, it should form part of a wider programme of management. Patients should be given adequate training in self-monitoring techniques, and patients and health care professionals should be clear what they hope to achieve by self-monitoring blood glucose.
- ❑ Measuring glycosylated haemoglobin (HbA_{1c}) can contribute to improved long-term blood glucose control and reduce morbidity. Reductions in HbA_{1c} levels have been associated with a lower risk of microvascular endpoints.
- ❑ Self-monitoring might be most appropriate for patients with type I or type II diabetes who use insulin and adjust their dose as a result of blood glucose testing, and for all diabetic patients when they have intercurrent illness.
- ❑ It is not known what the ideal frequency of self-monitoring should be in type II diabetes. Current recommendations are based on consensus opinion.
- ❑ There is no evidence that blood testing is more effective than urine testing at improving blood glucose control in people with type II diabetes. In addition, such patients often prefer to monitor urine. People with type I diabetes often prefer testing blood, because it makes them feel more in control of their condition.

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annual cost of which was £2,450 per person in 1999.¹

The NHS spends about 40% more on materials used for testing blood glucose in people with diabetes than it does on oral hypoglycaemic drugs. In 2001, the net ingredient cost (NIC) of such materials in England was about £90m (this excludes the cost of blood glucose monitors, which are not available on NHS prescription). Most of this was for materials used to test blood. The equivalent figure for oral hypoglycaemic drugs was about £64m.⁴ Both figures are a 20% increase on the equivalent NICs for 2000.⁵

Standards for care of patients with diabetes were issued in the first part of a National Service Framework (NSF) in December 2001 (the implementation section is expected later this year).¹ In addition, clinical guidelines for the management of people with type I and type II diabetes are being produced as part of the work programme of the National Institute for Clinical Excellence.

Are blood glucose levels important?

Strict control of blood glucose levels improves long-term outcomes in patients with diabetes.¹ Evidence for this in **type I diabetes** was provided by the Diabetes Control and Complications Trial (DCCT).⁶ In this study, 1,441 patients were randomised to receive either conventional treatment (insulin used once or twice daily) or intensive therapy (insulin used three or more times daily). Patients were followed up for an average of 6.5 years. Those in the intensive therapy group monitored blood glucose levels at least four times in 24 hours, whereas those receiving conventional treatment monitored blood or urine daily.

The results of the trial showed that the mean risk of developing retinopathy, microalbuminuria or albuminuria was reduced by 76% (95% confidence intervals [CI] 62% to 85%), 39% (21% to 52%)

and 54% (19% to 74%), respectively, in the intensive therapy group, compared with that of patients receiving conventional treatment. In addition, intensive therapy reduced the occurrence of neuropathy by 60% (95% CI 38% to 74%) compared with conventional treatment.

Although patients receiving intensive therapy monitored blood glucose levels more frequently than those having conventional treatment, it cannot be assumed that this gave rise to their improved outcomes.

The UK Prospective Diabetes Study (UKPDS 33) provided similar results for patients with **type II diabetes**.⁷ This randomised controlled trial involved 3,867 people who had been newly diagnosed with type II diabetes, and who were followed up for 10 to 11 years. Those in the intensive therapy group were prescribed either insulin or a sulphonylurea; patients who received conventional treatment were managed using diet. In either group, other drug treatment could be added to control blood glucose levels, if necessary.

Median glycosylated haemoglobin (HbA_{1c}) levels, which give an indication of long-term control of blood glucose, rose in both trial groups. However, levels were 11% lower in the intensive therapy group after 10 years than in those receiving conventional treatment (7.0% [95% CI 6.2% to 8.2%] and 7.9% [95% CI 6.9% to 8.8%], respectively).

Microvascular endpoints (e.g. retinopathy or renal failure) were reduced by 25% in patients receiving intensive therapy. However, macrovascular surrogate endpoints (e.g. stroke or angina) did not differ between groups, although the reduction in myocardial infarction with intensive therapy almost reached statistical significance.

In both studies, patients in the intensive therapy group were much more likely to suffer hypoglycaemia (including severe and/or multiple episodes in

some patients) than those receiving conventional therapy.

