REVIEW

SHANNON KNAPP, BSN, RN, CDE
Manager of Diabetes Education, Department of Endocrinology, Diabetes, and Metabolism, Cleveland Clinic

POOJA MANROA, MD
Division of Endocrinology, Diabetes, and Metabolism, University of Pittsburgh Medical Center, Pittsburgh, PA

KRUPA DOSHI, MD
Department of Endocrinology, Diabetes, and Metabolism, Cleveland Clinic

Self-monitoring of blood glucose: Advice for providers and patients

ABSTRACT

Self-monitoring of blood glucose is a critical element in diabetes management. Providers must determine if and when patients are to perform glucose self-monitoring, set blood glucose targets, and help patients to interpret the results. Patients have a variety of continually evolving meters, supplies, and technology from which to choose. Making sense of these expectations and options is perhaps the greatest challenge for providers and patients. Working together, healthcare providers and certified diabetes educators can ensure that people with diabetes get the most out of self-monitoring of blood glucose.

KEY POINTS

Glucose self-monitoring not only yields valuable information on which to base diabetes treatment, it also helps motivate patients and keep them engaged in and adherent to their care.

The cost of test strips varies widely and can be a burden for some patients.

Meters come with many different features, which patients may or may not need.

One of the most useful resources at the disposal of providers is the assistance of a certified diabetes educator.

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SELF-MONITORING OF BLOOD GLUCOSE is a critical part of diabetes management, with many benefits. It promotes personal responsibility and provides opportunities for better control. It allows for detection of blood glucose extremes, thus helping to reduce blood glucose fluctuations. It also helps both the patient and the provider make informed decisions and can help reduce microvascular and macrovascular complications.

Studies have shown that hemoglobin A_{1c} levels are lower if glucose is tested more frequently.[1] Most people with type 1 diabetes and many with type 2 diabetes self-monitor their blood glucose levels.

This article discusses who should monitor their blood glucose and how often, types of meters and supplies available, advances in technology, and limitations of current blood glucose meters.

WHETHER AND HOW OFTEN TO MONITOR

In clinical practice, advice about whether patients should monitor their blood glucose levels and how often to do it depends on the type of diabetes therapy, the need to titrate the dose or change the regimen, and the patient's preferences, dexterity, and visual acuity. The frequency of testing also often depends on financial considerations and insurance coverage.

In patients with type 1 diabetes and insulin-treated type 2 diabetes, the role of glucose self-monitoring is clear. The American Diabetes Association (ADA) recommends that patients receiving multiple insulin injections daily or on an insulin pump measure their blood glucose at least before meals and snacks, occasionally after meals, at bedtime, before ex-

ercise, when they suspect their blood glucose level is low, after treating low blood glucose until they are normoglycemic, and before critical tasks such as driving.[2]

The Diabetes Control and Complications Trial (DCCT)[3] and the DCCT/Epidemiology of Diabetes Interventions and Complications (DCCT/EDIC) study[4] showed that intensive insulin therapy effectively delays the onset and slows the progression of microvascular and macrovacscular disease. Self-monitoring of blood glucose is an integral part of intensive insulin therapy, allowing for dose adjustments based on immediate blood glucose readings, thereby reducing the risks of hyperglycemia and hypoglycemia.

For patients taking a single daily dose of basal insulin, fasting blood glucose values are often used to titrate the basal insulin dose.[3]

Patients with type 2 diabetes on oral hypoglycemic agents such as sulfonylureas and meglitinides are at risk of hypoglycemia. Although a review of the literature could find no studies to support recommendations for specific testing frequency for patients taking these medications, it stands to reason that the potential for hypoglycemia would indicate a clear need for regular self-monitoring. Checking the blood glucose once or twice daily, typically fasting, 2 hours after the largest meal or at bedtime, provides useful data points for the patient and the provider. As with patients on insulin, testing before driving also reduces the risk of a motor vehicle accident caused by hypoglycemia.

