Self-monitoring of blood glucose and type 2 diabetes mellitus

C Le Dévéhat

SUMMARY
Self-monitoring of blood glucose (SMBG) in management of type 2 diabetes mellitus continues to be debated. However, SMBG is recognized as being useful (professional agreement) in three situations: sensitizing the type 2 diabetic patient to the advantages of diet control and physical exercise, determining and adapting the dosage of oral antidiabetic medication at the beginning of treatment or during a dosage change, and monitoring plasma glucose during intercurrent disease or during a treatment that may lead to acute blood glucose imbalance. However, the frequency, the timing of blood glucose monitoring, and the target blood glucose values remain poorly defined. It is well known that the postprandial period covers approximately 50% of the day, and several recent studies have shown the respective role of fasting, pre- and postprandial glucose levels in overall diurnal hyperglycemia in the type 2 diabetic and their respective contribution to the mean HbA1c level depending on how well blood glucose levels are controlled. Based on these studies, it is now possible to propose a SMBG scheme, specific to a given patient and for a defined therapeutic objective, taking the three physiological periods into account: postprandial, postabsorptive, and fasting. However, the optimal use of SMBG requires patient education and training. Using a specific, adapted, and optimal SMBG is only advantageous if the results are usable, and used, by the patient and healthcare professionals to improve the quality of blood glucose control (as shown by the HbA1c level) and the safety of intensified oral antidiabetic treatments (minimal risk of hypoglycemia).

Key-words: Self-monitoring of blood glucose · Type 2 diabetes mellitus · Postprandial blood glucose · Glycated hemoglobin A1c.

The majority of type 2 diabetic patients present with an inadequate glucose control. Indeed, 64% and 69% have an HbA1c level equal to or greater than 7% and 6.5%, respectively [1, 2]. Since the results of the United Kingdom Prospective Diabetes Study (UKPDS), the importance of hyperglycemia and particularly postprandial hyperglycemia is patently clear.

Measuring capillary blood glucose or self-monitoring of blood glucose (SMBG) is one of the major technical advances over the last few decades in type 2 diabetes management. It should be recalled that strict blood glucose control reduces the risk of micro- and macrovascular complications: a 1% reduction in the HbA1c level is associated with a 37% reduction in the risk of microvascular complications and a 21% reduction in the risk of death [3-5].

Although today the importance of SMBG leaves no doubt in the management of the type 2 diabetes, its practice is still a subject of debate. The meta-analysis of Welschen et al. [6] confirms that there are still few, or not enough, high-quality studies to convince the most reticent of challengers. Although SMBG is recommended and recognized as useful for some [6, 7], for others [8] it remains an excessive economic cost, even a public health expense that is insufficiently warranted: it is true that SMBG induces a low reduction in the HbA1c level (– 0.39%), although it is statistically significant [8].

**Current recommendations**

Although for some experts, patients SMBG should not be systematically recommended for follow-up and treatment of type 2 diabetes since the advantages are not clearly established and its cost is excessive in relation to the benefit, SMBG is still recognized as useful, with a professional agreement, in three situations:

- sensitizing the type 2 diabetic patients to the advantages of diet control and physical exercise;
- determining and adapting dosage of oral antidiabetic drugs (OADs) at the beginning of treatment or during a dosage change;
- monitoring blood glucose levels during intercurrent disease or during a treatment that may lead to an acute blood glucose imbalance.

The recommendations of the American Diabetes Association (ADA) [9] remain too vague. Most certainly, SMBG is an integral part of the diabetic’s therapy. However, “the optimal frequency and timing of SMBG in type 2 diabetic patients is not known but should be sufficient to facilitate reaching glucose goals”. For the American College of Endocrinology (ACE) and the American Association of Clinical Endocrinologist (AACE), the recommendations from the 2005 consensus conference [10] are more precise and recognize the utility and the importance of SMBG, but without specifying target blood glucose values. To date, it is difficult to recommend a typical SMBG scheme, on the one hand because of a conceptual problem – measuring blood glucose is only helpful if the information provided is usable by the patient and the healthcare professionals concerned – and on the other hand for a technical problem: which blood glucose level(s) should be measured? How often? When? Which blood glucose value(s) should be targeted? Finally, is there a rationale behind SMBG in diabetes?

