The Importance of Monitoring Blood Glucose

a report by
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DOI: 10.17925/USE.2007.00.2.42

It is estimated that diabetes, both type 1 and type 2, currently affects more than 195 million people worldwide. This figure is expected to rise to more than 330 million by 2030.[1,2] The rise in type 1 diabetes has been linked to changing environmental factors,[3] while the rise in type 2 diabetes is strongly associated with increasing rates of obesity.[4]

In people with normal glucose tolerance, blood glucose levels are automatically monitored and controlled by the body. After eating, the body releases enough insulin to keep the plasma glucose within a normal range that rarely rises above 7.8mmol/l (140mg/dl) and usually returns to pre-meal levels within two to three hours. In people with impaired glucose tolerance or diabetes, the body has little or no automatic control of blood glucose levels. After eating, they often experience extended periods of elevated blood glucose levels.

The chronic hyperglycemia of diabetes is associated with both micro- and macrovascular complications, which result in significant increases in morbidity and mortality. Improving glycemic control in diabetic patients has been shown to reduce these complications. Indeed, two large landmark randomized clinical trials, the Diabetes Control and Complications Trial (DCCT)[5] and the UK Prospective Diabetes Study (UKPDS),[6,7] confirmed the benefits of tight glycemic control in all patients with diabetes in terms of reducing the risk of macro-vascular complications.[8]

Measuring Glycemic Control

The level of glycated hemoglobin (HbA_{1c}) is the preferred standard for assessing glycemic control. HbA_{1c} values reflect the average blood glucose for the preceding three to four months. The upper normal limit for HbA_{1c} is approximately 6%. The American Diabetes Association (ADA) recommends an HbA_{1c} target of less than 7% in general, but suggests targeting an HbA_{1c} as close to normal as possible without causing significant hypoglycemia in individual patients.[9] Other guidelines are generally consistent with this recommendation, although the recommended HbA_{1c} targets differ slightly.[10–12]

However, there are limitations to monitoring glycemic control using only HbA_{1c}. As an integrated measure of fasting, pre-prandial, and post-prandial glucose levels, HbA_{1c} does not fully represent the risks that diabetic patients face on a daily basis, as it does not readily reflect the degree of glycemic variability that a patient may experience during a given day.[13–15]

Optimal diabetes management involves control of fasting, pre-prandial, and post-prandial glucose levels. HbA_{1c} alone cannot be used to identify whether a particular patient's abnormal glycemic patterns are due to high fasting plasma glucose levels or high post-prandial plasma glucose levels. In fact, the relative contributions of fasting plasma glucose and post-prandial plasma glucose to HbA_{1c} vary according to HbA_{1c} levels, with post-prandial plasma glucose measurements becoming increasingly important as HbA_{1c} decreases toward target levels.[16]

Self-monitoring of Blood Glucose

Self-monitoring of blood glucose (SMBG) can help both patients and their healthcare professionals better adjust to therapy and assess the responses to therapy. Benefits of SMBG include the fact that patients can immediately assess the impact of an action on blood glucose levels and consequently undertake prompt interventions designed to counter the high or low blood glucose concentration. In addition, when adjusting oral agent or insulin doses, it is important to know the pattern of blood glucose values, i.e. when during the day the levels are high, in the targeted range, or low, since the design of the treatment regimen may differentially affect glucose concentrations at various times after drug ingestion or injection. SMBG can help healthcare professionals implement a treat-to-target approach, and it can help patients better adhere to treatment by showing them the responses they are having to their treatment.

The ADA recommends SMBG for all type 1 and type 2 diabetic patients being treated with insulin.[9] SMBG should be part of a total treatment regimen that includes diet, exercise, weight loss, and insulin or oral medications when indicated. The optimal frequency and timing of SMBG depends on many variables, including diabetes type, level of glycemic control, management strategy, and individual patient factors. Healthcare professionals will also need to modify SMBG regimens to accommodate changes in therapy and lifestyle. The ADA recommends that all diabetes

