



Strategies for improving glycemic control: effective use of glucose monitoring

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Despite the increasing prevalence of diabetes, improved understanding of the disease, and a variety of new medications, glycemic control does not appear to be improving. Self-monitoring of blood glucose (SMBG) is one strategy for improving glycemic control; however, patient adherence is suboptimal and proper education and follow-up are crucial. Patients need to understand why they are being asked to self-test, what their glycemic targets are, and what they should do based on the results of self-monitoring. Patients also must be taught proper technique and must be given specific recommendations regarding frequency and timing for self-monitoring. Situations in which SMBG is essential or should be more frequent include self-adjustment of insulin doses, changes in medications, lack of awareness of hypoglycemia, gestational diabetes, illness, or when hemoglobin A_{1c} (HbA_{1c}) values are above target. SMBG should include postprandial monitoring to identify glycemic excursions after meals, to indicate the need for lifestyle adjustments, and to provide patient feedback on dietary choices.

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Over the past 2 decades, evidence has accumulated regarding the critical importance of tight control of blood glucose levels in individuals with diabetes. A variety of practice guidelines for achieving such control has been developed and widely publicized. Nevertheless, data from the Third National Health and Nutrition Examination Survey (NHANES III), 1988 to 1994, and NHANES 1999 to 2000 indicated that overall glycemic control did not improve—and actually worsened among individuals with type 2 diabetes—between the 2 survey periods.^{1,2} This has also been observed in the United Kingdom, Sweden, and the Netherlands.^{3–5}

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Facilitating diabetes treatment success

Among the recommendations for improving glycemic control to emerge from NHANES are ongoing monitoring and measurement of the quality of care; empowerment of healthcare providers with medical-decision support tools; provision of patient information to improve the quantity and quality of self-participation both in disease management and in care received; and incorporation of economic incentives in the healthcare system (such as incremental payments for improved clinical performance) for providing comprehensive care.^{1,6} Early, aggressive management of diabetes, including type 2 diabetes, is crucial to increasing glycemic control.² In addition to lowering blood glucose levels in patients with diabetes, attention should be paid to cardiovascular risk factors (i.e., serum triglyceride levels, low-density lipoprotein and high-density lipoprotein cholesterol, blood pressure, and body weight) that can also contribute to complications.⁷ Clearly, to avoid devastating complications of diabetes, greater efforts must be made to increase patient

awareness of the importance of glycemic control and enhance implementation of effective management strategies by patients and healthcare providers.

Self-monitoring of blood glucose (SMBG) is considered a tool for guiding patient and healthcare provider actions regarding dietary changes, physical activity, and pharmacologic therapy.^{1,8,9} Healthcare providers can help patients understand that diets lower in fat can help control cholesterol, that body weight control through diet and exercise can affect lipid levels and blood pressure, and that all of these interventions can facilitate glycemic control.¹ Guidance and interactive training regarding appropriate choices of diet and exercise plans, combined with encouragement and monitoring of progress, can empower patients to make beneficial lifestyle modifications.⁸

SMBG is considered a tool for guiding patient and healthcare provider actions regarding dietary changes, physical activity, and pharmacologic therapy.¹⁰ Once a patient is diagnosed with diabetes, SMBG should be considered essential in all individuals, even though specific frequency and timing may vary due to degree of glycemic control. This recommendation is based on the fact that self-monitoring is an excellent educational tool to help inform patients about their disease and the effects of diet, exercise, and medications on glucose levels. Changes in diabetes management in response to glycemic fluctuations are the joint responsibility of patients and healthcare providers. A team approach involving healthcare providers, patients, and family members is useful in managing diabetes effectively.

Using self-monitoring of blood glucose as part of an overall strategy to improve glycemic control

Barriers to self-monitoring

The majority of the evidence—and almost all guidelines for diabetes management—support the integral role of SMBG in overall treatment programs.^{11–13} Use of self-monitoring is recognized as valuable in assisting patients and healthcare providers in evaluating therapeutic effectiveness, adjust medication dosages, and detect or prevent hypoglycemia.¹⁴ However, adherence to SMBG regimens and frequency of testing remain below recommended levels^{10,14–16}; 60% of patients with type 1 diabetes and 67% of those with type 2 diabetes fail to self-monitor at the frequencies recommended by the American Diabetes Association (ADA).¹⁴ Furthermore, the patients at greatest risk for poor health outcomes—and who might reap the greatest benefit from this testing—are the least likely to self-monitor.¹⁷

A longitudinal 12-month study found that easier availability (free of charge) of self-monitoring supplies increased frequency of use and improved glycemic control compared with more limited access (necessity to purchase).¹⁸ Financial, linguistic, and educational factors—as well as patient

inability to interpret results of SMBG or act on them—have also been identified as barriers to more adherent self-monitoring and thus to more effective glycemic control.^{14,19–21} Facilitating access to SMBG, along with training and education about its use and value, can increase adherence and improve glycemic control, helping to avoid complications of diabetes. Patients need to know and understand the ranges of test results and what steps to take, such as modifying diet, exercise, and/or medication, in response to a high or low reading.