Most patients with type 1 diabetes and many with type 2 self-monitor

In any patient who is testing one or two times per day, staggering the testing time on different days can give valuable insight into glucose control at different times of day, including after meals and at night.

In patients on nonintensive regimens and at low risk of hypoglycemia, glucose self-monitoring may be less critical. Nonintensive regimens with a low risk of hypoglycemia include diet and exercise alone and diet and exercise with a medication that is not insulin or an insulin secretagogue. In these cases, self-monitoring is often not seen as clinically useful or cost-effective, and hemoglobin A_{1c} is used as a marker.

Admittedly, few randomized controlled trials have been done in which patients were treated according to identical protocols except for glucose self-monitoring, but outcomes from the published studies support the use of structured self-monitoring of blood glucose for improvement in clinical outcomes and quality of life when self-monitoring is incorporated into a comprehensive management plan.[5–9] By providing feedback, self-monitoring encourages patients to actively participate in controlling and treating their disease. It helps them to recognize the impact of blood glucose on their own self-management decisions in the areas of diet, exercise, stress management, and medications. Therefore, the ADA recommends that healthcare providers encourage their patients to perform self-monitoring even if on nonintensive regimens. For these patients, checking even two or three times per week can help them to learn about the factors that affect their blood glucose.[2]

BLOOD GLUCOSE TARGETS

The ADA[2] recommends the following glycemic goals for most nonpregnant adults:

- Fasting and premeal—80–130 mg/dL
- 2-hour postprandial—less than 180 mg/dL
- Bedtime—100–150 mg/dL.

However, diabetes management should be individualized on the basis of age and other comorbidities. For example, geriatric patients who have frequent episodes of hypoglycemia are prone to more harm than benefit from intensifying therapy to achieve these targets. Consequently, they may be candidates for more relaxed goals to avoid episodes of dangerous hypoglycemia.

When discussing blood glucose targets, an important but often overlooked concern is how the patient perceives the results. Providers and patients alike often describe readings as "good" or "bad." This interpretation can lead to feelings of disappointment and failure in the patient and frustration in the provider. Instead, high blood glucose readings should be viewed as a way to identify opportunities for change. Patients may be more willing to check and even log their blood glucose levels if they see this information as an instrument to be used in the collaborative relationship with their provider.

CHOOSING A BLOOD GLUCOSE METER

Barring any special needs of the patient, meters are often selected on the basis of the patients' insurance coverage for self-monitoring supplies (test strips and lancets), because of the high cost of test strips when purchased out-of-pocket. Meters themselves are usually relatively inexpensive, since the manufacturers commonly give them away as free samples to providers, who pass them along to patients. They also can often be purchased using coupons at a significant discount.

Without insurance coverage, test strips can cost $0.83 to $1.76 per strip for the most popular brands of meters. For patients without insurance coverage for supplies, the lowest-cost test strips currently available are for the **ReliOn Prime Blood Glucose Monitoring System** (ie, meter) sold at Walmart. Although ReliOn meters are not given out as samples in providers' offices, the manufacturer's suggested retail price is $16.24. More importantly, the suggested retail price for ReliOn Prime test strips is $9.00 for a bottle of 50 strips, or $0.18 per strip.[10]

For patients with special needs

For patients with special needs, there are meters that can make self-monitoring more convenient. For a patient who has problems with dexterity, grasping small test strips may be difficult. Two options are:

- **Accu-Chek Compact Plus,** which uses a 17-strip drum loaded into the meter
- **Bayer Breeze2,** which uses a 10-strip disk.

Both of the above dispense one strip at a time and eliminate the need to handle individual test strips.

Patients with poor visual acuity also face challenges with self-monitoring. Meters with options such as a backlight, a color screen, or a large display can help. Other meters talk, allowing patients to hear settings and blood glucose results. Examples are:

- **Prodigy Autocode**
- **Prodigy Voice**
- **Embrace.**

Other meter options depend on patient preference. Features that can affect patient choice include the ability to flag readings (eg, premeal, postmeal, exercise) and transfer data to other devices, blood sample size, meter size, touchscreen, meter memory and storage, rechargeable vs replaceable batteries, and the time it takes the meter to display the glucose reading.

