A Practical Look at Self-Monitoring of Blood Glucose

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ABSTRACT

Background: Being able to check their own blood glucose levels can enable individuals with diabetes mellitus (DM) to better understand and manage their illness. Intensive glycemic control has been shown to reduce the long-term microvascular complications of DM.

Objective: The goal of this article was to provide an overview of self-monitoring of blood glucose (SMBG) and its role in the management of DM.

Methods: Relevant articles were identified through a literature search of MEDLINE from 2000 to 2006 (English-language articles only). Search terms included *blood glucose*, *self-monitoring*, and *glucose monitoring*. Materials also came from the author's own collection of journals and articles. Case studies are provided to illustrate some issues that arise in DM management.

Results: For patients receiving multiple insulin injections, SMBG should be done ≥3 times per day. SMBG has been shown to be a useful tool in helping patients achieve their glycemic targets. Blood glucose may improve when a patient is on insulin, and SMBG guides the provider and patient in making changes to insulin therapy and dosing. Unfortunately, more thorough examination of SMBG in non–insulin-treated patients is needed to demonstrate its usefulness in this population. Cost can sometimes be a barrier to SMBG use, as insurance companies and Medicare may have specific restrictions on how often certain supplies can be purchased. In addition, glucose monitoring requires a particular level of literacy, dexterity, and judgment to conduct a proper test and interpret the results. Although the accuracy of the meters can vary, the following factors can help ascertain an exact reading: proper storage of the meter and strips; thorough instruction of the patient in the correct techniques for obtaining a blood sample; and the use of alternative site testing. Various patient groups (eg, children, the elderly, the visually impaired) may require different meters. Individualization of treatment and education is necessary for any patient with DM, and SMBG can be used to help make treatment decisions, such as amount of insulin to take; to identify hypoglycemia or hyperglycemia; to determine the effect of food, medicine, stress, or activity on blood glucose; to manage blood glucose during illness; and to recognize patterns in blood glucose trends.

Conclusion: Although SMBG can be a valuable tool for individuals with DM, its true usefulness lies in what is done with the results. With education, people with DM can learn to make appropriate lifestyle choices and communicate more with their health care provider to achieve optimal glycemic control. (*Insulin*. 2006;1:141–147)

Key words: self-monitoring of blood glucose, diabetes mellitus, education, insulin.

INTRODUCTION

Despite all the medications, nutritional information, exercise recommendations, and diagnostic tests given to people with diabetes mellitus (DM), the majority of the responsibility for care rests with the individual who has the disease. Being able to check their own blood glucose levels can enable people with DM to better understand and manage their illness. It has been shown that intensive glycemic control can reduce the long-term microvascular complications of DM.[1] Recently, the long-term follow-up to the Diabetes Control and Complications Trial (DCCT) revealed that intensive therapy for type 1 DM could also reduce the risk of a cardiovascular event when compared with conventional therapy.[2] An important component of the intensive treatment of DM is self-monitoring of blood glucose (SMBG). Glycosylated hemoglobin (A1C) measurements can be useful for giving health care providers and patients an overall view of glycemic control and the risk of complications. However, specific treatment changes—such as fine-tuning insulin dosages or determining times of hypoglycemia—may be more difficult to assess without the help of SMBG.

The goal of this article was to provide an overview of SMBG and its role in the management of DM.

MATERIALS AND METHODS

Relevant articles were identified through a literature search of MEDLINE from 2000 to 2006 (English-language articles only). Search terms included *blood glucose, self-monitoring*,

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and *glucose monitoring*. Materials also came from the author's own collection of journals and articles. Case studies are presented to illustrate some of the issues that arise in DM management.

USE OF SELF-MONITORING OF BLOOD GLUCOSE

The American Diabetes Association regards SMBG as part of its standards of medical care. For patients receiving multiple insulin injections, SMBG should be done ≥3 times per day.[3] For those receiving other treatments, SMBG may be useful in achieving glucose goals.[3] In the DCCT, SMBG was an effective tool in helping patients achieve their glycemic targets.[1] Blood glucose may improve when a patient is on insulin, and SMBG guides the provider and patient in making changes to insulin therapy and dosing.