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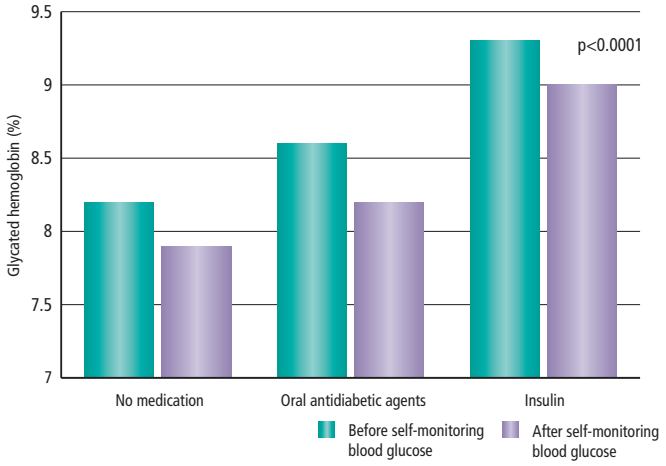
Figure 1: Relationship between Self-monitoring of Blood Glucose and Glycemic Control in Type 2 Diabetes Patients



Source: adapted from Karter et al.[18]

management programs should encourage at least daily monitoring. More specifically, it recommends that patients requiring multiple insulin injections should perform SMBG three or more times a day.[9]

SMBG can be particularly useful in certain circumstances, such as identifying hypoglycemic episodes. Often, fear of hypoglycemia can lead to a less intensive glucose management approach, resulting in suboptimal glycemic control. SMBG provides a means of identifying daily hypoglycemic events, allowing immediate treatment and/or modification of therapeutic regimens to allow tighter glycemic control.

Currently, there is a great deal of debate about the need for and frequency of SMBG for patients with non-insulin-treated diabetes. The debate is focused on the balance between the high and rising cost of blood glucose monitoring and the importance of the involvement and empowerment of people with diabetes in their own care. Currently, the ADA recommendations for SMBG in type 2 diabetes patients not being treated with insulin remain ambiguous: "The optimal frequency and timing of SMBG for patients with type 2 diabetes on oral agent therapy is not known but should be sufficient to facilitate reaching glucose goals."[9]

Self-monitoring of Blood Glucose and Glycemic Control

Although large clinical trials have yet to be conducted to assess the impact of SMBG on diabetes outcomes, recommendations for the use of SMBG in patients with type 1 diabetes are clearly defined.[9,10] Moreover, several studies have shown that treatment strategies involving SMBG are associated with improved glycemic control in both type 1 and type 2 diabetes.

In a longitudinal study from the Kaiser group, researchers studied more than 24,000 adult patients with diabetes in a large group-model managed-care organization.[17] They demonstrated that there is a relationship between SMBG and HbA_{1c} in type 1 diabetes patients (if they conducted glucose monitoring three or more times per day) and pharmacologically treated type 2 diabetes patients, irrespective of what pharmacological treatment they were on. SMBG performed at least once a day was associated with a lower HbA_{1c} than less frequent monitoring: type 1 patients who performed SMBG three or more times per day had a 1% lower HbA_{1c} than those who monitored less frequently or did not monitor. Type 2 patients who monitored once a day or more had a 0.6% lower HbA_{1c} than those who monitored less frequently. In this study, non-pharmacologically treated type 2 patients who conducted SMBG at any frequency had a 0.4% lower HbA_{1c} level than those not conducting it at all.

A more recent longitudinal study from the Kaiser group found that in patients who had previously not used SMBG, initiation of once-daily SMBG reduced HbA_{1c} levels significantly, regardless of treatment type (see *Figure 1*).[18] The study analyzed glycemic control among 16,091 patients initiating SMBG and 15,347 ongoing users of SMBG. Greater SMBG practice frequency among new users was associated with a graded decrease in HbA_{1c} (relative to non-users) regardless of diabetes therapy ($p<0.0001$). In the ongoing users group, changes inSMBG frequency among prevalent users were associated with an inverse graded change in HbA_{1c} only among pharmacologically treated patients ($p<0.0001$).

