Self-monitoring of blood glucose (SMBG) is considered an essential component of diabetes self-management. However, research has yielded mixed results regarding the value of SMBG for people with type 2 diabetes who are not treated with insulin. Some studies have shown no benefit, whereas others have demonstrated improved A1C and behavior change linked to SMBG in a diabetes self-management education program that teaches how to use SMBG data. When used appropriately in these patients, SMBG can help to identify factors associated with hyper- and hypoglycemia, facilitate learning, and empower patients to make changes to improve their glycemic control. SMBG can also be useful to health care providers, who can teach patients to monitor glucose at specific times to assess the effectiveness of medications and guide medication management. All people with type 2 diabetes should be given the opportunity to learn about the value of and skills required to monitor blood glucose as appropriate to their specific needs.

Using Self-Monitoring of Blood Glucose in Noninsulin-Treated Type 2 Diabetes

Self-monitoring of blood glucose (SMBG) is frequently identified as an essential component of diabetes self-management and enables people with diabetes to make the day-to-day decisions necessary to achieve and maintain glycemic control. There is little argument regarding the value of SMBG for people with type 1 diabetes or insulin-requiring type 2 diabetes. However, controversy exists regarding the value of SMBG for people with diabetes who are not treated with insulin.

Studies that have shown no or minimal benefit have not consistently looked at whether study participants worked with a health care team, received diabetes self-management education and training (DSME/T), or achieved health behavior changes, nor have they examined whether treatment changes were made as a result of SMBG. However, several studies have shown a positive association between SMBG and behavior change, and others, including meta-analyses and reviews, have noted modest benefits in A1C. Most recently, Polonsky et al., using a structured blood glucose testing schedule, were able to show A1C improvements in people with diabetes who were followed in a diabetes education program. In addition, they found an association between clinicians who knew how to interpret and respond to SMBG data by making treatment changes and improved A1C. The American Diabetes Association (ADA) Standards of Care in Diabetes—2013 recognizes the importance of SMBG in both insulin-treated and noninsulin-treated people with diabetes when prescribed within a broader educational context. ADA indicates that SMBG can be useful in guiding treatment decisions but recommends an ongoing and regular evaluation of patients' knowledge and skills to effectively use SMBG data to adjust therapy.

This article is not intended to review all of the pros and cons of SMBG in noninsulin-treated type 2 diabetes. Instead, its purpose is to review the role and importance of SMBG in DSME/T, behavior change, and treatment and to propose guidance to health care professionals in designing an SMBG schedule and using the information it yields to educate patients and make treatment decisions.

Importance of SMBG in DSME/T

A recent review of guidelines for SMBG in people with type 2 diabetes concluded that, because SMBG interventions cannot be isolated from self-management education, it is unclear whether SMBG itself is effective. The review questioned the...
validity of numerous guidelines proposing SMBG for patients with type 2 diabetes because these recommendations were not evidence based.

However, SMBG cannot and should not be isolated from DSME/T. Without DSME/T, SMBG would have little if any benefit. Another researcher has cited the self-regulation model, or common-sense model, of illness as appropriate for using SMBG in patients with diabetes who do not take insulin. This would seem to make sense in that it puts the responsibility for changing behavior and controlling diabetes in the hands of patients, who can then decide whether diet, exercise, or other interventions are necessary to decrease their glucose values and improve their glycemic control. Successful treatment of all self-care behaviors in combination with SMBG requires that practitioners address both individuals’ physiological and behavioral control systems that work to regulate blood glucose levels.7

The literature to date has been inconsistent. However, the International Diabetes Federation noted in its 2008 guidelines on SMBG for noninsulin-treated patients with type 2 diabetes that “Data available from randomized controlled trials suggest that SMBG is likely to be an effective self-management tool only when results are reviewed and acted upon by healthcare providers and/or people with diabetes to actively modify behavior and/or adjust treatment. SMBG should be used only when individuals with diabetes (and/or their caregivers) and their health care practitioners have the knowledge, skills, and willingness to incorporate SMBG monitoring and therapy adjustment into their diabetes care plan in order to achieve agreed upon treatment goals.”

Reflections from Clinical Practice

Sometimes, patients who are referred to diabetes educators or diabetes practitioners have stopped performing glucose tests because, “They are all high . . . I get depressed looking at the results . . . And what am I supposed to do with the results?” Many do not know what their target ranges should be. In addition, with the advent of memory meters that can be downloaded, many patients arrive at their appointments and have their meter downloaded but may never have actually looked at the results.