> Blood glucose may improve when a patient is on insulin, and self-monitoring of blood glucose levels guides the provider and patient in making changes to insulin therapy and dosing.

Barriers to Use

Unfortunately, more thorough examination of SMBG in non–insulin-treated patients is needed to demonstrate its usefulness in this population. One argument against the use of SMBG in patients not receiving insulin is cost.[4] The average cost for 1 test strip is US $0.75. If SMBG does not lead to a reduction in A1C, it simply adds to the overall cost of DM care without adding any benefit.[5] One explanation for the lack of effect of SMBG in some patients is that there is no feedback on results, which could have led to changes—and thus improvements—in treatment. What is important, therefore, is that the results need to be interpreted by the patient and/or health care provider and then acted upon.[6] SMBG has the potential to help patients gain a better understanding of the factors that affect their DM and may even help with adherence to medications, diet, activity, and insulin use.[7]

In addition to cost, there are other barriers to the use of SMBG. Glucose monitoring requires a certain level of literacy, dexterity, and judgment to conduct a proper test and interpret the results. Although errors are common, education is the key to success.[8] Referral to a certified diabetes educator (CDE) can greatly benefit the patient. If a CDE is not available, having a health care provider with a working knowledge of glucose meters and the support of a staff member, such as an informed medical assistant, can help the patient learn about the meters and technique. Written materials, videos, Web sites, and booklets can be used by the patient to enhance learning. Adherence to SMBG can be improved through something as simple as providing a manual in addition to these educational devices.[9]

A certain amount of skill is required to operate a glucose meter. The actual testing requires the pain of a needle puncture and dealing with blood. Patients must learn how to handle needles and blood in a safe manner. Patients may have "test anxiety" and worry about their ability to contend with the results.[10] Adequate follow-up and education can help the patient understand what to do with the results. Also, referring to the monitoring as a "check" rather than as a "test" can help eliminate the perceived potential for failure.

On the positive side, however, newer meters require smaller amounts of blood. Proper technique using an ultrafine lancet and lancing device can decrease discomfort. When appropriate, the option of using an alternative site other than the fingertip is available[11] (discussed below).

Meter Use and Accuracy

The accuracy of the results can be variable. Glucose meters often require proper coding to match the batch of strips to the meter. The meter and strips must be properly stored to avoid extremes of temperature and humidity, and the control solution should be used properly to check the accuracy of the meter. Although test strips have expiration dates, because supplies can be costly, patients may be tempted to use expired strips. Patients should be instructed in all aspects of the meter itself as well as the technique for obtaining a blood sample. This includes washing the area with warm soap and water as opposed to using rubbing alcohol on a regular basis (this can make the finger cold and tougher to puncture). In the office or hospital, the patient may have seen an alcohol wipe used on his or her finger and assumed that this is the preferred method for cleaning the fingertip. Patients will have an easier time obtaining the blood sample if the area is rubbed to warm the skin and promote blood flow.

> Patients should be instructed in all aspects of the glucose meter itself as well as the technique for obtaining a blood sample.

Most lancing devices can be adjusted, either by altering the depth of penetration or by using a different cap for alternative sites. Testing done on the sides of the fingertip work better than the very tip. Patients should demonstrate to the CDE or the health care provider their ability to use the meter and place a drop of blood on the strip to ensure they are getting an adequate-sized sample.

Alternative site testing is available with several meters. Patients need to be aware that different results may be obtained from the forearm versus the finger, so it is important not to use an alternative site when hypoglycemia is suspected or when doing a postmeal glucose check.[12]

SPECIAL NEEDS POPULATIONS

Various patient groups may require different types of meters. **Table I** provides some examples of these meters.