Current recommendations for self-monitoring

A consensus guide produced by the European Non-Insulin-Dependent Diabetes Mellitus Policy Group in 1994, states that self-monitoring of blood glucose is mandatory for patients with type II diabetes who are being treated with insulin, and is desirable for those receiving oral hypoglycaemic drugs.⁸ A position statement of the American Diabetes Association (ADA) published in 2002 recommended self-monitoring of blood glucose for all patients being treated with insulin.⁹ Only the European consensus guide gives details about how and when to test urine.

What is the evidence for self-monitoring?

Although self-monitoring is common practice and a consensus view encourages it, evidence for its effect on control of blood glucose is unclear, particularly in patients with type II diabetes. In addition, the effects of self-monitoring of blood glucose on patient outcomes have not been adequately documented.³

A health technology assessment (HTA) on monitoring blood glucose in diabetes analysed eight studies involving patients with **type I diabetes**. Six of these studies compared blood testing with urine testing, one compared blood testing with no testing and one evaluated different frequencies of blood testing.³

Of these, only one (which was conducted in children) showed a statistically significant decrease in mean HbA_{1c} in the group that monitored blood compared with the subjects who tested urine. However, the mean decrease was only from 11.88% to 11.0% compared with a reduction from 12.04% to 11.88% in the urine testing group, and normal HbA_{1c} levels range from 6.5% to 7.5%.

The above studies did not provide decisive evidence for self-monitoring of blood glucose by patients with type I diabetes. The improvements seen in blood glucose control might have occurred because of a greater level of adherence to other aspects of management.³

The HTA also looked at self-monitoring in **type II diabetes**. It assessed six studies, and a meta-analysis of four of these, that compared blood or urine monitoring with no monitoring.

Of the six studies, five showed no difference between blood glucose control in subjects who monitored and those who did not. In the sixth study, a small but statistically significant decrease in HbA_{1c} was found in the self-monitoring group, but the effect of self-monitoring was confounded by differences in patient management between trial groups.

The meta-analysis showed a non-significant reduction in HbA_{1c} of 0.25% (95% CI -0.61% to 0.10%) in the self-monitoring group but the results were imprecise. The HTA concluded that self-monitoring might often be unnecessary in patients with type II diabetes.³

A more recent cohort study that involved 24,312 patients (1,159 had type I diabetes, the remainder had type II disease), found that the adjusted mean HbA_{1c} level in self-monitoring patients with type I diabetes was 7.7% (95% CI 7.6% to 7.9%), compared with 8.7% (95% CI 8.6% to 8.9%) for those who did not monitor.¹⁰

The equivalent figures for patients with type II diabetes varied according to the method used to manage their disease, but ranged between a mean of 7.7% and 8.2% in the monitoring group and 8.1% and 8.8% in the non-monitoring group. The greatest improvement in HbA_{1c} levels was seen in patients who reported that they had monitored their blood glucose levels at least three times a day if they had type I diabetes and at least daily if they had type II disease.

However, the only measure of compliance with self-monitoring was a count of the number of test strips collected from pharmacies by trial subjects. There was no record of the numbers of test strips that the patients had actually used.

In contrast, a cross-sectional study found that self-monitoring could be detrimental to some patients with type II diabetes.¹¹ It involved 2,855 subjects and found that in those not treated with insulin, increased frequency of self-monitoring was associated with significantly higher HbA_{1c} levels and greater distress, worry and depressive symptoms. Self-monitoring only seemed to help patients treated with insulin, who adjusted their dose in response to the test. The authors concluded that this group of patients was the only one for which self-monitoring could be recommended. However, the results of both of the above studies might have been confounded.

Overall, there is not enough evidence to support the current recommendations for self-monitoring in **type II diabetes**, and it is not yet known how often glucose levels should be tested in such patients.^{3,11} In addition, although some studies support self-monitoring by patients with **type I diabetes**, especially when they have intercurrent illness, the evidence that it is appropriate for all patients is not convincing.

Patients using insulin for either type I or type II diabetes, who adjust their dose according to the results of blood or urine glucose level tests as part of a management programme, are most likely to be suitable for self-monitoring.

Urine or blood?