Patients often do not understand how to interpret SMBG results or how their eating habits, physical activity, other behaviors, and medications influence their blood glucose levels. When asked why a glucose reading is 250 mg/dl, a patient may respond with, “I don’t remember” or “I don’t know.”

So, what is the purpose of SMBG in the context of noninsulin-treated type 2 diabetes if patients and/or their health care providers (HCPs) do not know what to do with the data it provides? Out of frustration, some HCPs simply increase patients’ medication when their A1C is elevated without trying to determine the reasons behind the high A1C level.

Certainly, asking people to check their glucose levels at home and not looking at their records during office visits sends a message that this task is not important, rendering the glucose records useless. In addition, the costs of SMBG can be prohibitive for some patients. Yet, devising a structured monitoring program for checking glucose levels at specific times of day can yield important information for both patients and HCPs. SMBG schedules can also be tailored based on the types of medications a person may be taking. Thus, SMBG can be an effective tool in patient-centered care, providing HCPs with vital information to help educate patients and manage their disease.7

Patient Assessment and SMBG

Patient assessment is required to develop and implement an effective program for SMBG and DSME/T. Before implementing any medical or behavioral intervention, it is necessary to obtain a comprehensive history on each patient. This is not the same type of comprehensive assessment that is performed in the setting of a medical office visit. Rather it includes details about an individual’s lifestyle.

Finding out such things as the time an individual awakens, sleeps, eats, takes medications, and checks glucose is important in designing a treatment program. In addition, information about what people do during the day, what types of activities they enjoy, what their work setting is like, their exercise habits and alcohol intake, and other aspects of their daily life should be considered in devising a treatment plan that includes SMBG. Determining how patients with diabetes think about their diabetes and even whether they are willing to check their glucose may change an HCP’s approach to their diabetes management.

Because SMBG requires an understanding of numbers for interpretation of results, assessing patients’ numeracy and health literacy is crucial. This includes patients’ basic reading skills, ability to understand and act on health care information, ability to perform calculations and other numerical tasks, and quantitative skills that may be needed to successfully self-manage diabetes.18,19 Performing patient-centered assessments helps to involve people with diabetes in meaningful discussions about interpreting SMBG results to develop individualized goals and prescribe medications.

Using SMBG to Enhance Patient Education and Change Behavior

The outcome of DSME/T is measurable behavior change. People with diabetes must incorporate knowledge of and skills relating to SMBG to effectively change behavior that is under their control.20 The American Association of Diabetes Educators’ AADE7 Self-Care Behaviors system21 includes monitoring as one of the essential behaviors in self-management and has identified daily SMBG as an effective tool that provides immediate feedback about the effects of food, physical activity, stress, and medications. Some consider SMBG to be an integral part of a multicomponent system for effective self-regulation of blood glucose.7

Although not all randomized, controlled trials of SMBG have shown improvement in A1C, some11,12 have found that patients who changed their self-management behaviors in response to SMBG improved their A1C.

Therefore, an SMBG education program should go beyond the basic how-to skills of performing SMBG to include knowledge and applications regarding appropriate self-care behaviors (the AADE7)21 and the encouragement needed for patients to become self-managers of their diabetes. As described by McAndrew et al.,7 the components of an SMBG education program should include 1) instruction on how to use a glucose meter; 2) interpretation of SMBG results and identification of target ranges; 3) determination, through problem-solving, of the connection between a blood glucose value and patients’ prior behaviors; 4) deter-
mination of an action plan based on SMBG results to bring glucose values into the target range; 5) explanation that a particular feeling or symptom may not always indicate that blood glucose is high or low; 6) creation of a regimen that facilitates the integration of SMBG (and other behaviors) into patients' lifestyle; and 7) nonjudgmental evaluation of SMBG results.

Nonjudgmental evaluation is particularly important. HCPs sometimes unwittingly promote the concept of "good" or "bad" blood glucose levels, which may affect how patients think about themselves (e.g., "I am a bad person because my glucose levels are high.") The value judgments that people place on themselves as a result of unacceptable glucose values can trigger emotional issues.22 Similarly, the word "test" (as in, "blood glucose test") can cause anxiety for some people. SMBG results can reduce these negative feelings by referring to glucose values using terms such as "in range" or "out of range" instead of "good" or "bad" and by referring to SMBG as "glucose checks" or "glucose measurements" instead of "glucose tests."