In type 2 diabetes, it has been shown that meal-related SMBG within a structured counseling program improves HbA_{1C} levels.[19] More recently, a large epidemiological study that followed more than 3,000 patients over six years showed that SMBG was associated with decreased diabetes-related morbidity and all-cause morbidity in type 2 diabetes. This association was even seen in the subgroup of patients not taking insulin.[20] A recent meta-analysis reported that SMBG was associated an overall 0.4% reduction in HbA_{1c} levels ($p<0.0001$) in non-insulin-treated patients with type 2 diabetes.[21]

In many ways, the patient is the most important individual in the diabetes care team. They should be trained to prevent and treat hypoglycemia and to adjust their medication with the guidance of healthcare providers to achieve glycemic goals. The measures of glycemia that are initially targeted are the fasting and pre-prandial glucose levels. SMBG is a vital component in adjusting or adding new interventions and, in particular, in titrating insulin doses. To fully utilize the benefits of SMBG, patients must obtain readings at appropriate times during the day, recognize readings that are outside their target range, and take the appropriate action to improve glycemic control. The best way to achieve this is by having patients assemble a glucose profile by taking a series of measurements at different times on different days that encompass information from the fasting, post-prandial, and late post-prandial timeframes. These data are most useful if seven or eight measurements are captured within a given 24-hour period. This should enable the accurate generation of daily glycemic excursions, which will need to be addressed to obtain the best glycemic control possible. Patients should be especially encouraged to collect data following meals, since meal-based SMBG testing has been shown to facilitate improved HbA_{1c} levels.[19,22]

The levels of plasma glucose that should result in HbA_{1c} in the target range are between 70 and 130mg/dl for fasting and pre-prandial levels. If these targets are met but HbA_{1c} remains above the desired target, glucose levels measured 1.5–2 hours after a meal should be checked. They should be below 180mg/dl to achieve HbA_{1c} levels in the target range.

However, there are limitations to SMBG. These mainly relate to the inconvenience of having to take (multiple) measurements, discomfort of

a finger-stick, cost of supplies, and the requirement for training and education of patients and healthcare professionals about appropriate analysis and use of data.

New Guidelines for Management of Post-prandial Glucose

Until recently, an key recommendation for good diabetes management was to lower fasting or pre-meal blood glucose levels; however, recent studies suggest a link between post-meal glucose control and improved vascular outcomes in people with diabetes. In addition, epidemiological studies have shown a strong association between post-meal hyperglycemia, carotid intima-media thickness, and endothelial dysfunction, all of which are linked to cardiovascular disease.[23] Post-meal hyperglycemia is also linked to retinopathy[24] and cognitive dysfunction in the elderly.[25]

Opinions on post-prandial management targets vary among medical organizations and members of the medical community. Generally, the aim should be to reduce post-prandial glucose levels to as low as possible without risking hypoglycemia. The International Diabetes Federation (IDF) guidelines recommend that people with diabetes try to keep post-meal blood glucose levels to less than 7.8mmol/l (140mg/dl) two hours following a meal. The two-hour time-frame for measuring glucose conforms to guidelines published by most of the leading diabetes organizations and medical associations, although it should be understood that this is not necessarily the time-frame that defines the peak post-meal glucose excursions.

The IDF advises SMBG because it is the most practical method for measuring post-meal glucose and it allows people with diabetes to obtain 'realtime' information about their glucose levels. However, in patients with poor glycemic control, fasting plasma glucose is likely to more strongly affect overall glycemia.[16]

Conclusion

All healthcare professionals who help with the management of people with diabetes must have good working knowledge of SMBG tools and procedures. It is their responsibility to teach a number of skills to the patients so that the patient is equipped to undertake SMBG accurately. The skills that need to be taught include: selecting a glucose-monitoring system best suited to the individual's situation; instruction on correctly performing SMBG and recording glucose values; discussion and selection of mutually agreed target glycemic goals; making appropriate adjustments in diabetes care by using these results; and periodic reassessment of user technique and data use.[26]

> Self-monitoring of blood glucose (SMBG) regimens must reflect individual needs and healthcare professionals should modify SMBG regimens to accommodate therapeutic and lifestyle changes.

The optimal impact of SMBG is achieved only when the data obtained through monitoring are consistently applied in an individualized program of monitoring, assessment, reassessment, problem-solving, and decision-making. SMBG regimens must reflect individual needs and healthcare professionals should modify SMBG regimens to accommodate therapeutic and lifestyle changes. In addition, the healthcare professional will need to periodically review the monitoring program and data with the patient. ■

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