Children

Depending on the age and maturity of the child, the parent may be doing the glucose monitoring and interpreting

Table I. A sample of some common meters and their features for self-monitoring of blood glucose levels.

Manufacturer	Name of Meter	Result Range, mg/dL	Test Time	Alternative Site Testing?	Comments
Abbott Laboratories, Abbott Park, Illinois; www.abbottdiabetescare.com	FreeStyle® and FreeStyle Flash®	20–500	Usually 7 seconds	Yes	These meters have the ability to download data to a computer. The FreeStyle Flash is very small for easy portability. Each meter has a memory and gives an average of the blood glucose levels measured.
Bayer HealthCare, West Haven, Connecticut; www.ascensia.com	Ascensia® BREEZE®	10–600	30 seconds	Yes	No coding needed. Only meter to receive a commendation from the Arthritis Foundation for ease of use. Uses a disk to avoid individual strip handling.
	Ascensia® CONTOUR®	10–600	15 seconds	Yes	No coding. Can download data from this meter and the Ascensia BREEZE to a computer.
Becton, Dickinson and Company, Franklin Lakes, New Jersey; www.bddiabetes.com	BD Logic®	30–600	5 seconds	Yes	Memory function allows the user to record insulin information. Data can be downloaded to a computer.
Home Diagnostics, Inc., Fort Lauderdale, Florida; www.homediagnostics.com	Prestige IQ®	25–600	10–50 seconds	No	Has a confirmation spot on the strip to verify that a large enough sample has been obtained. Able to download data to the Internet.
LifeScan, Inc., Milpitas, California; www.lifescan.com	OneTouch® Ultra®, One Touch® Ultra®2, and UltraSmart®	20–600	5 seconds	Yes	UltraSmart contains an electronic log book. Data from each of these meters can be downloaded to a computer.
Roche Diagnostics, Basel, Switzerland; www.accu-chek.com	Accu-Chek® Compact	10–600	8 seconds	Yes	No individual strip handling. Able to download data to computer. Has a toll-free call center with multilingual representatives.
	Accu-Chek® Voicemate	10–600	26 seconds	No	For visually impaired users. Provides voice instructions and results.

the results. Both the parents and the child should be included in the education, however. Meters for children should be easy to use, small in size, require the least amount of blood possible, use ultra-fine lancets, have a short time before providing a result, require minimal cleaning of the meter, and be able to store multiple results in case the parent or child cannot write down the result in a log when it is obtained.[13]

Elderly

Age should not be a limiting factor for SMBG. The older adult (ie, those aged ≥65 years) is at the greatest risk for a hyperosmolar hyperglycemic state, which is often caused by infection.[14] Increases in blood glucose may signal the presence of such an underlying infection. Early detection through SMBG may lead to earlier treatment, before the progression to a more serious hyperglycemic state. There is also a heightened risk of hypoglycemia that can occur because of medication sensitivity, polypharmacy, or erratic dietary patterns. Older individuals and/or caregivers should be instructed to notify the health care provider when there are changes in blood glucose levels.

Meters for older adults should have ease of dexterity, clear numbers, and be simple to use and maintain. For example, a meter that is easy to grip, with a large display window, may be more useful than a very small meter with minimal display space. "Coding" the meter may be difficult, so some meters are available that do not require coding (ie, inserting a chip from the bottle of strips or programming a number on the screen of the meter). Bottles of strips with an easy-to-open flip cap or meters without individual strip handling may be helpful for patients with dexterity or arthritis issues.

If appropriate, a caregiver or family member ought to be included in the education about the meter. Cost is often a concern for older adults on fixed incomes. It should be confirmed that the meter prescribed is preferred by their insurance plan. The opportunity for questions, concerns, and ample time for return demonstration of monitoring technique should be given for older patients.