Meters with advanced functions

For patients who want or need more advanced options, meters are now offering more feedback.

The OneTouch Verio family of meters helps patients spot patterns in their blood glucose levels. In addition, the Verio Flex and Verio Sync meters can sync with the OneTouch Reveal mobile app, which provides reports for the patient to view and send to the healthcare provider.

The Accu-Chek Aviva Expert has a bolus calculation function. Settings such as carbohydrate ratios, insulin sensitivity, targets, and active insulin can be programmed into the meter, which uses this information to give the patient dosing suggestions for rapid-acting insulin when carbohydrate intake is entered or blood glucose levels are checked. Another Accu-Chek meter, the Aviva Connect, can wirelessly transmit blood glucose results to the Accu-Chek Connect mobile app.

For a complete and regularly updated list of meters and their features, we encourage patients and healthcare providers to refer to the ADA's *Diabetes Forecast* magazine. The magazine publishes a consumer guide every January that includes a comprehensive list of blood glucose meters. Past issues of the guide are available at www.diabetesforecast.org/past-issues-archive.html.

Test results are not 'good' or 'bad'—they are opportunities for change

METER ACCURACY

Even though patients and providers use glucose self-monitoring results to make important decisions about diabetes management, the meters have limitations in accuracy. Accuracy comparisons from third-party sources are rare due to the cost of accuracy testing. However, the US Food and Drug Administration (FDA) requires all home glucose meters to meet accuracy standards set by the International Organization for Standardization (ISO). Currently, the FDA uses ISO standard 15197:2003, but ISO has published a revision, ISO standard 15197:2013, with stricter guidelines that have yet to be adopted by the FDA.[10,11] Current and

Advice for patients on how to improve testing accuracy

The following steps improve the accuracy of glucose meter results:

- Wash your hands with soap and water and dry them thoroughly before every glucose check. Do not use scented soaps. Use an alcohol swab to clean the testing site when soap and water are unavailable.
- If a reading is unexpectedly high or low, wash your hands again, dry thoroughly, and do another check for verification.
- Some test strips are good until the expiration date printed on the package, but others are good only for 3 or 6 months after the package is opened. Dispose of any strips that are past the expiration date or the discard date recommended on the package (whichever is earlier).
- Do not expose strips to extreme hot or cold temperatures or high humidity. Test strips work best when kept at or below room temperature (but not freezing).
- If the accuracy of the meter or the test strips is in question, do a control test using control solution for that meter (available at pharmacies). Control solution contains a known amount of glucose, and when applied to the test strip according to the package instructions, it can let you know if the meter and strips are working properly.
- If you are testing at sites other than the fingertips, such as on the arms or palms, only do it when blood glucose levels are stable, such as immediately before each meal or at bedtime. Results will be inaccurate when levels are changing quickly, such as after exercise, after eating, or after an injection of rapid-acting or fast-acting insulin.

future guidelines are shown in **Table 1**.[10]

In addition to variations in accuracy that are deemed acceptable by the FDA, there are other more controllable factors that can further affect the accuracy of glucose meter results. Expired test strips, unwashed hands, poor sampling technique, storage of test strips in extreme temperatures or humidity, and a low hematocrit level all can cause inaccurate readings.

If the patient has a low hematocrit, consider recommending a meter proven to have stable performance in the setting of low hematocrit. These meters are highlighted in a 2013 study by Ramljak et al.[12]

LANCETS, LANCING DEVICES, AND TECHNIQUES

Along with a variety of meters, patients also have an array of lancets and lancing devices from which to choose. Many patients use the brand of lancet device and lancets that come in their meter starter kit, but they can use other brands if desired. For cost-conscious patients, lancets are significantly more affordable than test strips, even for those without insurance coverage. Prices can be as low as $0.03 per lancet for some store-brand 33-gauge lancets. Name-brand lancets are more expensive than store-brand, but at $0.06 to $0.16 per lancet, many patients will even find these to be affordable if they must pay out of pocket.