Having patients keep a diary for a week is helpful when teaching the associations between SMBG results and behaviors. Instructing patients to check their blood glucose in the morning a few times a week may not provide enough information for meaningful education.

One approach HCPs may consider would be to suggest to patients who are just beginning SMBG that they treat the process like a scientific experiment, the goal of which is to discover how their body responds to a variety of factors (e.g., eating more or less food, being psychologically stressed, or getting more or less exercise). Treating SMBG as a data-gathering process can help to remove potential negative judgment; if your goal is to find out how your body responds, then all results are "good" because they expand your knowledge.

Some studies have examined the effects of a variety of structured glucose monitoring schedules on behavior. In one study,12 participants were asked to follow a regimen that involved performing SMBG six times per day (before and 1 or 2 hours after meals) on 2 or 3 days per week that included 1 or 2 weekdays and a weekend day. Participants kept diaries of SMBG results, foods they ate, and feelings of well-being. Participants were taught to use the data they collected, and medical staff used a counseling algorithm to help the participants learn problem solving. The algorithm was a series of six questions focusing on self-perception, self-reflection, and self-regulation.

The results of this study showed that participants who received this training were able to make behavioral changes based on interpretation of their SMBG data to improve metabolic control and lower A1C levels 1.0 ± 1.08% in the intervention group (compared to 0.54 ± 1.41% in the control group, P = 0.0086). Thus, carefully designing an SMBG schedule and teaching people what the results mean and what they can do in response to improve their diabetes control can result in behavioral changes and improvements in metabolic control.

Incorporating adult learning principles and styles of learning
Because many individuals with non-insulin-requiring type 2 diabetes are adults, using the principles of adult learning in patient education programs may facilitate self-motivation and self-management of diabetes. Most adult learners are problem-centered and appreciate being shown how a new skill or knowledge can be applied to their own situation. Most are also results-oriented, self-directed, and somewhat skeptical; thus, they need to try something out before accepting it.24 SMBG education seems to fit well into this framework by showing people with diabetes why and how they need to perform SMBG, explaining what the numbers mean, and then allowing them, with guidance, to experiment with behaviors that affect their glucose levels.

Styles of learning should also be incorporated into SMBG education programs. Graphic displays and pictures appeal to those who prefer visual learning, listening to information appeals to auditory learners, and assignments to record events surrounding blood glucose results can appeal to kinesthetic learners.25 Employing a variety of strategies may help to ensure that the information reaches all participants.

Creating teachable moments
Some people with diabetes believe SMBG is unnecessary because they believe they “can tell” when their glucose is high or low. However, research has shown just the opposite: that patients generally underestimate their blood glucose levels compared to their actual test results. Many individuals become enlightened when they see SMBG results much higher or lower than they felt their blood glucose level was.

Another “teachable moment” can be brought about by randomly checking patients’ capillary blood glucose (CBG) level during an office visit. Frequently, a patient whose CBG result is, for example, 230 mg/dl, will say, “I don't understand! My sugar was 118 mg/dl this morning when I woke up!” Patients will swear that their glucose is never that high when they check it at home, without considering the variations in glucose levels that can occur at different times throughout the day.

Another scenario that sometimes occurs when CBG results are high in the office is for patients to explain that they just finished eating “a few minutes ago,” as if that explains the hyperglycemia. This offers an opportunity to educate people with diabetes about target glucose levels, normal glucose values, and the effects of different foods, and perhaps stress, on glucose levels. Comparing normal glucose fluctuations to their own glucose fluctuations can help people with diabetes visualize when their levels are out of range.

Using SMBG to Guide Pharmacological Therapy
A well-designed SMBG schedule can aid HCPs in selecting and evaluating the effectiveness of diabetes medications.

Pathophysiology review
It is helpful to briefly review the basic pathophysiology of type 2 diabetes because pharmacological agents target different abnormalities related to diabetes.26 Type 2 diabetes is frequently attributed to impaired insulin secretion and insulin resistance in the skeletal muscle tissue, adipose tissue, and liver. Impaired insulin secretion is caused by dysfunction of pancreatic β-cells. Insulin resistance is decreased glucose uptake and clearance in the skeletal muscles and liver and results in increased hepatic glucose production and inability to suppress glucagon.