Visually Impaired

The severity of the patient's visual impairment will dictate what assistance is necessary, as different forms are available. For some people, using a quality magnifier to read the meter display may be enough help. Some companies now make meters that "talk" to the user. These can provide verbal instructions to the patient and can give verbal results.[15]

OBTAINING AND INTERPRETING RESULTS

Blood Glucose Goals

Although goals for blood glucose should be individualized based on the patient's needs, guidelines do exist. The American Diabetes Association sets the targets for glycemic control as follows: fasting plasma glucose, 90 to 130 mg/dL; and 2-hour postprandial glucose, <180 mg/dL.[3] The American College of Endocrinology sets the targets for glycemic control as follows: fasting plasma glucose, <110 mg/dL; and 2-hour postprandial glucose, <140 mg/dL.[16]

Most meters read the plasma glucose level, which is closer to laboratory results than whole blood levels. Patients can be encouraged to actively watch for any abnormal glucose levels. Often, patients may see the SMBG as a "test" and fear failing.[10] After a special treat, an increased intake of food (ie, at holidays), or lack of activity, patients may avoid checking their blood glucose because they want to avoid a "bad" result. Again, educating the patient that this is "checking" and "monitoring"—rather than a test—may be helpful.

SMBG can be used to help make treatment decisions, such as amount of insulin to take; to identify hypoglycemia or hyperglycemia; to determine the effect of food, medicine, stress, or activity on blood glucose; to manage blood glucose during illness; and to recognize patterns in blood glucose trends. Checking glucose at various times can provide a large amount of information (**Table II**).

Self-monitoring of blood glucose can be used to help make treatment decisions, such as amount of insulin to take; to identify hypoglycemia or hyperglycemia; to determine the effect of food, medicine, stress, or activity on blood glucose; to manage blood glucose during illness; and to recognize patterns in blood glucose trends.

Written Records of Results

Written records (log or diary) of the glucose-monitoring results are important because they can often show patterns. This makes sharing the information with the health care provider easier for the patient. Several meters have a memory feature that can hold large numbers of readings, but this may not be as helpful as a written log. The memory feature can be used if the patient cannot write the result down at the time of the reading but can go back to it later and record the result. Most meters have data management systems with computer software that can provide a printed diary, global comments, graphs, and averages. Because the record of blood glucose readings will be used by both the patient and the health care provider, it is important to have a method of recordkeeping that is useful to both parties.

Log books can be further analyzed by instructing the patient in the use of colored pencils or markers. The patient should circle all results higher than goal with one color and all those lower than goal with another. The patient and the health care provider can then look at the results and get a general view of patterns. For example, if the patient circles low blood glucose with yellow, and numerous yellow circled results appear before breakfast, then the basal insulin may need to be reduced or a bedtime snack may help. With a written log, the patient can include comments such as changes in food, activity, health status, or omitted dosages of medication or insulin.

Table II. Reasons for conducting self-monitoring of blood glucose at various times of the day.

Times to Check	Reasons to Check
Before breakfast (fasting)	Provides information about blood glucose throughout the night, effects of liver production of glucose, and effect of the bedtime snack; the dosage of basal insulin can also be managed by monitoring this level. In addition, the morning dosage of rapid- or short-acting insulin can be adjusted based on this result.
Two hours after breakfast or before lunch	This will show the effect the breakfast meal had on glucose, how effective the breakfast insulin was, and the effect of morning activity on glucose. Determination of the rapid-acting insulin dosage for the lunch meal can be made from the prelunch glucose reading.
Two hours after lunch or before dinner	This will show the effect the lunch meal had on glucose, the effectiveness of the lunch insulin, the effect of intermediate insulin given in the morning, and the effect of afternoon activity or snack. The predinner rapid-acting insulin dosage can be determined based on the predinner glucose result.
Two hours after dinner or bedtime	Provides information about the effectiveness of dinner insulin, effect of evening activity, the effect of the dinner meal on glucose, and the need for a bedtime snack.
Middle of the night	Can be helpful if nighttime hypoglycemia is suspected. Helps determine need for bedtime snack. This may be very important to check if there has been an increase in evening activity, especially in children (such as increased play or an evening sports activity).