**SMBG rationale in type 2 diabetes**

Physiology of intestinal carbohydrate absorption and of glucose metabolism over daytime teaches us that any food intake or meal is followed by three periods [11]:

- a 4-h postprandial period;
- a 6-h postabsorptive period;
- an approximately 4-h fasting period.

Given the pace of life of a subject eating three meals a day (breakfast 8:00 am; lunch 12:00 am, and dinner 7:00 pm), the postprandial periods covers 50% of the day. Knowing how the blood glucose varies over the day in type 2 diabetic patients [11, 12], the importance of postprandial blood glucose is obvious and has been clearly shown by Monnier et al. [11-13], who, in several articles, have also clearly shown the respective role of fasting, preprandial, and postprandial blood glucose in accumulated overall diurnal hyperglycemia in the type 2 diabetic patient [11, 13]. These studies clearly demonstrate the contributing role of postprandial blood glucose in protein glycation in type 2 diabetic patients when the HbA1c level is equal to or less than 7.3% [13]. These investigations confirm once and for all the respective contributions of the different physiological periods of the day and corresponding glucose values in the quest for blood glucose normalization in type 2 diabetes.

With the knowledge that the day’s glycemic excursions generally obey a certain order, it is possible to propose a SMBG scheme specific to a single patient and to a particular therapeutic goal. This SMBG scheme should provide information on the minimal and maximal blood glucose values of the three physiological periods: the postprandial, postabsorptive, and fasting. The choice of the appropriate SMBG timing and the choice of target glucose values should help make a rational choice of the therapeutic strategy and management of a diabetic patient.

These proposals mean attempting to define and explain the best timing and values for SMBG monitoring over the day:

- fasting glucose testing, before breakfast?
- postprandial glucose testing, after which meal?
- postabsorptive glucose testing, when?

Choosing the timing and the values for each glucose determination should lead to recommending [11, 12]:

- the upper glucose thresholds: for a glucose level under this threshold, therapeutic success is probable, i.e., prediction of an HbA1c level under 7% with a high specificity of at least 90% and higher;
– the lower glucose thresholds, i.e., a glucose level for which the risk of hypoglycemia is highly improbable.

**Justification of fasting blood glucose testing: timing and value**

Glucose testing before breakfast is the most representative of fasting blood glucose because it is far from any meal; it reflects the maximum liver production of glucose and takes the dawn phenomenon into account most. At this time, the duration of fasting compared to the preceding meal is approximately 12 h. This glucose value is useful for providing advice on a therapeutic strategy in view of slowing down the hepatic production of glucose, poorly regulated in type 2 diabetes [14].

The lower blood glucose target of 1.10 g/l can predict an HbA1c level lower than 7% with a specificity of 90% and higher [12].

**Justification of postprandial blood glucose testing: timing and value**

According to Monnier et al. [11], the day’s glucose maximum concentration is found in the middle of the morning; this pre-lunch glucose hyperglycemia accumulates the effects of the carbohydrates from breakfast and the liver’s production of glucose, which remains high because of a prolonged dawn phenomenon. This midmorning glucose value is valuable for advising on a therapy aiming to limit and reduce the morning blood glycemic excursions. Avignon et al., [15], and more recently Monnier et al. [12], have clearly shown the advantage of glucose testing performed after the midday meal (2:00 pm) [Tables 1 and 2]. If the time when postprandial glucose is measured can be chosen (after breakfast and/or after lunch), the target value of this postprandial glucose level is variable depending on the time: a glucose level lower than 1.60 g/l can predict an HbA1c level lower than 7% with a specificity of 90% or greater [12]. The same can be said for a glucose level of 1.26 g/l measured 2 h after the beginning or 1.5 h after the end of lunch.

Like Monnier et al. [12], El-Kebbi et al. [16] identified a mean postprandial blood glucose value of 1.50 g/l as a cut-off value for deciding to modify therapy in order to avoid what he termed “clinical inertia”. This value – when higher than 1.50 g/l – predicts in 88% of cases an HbA1c level over 6.5% with a sensitivity of 74% and a specificity of 66%.