The European consensus guide states that urine testing is useful when blood testing is not possible.⁸ The ADA position statement adds that although urine testing is low in cost and easy to perform, its limitations (e.g. it does not identify impending hypoglycaemia) make

blood testing the preferred method of measuring glycaemic control.⁹

There is no evidence that blood testing is more effective than urine testing at improving blood glucose control in people with type II diabetes.³ Four trials that compared blood and urine testing, found no significant difference between the two techniques.³ This was confirmed by a meta-analysis of three studies involving 278 patients, in which no significant difference was found in HbA_{1c} levels between the group that tested blood and those who monitored urine (-0.03% [95% CI -0.52% to 0.47%]).

In two studies that assessed patients' views about testing, about 70% of 177 people with type II diabetes preferred testing urine to blood. This was largely because urine testing did not require painful finger-pricking. However, patients with type I diabetes often preferred blood testing, because it made them feel more in control of their condition.³

Urine testing could be considered for people who find blood testing difficult or for those who do not like it. Blood testing is more expensive than urine testing. Meters (which are not available on NHS prescription) cost up to about £60 and the strips cost from 20p to 30p each. Urine testing strips cost 4p to 7p each.^{4,12}

Errors in testing

There does not appear to be a standard method for evaluating blood glucose meters in practice.³ Training of users, variability of devices, effects of long-term use on meters and patient acceptability are not usually assessed in studies. However, meter errors could be small compared with user error.³ User error or non-compliance often arise when patients are not given enough information about monitoring, lack motivation or find testing complicated and confusing.

A survey of 93 patients, who visited a UK pharmacy for advice

about blood glucose meters, revealed other problems.¹³ About half had difficulty sampling blood. For example, they could not produce enough blood to cover the test strip pad or forgot to wash their hands before testing (this removes residual sugar from the fingers). Over a third did not keep the measuring chamber of their meter clean, and one patient had bought three meters but could not use any of them.

Research has shown that people with diabetes often record blood glucose levels inaccurately.³ A study of 14 patients with type I diabetes, who did not know they were using a meter with a memory and who recorded blood glucose levels in a log book for 21 days, revealed errors in recording, such as addition of 'phantom' values, omission of readings and imprecise recordings.¹⁴ This example illustrates the importance of teaching patients how to use meters properly.

In addition, studies have shown that patients with reduced visual acuity or retinopathy, who do not use a meter can have difficulty with visual interpretation of test strips.^{15,16}

Even frequent monitoring of blood glucose may not provide an accurate reflection of 24-hour blood glucose levels. A small trial that involved 24 patients with type I diabetes compared blood glucose readings taken seven times a day with adipose tissue glucose obtained from a continuous microdialysis device.¹⁷ The diurnal variation in blood glucose levels was often too great to be accurately reflected, despite monitoring seven times a day.

What about HbA_{1c}?

HbA_{1c} can be a useful means of monitoring blood glucose control. In addition, decreases in HbA_{1c} levels have been associated with

a reduced risk of microvascular endpoints.³ The DCCT and UKPDS studies showed that HbA_{1c} measurement contributed to improved long-term blood glucose control and reduced morbidity.³

It is not known how often HbA_{1c} should be tested. However, the ADA recommends measuring levels at a patient's initial assessment, then repeating this according to the treatment regimen used and the judgement of the clinician. The ADA adds that the consensus view is to repeat the measurement of HbA_{1c} levels twice a year in patients with stable blood glucose control, and quarterly in those whose treatment has changed or in those who have unstable blood glucose control.⁹

Conclusion

Self-monitoring of blood glucose levels is common practice. However, there is little evidence to support its use in all people with diabetes — especially those with type II disease — unless there is also an effective programme of management in place for the patient. Self-monitoring is likely to be most appropriate for patients with type I or type II diabetes, who use insulin and adjust their dose as a result of the test, or for all patients with diabetes when they have intercurrent illness.

The standards of care set out in the NSF for Diabetes emphasise the importance of involving patients in decisions made about their diabetes. For self-monitoring of blood glucose to be useful, patients should be given adequate training in self-monitoring techniques. In addition, patients and health care professionals should be clear about what they hope to achieve by testing blood glucose levels.

Patients can find self-monitoring painful, inconvenient and difficult. If self-monitoring is used, the type of test employed should

be chosen after discussion of each method with the patient.

Trials have shown that HbA_{1c} can be a useful measure of blood glucose control and that reductions in levels have been associated with a reduced risk of microvascular endpoints.³ Measuring HbA_{1c} levels is, therefore, likely to provide more helpful information about glycaemic control than day-to-day monitoring of blood glucose.

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