Insurance companies and Medicare often allow just 1 glucose test to be covered per day. To make the most of this, patients should alternate the times they check their blood glucose levels (**Table III**). Occasionally, the patient should check both before the meal and 2 hours after that meal to determine the impact of the meal's carbohydrates. This can alert patients as to what effect their favorite meal may have on blood glucose and then help them modify their diet, such as skipping the bread when having pasta or taking a walk after meals heavy in carbohydrates.

If a patient brings in a log of fasting blood glucose results at goal but has an elevation of A1C, the meter and strips should be checked for proper coding, calibration, and expiration. Also, the patient should be asked to demonstrate using the meter. If there are no errors in usage, and the meter and strips are accurate, the patient should be instructed to change the times of monitoring to determine the elevations. Patients ought to check their blood glucose levels 2 hours after a meal, which may reveal the times of elevated glucose.

When a patient is taking multiple insulin injections, ideally, he or she can receive as many test strips as necessary to check before meals, after meals, at bedtime, and during the night. Additional strips may be needed to check for hypoglycemia or during periods of illness. Insurance coverage or cost constraints can sometimes limit what options the patient has for covered testing, and thus some individuals do not test as often as they should.[17] In these cases, a patient should make the most of the amount of times that blood glucose can be checked. Each day a different meal could be "framed out" in order to see the effect of that meal and whether the insulin is adequate. **Table IV** provides an example of this technique. If one particular meal shows a pattern of blood glucose readings that signal a need for medication adjustment, that meal can be checked for a number of days.

CASE STUDIES

Case Study #1

Mrs. W. is a 66-year-old woman who has had type 2 DM for 12 years who presents to the practice with multiple oral medications for her DM at maximum dosages. She is unaware of her previous A1C results but states her disease is "difficult to control." Mrs. W. denies any hypoglycemia symptoms but does report fatigue and nocturia. In the past, Mrs. W. did briefly check her blood glucose; she stopped, however, because "it didn't seem to make a difference" and she was unsure what she was supposed to do with the findings. Laboratory test results reveal her A1C level is 9.2%. Her physician prescribes a new meter, encourages her to begin checking her glucose again, and recommends she attend a local class on DM. Mrs. W. demonstrates the ability to use her meter, and she begins checking fasting blood glucose levels.

The log she keeps reveals fasting blood glucose readings ranging from 190 to 260 mg/dL. She is instructed on injection technique and begins insulin glargine QD in addition to her current medications. Because Mrs. W. is skilled at SMBG, she is instructed on how to titrate her insulin by increasing 2 units every 3 days until the fasting blood glucose is between 80 and 120 mg/dL each morning. The next time her laboratory work is done, her A1C is 8.0%. Mrs. W. is upset because her diary shows fasting blood glucose levels at goal. Mrs. W. is encouraged to check more frequently and especially to see if her blood glucose is going too high after her meals.

Since retirement, Mrs. W. and her husband have been eating a large mid-day meal out at restaurants. She finds this

Table III. Suggested times for daily blood glucose tests.

Sample test days	
Monday	Fasting, before breakfast
Tuesday	Before lunch
Wednesday	Before dinner
Thursday	Before bed
And then repeat	
Or, as an alternative	
One week of fasting blood glucose	
One week of premeal blood glucose	
One week of bedtime glucose	
And then repeat	

Table IV. Log page from a glucose diary. This is an example of "framing out" a different meal to see its effect on blood glucose levels and whether the insulin dosage is adequate. Different meals are focused on different days to provide a variety of information.

Day	1	2	3
Before breakfast	X	X	X
After breakfast*	X		
Before lunch		X	
After lunch*		X	
Before dinner			X
After dinner*			X
Bedtime	X		
Then repeat			

X = time of day the blood glucose level is checked.
*"After" meals is 2 hours following that particular meal.

meal is increasing her blood glucose greater than goal. Despite attempting to modify the meal, she was unable to get that glucose level to the goal target; she agrees to begin a dosage of rapid-acting insulin with the mid-day meal. She now checks her blood glucose before and after that meal and shares the information with her physician; her insulin can then be adjusted to an adequate dosage. Mrs. W. sees the value in checking blood glucose and is able to work toward better control of her DM.