**Justification of postabsorptive glucose testing: timing and value**

The end of the afternoon (extended post-lunch time) is one of the moments of the day when blood glucose is at its lowest. The risk of hypoglycemia is more pronounced at the end of the afternoon in type 2 diabetic patients treated with insulin secretors (sulfonylureas and glinides). This blood glucose nadir (lower point) expresses the persistence of stimulatable endogenous insulin secretion. Of the type 2 diabetics with an HbA1c level lower than 7%, 17% may have blood glucose less than 0.80 g/l at the end of the afternoon [12]. In this same study, Monnier et al. demonstrated that a glucose testing at the end of the afternoon, i.e., glucose measured toward 5:00 or 6:00 pm, lower than 1.10 g/l can predict an HbA1c level lower than 7% with a specificity equal or higher than 90% [12].

If today fasting or pre-breakfast plasma glucose level remains a so-called reference blood glucose in type 2 diabetics, it remains a quality marker, but not a safety marker, particularly in evaluating the hypoglycemic risk, as it is true also for postprandial plasma glucose measured at mid-morning and after lunch, whereas plasma glucose measured at the end of the afternoon (or postabsorptive blood glucose) is both a very good marker of the quality of the glucose control and safety. Its value should be between 0.80 g/l for optimal safety (i.e., a minimal risk of hypoglycemia) and 1.10 g/l to ensure a good glucose control, i.e., an HbA1c level remaining under 7%.

**Conclusion**

SMBG has now been in practice for more than 25 years, but its use was long reserved or essentially indicated for insulin-treated diabetes. The effect of SMBG use is also ben-

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**Table I**

Study of the relationships between HbA1c levels and blood glucose concentrations at different timepoints of the diurnal glucose profile [Adapted from ref. 12 and ref. 15].

<table>
<thead>
<tr>
<th>Time</th>
<th>Partial coefficient β</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:00 am, pre-breakfast (fasting)</td>
<td>0.605</td>
<td>0.079</td>
</tr>
<tr>
<td>11:00 am, pre-lunch</td>
<td>0.238</td>
<td>0.332</td>
</tr>
<tr>
<td>2:00 pm (14:00 h), post-lunch</td>
<td>0.845</td>
<td>0.009</td>
</tr>
<tr>
<td>5:00 pm (17:00 h), extended post-lunch</td>
<td>0.731</td>
<td>0.032</td>
</tr>
</tbody>
</table>

**Table II**

Monitoring plasma glucose values among the four timepoints of the diurnal glucose profile: optimal glucose threshold (cut-off values) for predicting patients with HbA1c < 7% [Adapted from ref. 12].

<table>
<thead>
<tr>
<th>Time points</th>
<th>Optimal plasma glucose value (mmol/l) (g/l)</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>At 8:00 am</td>
<td>8.0 (1.44)</td>
<td>89.4</td>
<td>72.2</td>
</tr>
<tr>
<td>At 11:00 am</td>
<td>11.0 (1.98)</td>
<td>94.0</td>
<td>78.0</td>
</tr>
<tr>
<td>At 2:00 pm (14:00 h)</td>
<td>9.0 (1.62)</td>
<td>92.8</td>
<td>78.3</td>
</tr>
<tr>
<td>At 5:00 pm (17:00 h)</td>
<td>7.0 (1.26)</td>
<td>90.9</td>
<td>81.1</td>
</tr>
</tbody>
</table>
eficial on the HbA1c level in type 2 diabetics still treated with OADs. SMBG requires patient’s education and training to be used. SMBG is only useful if the results are usable by the patient and healthcare professionals in improving the quality of overall glucose control (HbA1c level) and the safety of intensified OAD treatments (minimal risk of hypoglycemia).

The frequency of SMBG as well as the timing of the capillary glucose measurements should be determined for each patient according to the desired therapeutic goal, knowing that early and late (postabsorptive) postprandial blood glucose levels represent 50% of the diurnal plasma glucose. Today, it seems that fasting, mid-morning, post-lunch, and extended post-lunch glucose testing, are the most informative blood glucose measurements for choosing an effective therapeutic strategy to prevent the clinical/therapeutic inertia described above and frequently observed in daily practice, keeping in mind that fasting blood glucose is less specific and less precise in predicting an HbA1c level lower than 7% than the blood glucose levels after breakfast, after lunch and at the end of the afternoon.

References