Special needs may also prompt patients to choose a different lancet device than the one that came with their meter. For patients who have poor dexterity or are afraid to look at needles, the **Accu-Chek FastClix** lancing device uses drums with six preloaded lancets, eliminating the need to see and handle individual lancets. The FastClix device is included in the starter kits for the Accu-Chek Nano and Accu-Chek Connect meters and can also be ordered separately at pharmacies.

Reducing pain when testing

A common complaint about glucose self-monitoring is that it hurts. Below are some tips for reducing pain when testing:

- Use a new lancet for each blood glucose check.
- Choose a lancet device with a depth gauge and select the lowest setting that allows for a sufficient sample size.
- Lancets come in a variety of sizes, typically from 28 gauge to 33 gauge, so choose a lancet with a smaller gauge (ie, a higher gauge number).
- Poke the side of the fingertip instead of the end or the middle.
- Alternate the fingers instead of repeatedly using the same finger.
- To minimize pain from forceful squeezing of the fingertip to get a sufficient blood sample, start squeezing the palm and push the blood progressively into the fingertip.
- Consider alternate-site testing, especially if you have painful upper-extremity neuropathy.

TABLE 1

Accuracy requirements for glucose meters

Results	Current accuracy requirements	Future accuracy requirements
≥ 75 mg/dL	95% of meter results must be within ± 20% of the actual blood glucose level	99% of meter results must be within ± 15% of the actual blood glucose level
< 75 mg/dL	95% of meter results must be within ± 15 mg/dL of the actual blood glucose level	99% of meter results must be within ± 15 mg/dL of the actual blood glucose level

Information based on International Organization for Standardization (ISO). ISO 15197:2013. In vitro diagnostic test systems—requirements for blood-glucose monitoring systems for self-testing in managing diabetes mellitus. www.iso.org/obp/ui/#iso:std:iso:15197:ed-2:v1:en. Accessed April 8, 2016.

LOGGING BLOOD GLUCOSE READINGS

Although many meters can automatically transfer their data to mobile devices or computers, patients are still encouraged to log their glucose readings manually. Not only does this give feedback to the provider in the event that the downloading software is not available in that provider's office, it also allows patients to learn how to identify patterns in their readings and make changes in their diabetes self-management.

In the past, all logging was done on paper forms or in log books, but today's technology offers other options. Several meters offer downloading software for home use that displays the data in a usable format. Some smartphone apps allow patients to enter glucose readings and other useful diabetes information such as food intake and exercise. Below are examples of smartphone apps that can help patients track glucose levels and much more:

- **mySugr** (iPhone and Android)
- **Glucose Buddy** (iPhone and Android)
- **OnTrack Diabetes** (Android)
- **Glucool Diabetes** (Android) (also available in a premium version).
- **Glooko** (iPhone and Android). This app requires purchase of a compatible cable to connect the patient's phone to the meter, which then allows readings to be transferred directly to the app.

THE ROLE OF THE CERTIFIED DIABETES EDUCATOR

One of the most useful resources available to providers is the assistance of a certified diabetes educator, who can teach a patient the basic operation of a blood glucose meter and educate the patient on all topics discussed in this article and more.

Certified diabetes educators are instrumental in helping patients understand blood glucose targets, the rationale for glucose self-monitoring, logging, pattern management, special features in meters, control testing, and alternate-site testing, and using the results of testing to make meaningful changes in how they self-manage their diabetes. Education should include discussions about topics such as meal planning, exercise, and medications to help patients fully grasp the impact of their daily decisions on their blood glucose control. ■

Meters are often chosen on the basis of insurance coverage for the supplies

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***ADDRESS**: Shannon Knapp, RN, Patient Educator, Department of Endocrinology, Diabetes, and Metabolism, X20, Cleveland Clinic, 9500 Euclid Avenue, Cleveland, OH 44195; knapps@ccf.org*