Case Study #2

B.T. is a 70-year-old man with a 20-year history of type 2 DM. He has been on premixed insulin BID for the last few years. He checks his blood glucose level 2 to 3 times each day and keeps a log of the results. He states he feels fine, and the only problem he has had with the DM has been some retinopathy, which was treated. Despite a log of glucose levels at goal, his A1C level has been persistently elevated. B.T. was told to increase his insulin, but he has been afraid to increase the dosage because his meter tells him his blood glucose is normal.

A referral is made to a CDE. The CDE requests that B.T. bring his meter, which he has had for several years, to the next office visit. When B.T. demonstrates technique, the first thing the CDE notices is that the meter is not properly coded. The bottle of test strips says "17," but the meter says "19." Next, B.T. has difficulty getting a large enough blood sample for the strip. Improper coding and too little blood could both lead to incorrect readings.

B.T. is given a newer meter that is easy to handle, requires a very small blood sample, and does not need coding. With the new meter, B.T. obtains readings 50 to 100 points higher than he had seen previously. With more accurate readings, he is able to see the value of increasing his insulin dosage, which will ultimately help him reach his goal blood glucose level. Because there can be errors with SMBG, it is important to actually see the patient demonstrate use of his or her meter whenever possible.

Case Study #3

J.S. is a 22-year-old man who has had type 1 DM since he was 15 years old. He has always taken his DM care seriously, gives himself multiple injections, is able to use carbohydrate counting, and checks his blood glucose level several times each day. He has had A1C results consistently below 7.0%; the last one was 6.4%. He has been free from complications and has never been hospitalized because of DM. Recently, however, J.S. moved out of his family's home and into an apartment with friends. His lifestyle has changed and now includes erratic eating patterns, intermittent bursts of exercise, and drinking alcohol on the weekends.

Two times in the last month, his roommates have had to call for emergency help in the middle of the night when they found J.S. incoherent, sweating, and moving about in his sleep. Both times, the paramedics treated J.S. for severe hypoglycemia. He visits his physician, and it is determined that his A1C is now 5.6%; his glucose log reveals more low blood glucose readings in the morning and some missed bedtime readings on weekends. J.S. would attempt to cover increased carbohydrates, such as pizza on a Friday evening, with increased rapid-acting insulin but would then drink alcohol and skip checking his blood glucose before bed. He would also go to the gym with friends and not add in a snack or check his blood glucose later when the level could be falling.

From his experience, J.S. learned he needed to make sure he checked his glucose before bed, especially after exercise or if he had consumed alcohol. He also learned to be very careful with the effects of alcohol. J.S. added in an occasional blood glucose check in the middle of the night when he had exercised, so that he and his physician could review the results and thus make decisions about adjustment of insulin and carbohydrate intake. The A1C provides a general overview of the glycemic control, but in this case, it did not

show the specific problems J.S. was having with hypoglycemia, which SMBG could reveal.

CONCLUSIONS

SMBG can be a valuable tool for people with DM. Several glucose meters from a variety of manufacturers are available, thus giving patients numerous choices and the ability to find the meter that is right for their needs. Monitoring does require learning a new skill. Referral to a CDE can be of great value to patients and can provide them with another member of the health care team who will help them reach their DM goals.

The true usefulness of SMBG lies in what is done with the results, however. With education, people with DM can learn to make appropriate lifestyle choices and communicate more about their health status with their health care provider. SMBG adds information to the assessment of glycemic control to help the patient and health care provider make decisions regarding medication and insulin. SMBG can offer a detailed look at the day-to-day glycemic control and help guide patients to improved control.

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