In the gut, the hormones glucagon-like peptide-1 and glucose
Inhibitory polypeptide also affects glucose homeostasis. They augment glucose-stimulated insulin secretion by β-cells, facilitate uptake of glucose by muscle tissue and the liver, suppress glucagon secretion by pancreatic α-cells, and slow the rate of gastric emptying. People with type 2 diabetes often have a deficiency of or resistance to these hormones, just as they have a deficiency of or resistance to insulin.

**Timing SMBG for medication adjustment**

Table 1 provides a list of frequently used medications for type 2 diabetes, their specific mechanisms of action, and recommendations for SMBG scheduling to aid in evaluating their effectiveness in specific patients. To effectively and safely initiate and alter medication regimens, HCPs must know whether their patients are experiencing hyperglycemia primarily in the fasting state or postprandially or both. Adequate SMBG data are also necessary to determine whether selected medications have successfully ameliorated the hyperglycemia they were intended to resolve.

<table>
<thead>
<tr>
<th>Medication</th>
<th>Mechanisms of Action</th>
<th>Effects on Glucose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biguanides (metformin)</td>
<td>Suppress hepatic glucose production; minor effect of increasing glucose uptake at skeletal tissues</td>
<td>Lower fasting glucose; may have mild effect on postprandial glucose level</td>
</tr>
<tr>
<td>Insulin secretagogues:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Sulfonylureas (glimepiride, glipizide)</td>
<td>Enhance insulin secretion by stimulating β-cells to secreting insulin throughout the day</td>
<td>Lower both fasting and postprandial glucose</td>
</tr>
<tr>
<td>• Meglitinides (nateglinide, repaglinide)</td>
<td>Short-acting insulin secretagogues that stimulate insulin secretion from β-cells; taken before a meal</td>
<td>Lower postprandial glucose</td>
</tr>
<tr>
<td>α-Glucosidase inhibitors</td>
<td>Inhibit the enzyme that breaks down carbohydrate in the gut</td>
<td>Lower postprandial glucose</td>
</tr>
<tr>
<td>Thiazolidinediones (pioglitazone)</td>
<td>Increase insulin sensitivity in skeletal, adipose, and liver tissues</td>
<td>Lower fasting and postprandial glucose</td>
</tr>
<tr>
<td>Incretin mimetics:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• GLP-1 receptor agonists (exenatide, liraglutide)</td>
<td>Stimulate insulin release from β-cells in a glucose-dependent manner, suppress glucose-mediated glucagon secretion, help to decrease hepatic glucose production, slow gastric emptying, and increase satiety</td>
<td>Lower postprandial glucose but may also affect premeal glucose</td>
</tr>
<tr>
<td>• Amylin analogs (pramlintide)</td>
<td>Similar to GLP-1 receptor agonists except for nonappearance of insulin secretion</td>
<td>Lower postprandial glucose</td>
</tr>
<tr>
<td>• Dipeptidyl peptidase-4 inhibitors (sitagliptin, vildagliptin, linagliptin)</td>
<td>Because DPP-4 breaks down GLP-1, inhibiting it makes GLP-1 more available and reduces postprandial glucose levels by stimulating insulin release and decreasing glucagon levels to reduce hepatic glucose release after meals</td>
<td>Lower postprandial glucose</td>
</tr>
</tbody>
</table>

Table 1. Diabetes Medications and Recommendations for SMBG Schedules
Summary
All people with type 2 diabetes should be given the opportunity to learn about the value of and skills required to perform SMBG as it applies to their specific needs. Mastering the skills needed to perform and interpret SMBG empowers individuals with diabetes to learn more about their diabetes and to make behavioral changes to improve their overall diabetes control. SMBG also benefits HCPs by providing the blood glucose data necessary to confidently initiate and evaluate medication therapy for patients with diabetes.

SMBG is an important tool and skill set within DSME/T. As with all diabetes self-care activities, the process should begin with an individualized assessment leading to the development of a specific SMBG plan developed and negotiated with patients. Following an appropriately tailored SMBG regimen and sharing their results with their HCPs can greatly help people with diabetes optimize their diabetes treatment to achieve and maintain glycemic control.

References

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