Effective implementation of SMBG

Effective implementation of SMBG requires that healthcare providers familiarize themselves with the value, techniques, and objectives of self-monitoring and provide this information to their patients with diabetes.²¹ Because a substantial number of patients with diabetes use their glucose meters incorrectly, healthcare providers should provide periodic evaluation of testing technique and reinforcement or retraining if necessary.²² Close follow-up by healthcare providers has also been shown to enhance adherence and to increase glycemic control.^{23,24} Similarly, diabetes educators can be very helpful in properly preparing patients to self-monitor their blood glucose appropriately. It is important for patients to understand what they are trying to accomplish by using self-monitoring and to be aware that adherence to this element of self-care can allow them to respond appropriately in “real time” to help maintain control of their blood glucose.²⁵ Patients are more likely to self-monitor properly and at the recommended frequency if they understand that their proactive participation is a critical component of effective diabetes management.

Patients should know their target blood glucose goals in order to recognize out-of-range values requiring attention. Although such goals must be individualized, the American College of Endocrinology (ACE) recommends that, for adults with diabetes, fasting plasma glucose levels should target a value of <110 mg/dL (6.11 mmol/L); treatment-targeted 2-hour postprandial blood glucose levels should be <140 mg/dL (7.77 mmol/L).²⁶ Each patient needs to understand, for example, what specific postprandial glucose value he or she is aiming for and that large glycemic excursions should be avoided. Patients should be taught exactly how to interpret and use the data gained from SMBG to adjust medication dosage, food intake, and/or physical activity, as well as to make other lifestyle modifications to achieve specific glycemic goals.^{13,27}

Specific recommendations for self-monitoring of blood glucose

Situations in which self-monitoring is essential

Self-testing is an essential part of management for patients who self-adjust their insulin doses based on glucose mea-

surement.¹² Some patients are unaware of hypoglycemic symptoms or are known to experience asymptomatic periods of hypoglycemia. In these patients, self-monitoring can prevent glycemic deviations that might be hazardous during certain types of employment (e.g., shift work, night work), driving, or exercise.¹²

When a medication regimen is altered, SMBG provides detailed feedback on the effectiveness of the change, allowing prompt adjustments if necessary. Similarly, in patients with diabetes who also have an intercurrent illness, self-monitoring can help provide the specific information necessary to maintain stringent glycemic control. Regular blood glucose self-testing is essential in pregnant women with diabetes to optimize fetal and maternal outcomes.²⁸

Situations requiring frequent SMBG

When diabetes treatment regimens involve intensive insulin therapies, such as multiple daily injections or insulin pumps, the regular feedback provided by multiple daily self-monitored tests is essential for proper self-adjustment of insulin dose.¹² In people with suspected or confirmed impaired awareness of hypoglycemia, self-monitoring is crucial to identify excursions and enhance safety. In addition, patients whose hemoglobin A_{1c} (HbA_{1c}) levels are out of target range require more frequent self-monitoring to help identify the daily glucose fluctuations and the patterns of glucose readings over several days that periodic HbA_{1c} testing cannot capture.

Recommendations for frequency and timing of self-monitoring in individual populations

The ADA recommends that the frequency and timing of SMBG be determined by the needs and objectives of individual patients.¹³ General recommendations for the frequency and timing of self-monitoring cover a wide range in practice guidelines and in research studies.^{12,13,26,28–32} Within this range, it appears reasonable to provide more specific guidance that can be tailored to the requirements of each individual with diabetes within predefined patient groups (e.g., according to pharmacologic management strategies).

Type 1 diabetes and intensively treated type 2 diabetes

In intensively insulin-treated patients, i.e., patients with either type 1 or type 2 diabetes receiving multiple daily injections or using an insulin pump, an optimal course of action would be to self-test blood glucose levels ≥ 3 to 4 times daily. Many patients, including those above glycemic target or experiencing frequent hypoglycemia, will require more frequent monitoring. The timing for self-monitoring should include both preprandial and postprandial tests with

occasional values obtained at 2:00 AM to 3:00 AM to coincide with meals, exercise, and the peak action of the insulin used.^{13,30,33} At least twice-daily monitoring should be performed for patients receiving a single daily injection to monitor for and prevent hypoglycemia and to facilitate reaching glycemic goals.^{12,13,28,30,31,34} Under certain conditions—such as changes in medication and acute or intercurrent illness—self-monitoring should be performed more frequently.^{13,30,31}

Type 2 diabetes treated with oral antidiabetic agents or once-daily insulin

Studies in patients with non-insulin-treated type 2 diabetes have found that SMBG is statistically associated with better glycemic control than traditional management alone.^{35–37} Self-testing can demonstrate the hypoglycemic effectiveness of oral antidiabetic agents and provide feedback to patients and healthcare providers regarding the effects of diet, exercise, and medication changes. Meal-related blood glucose self-monitoring may be especially useful for improving patient adherence to diet or other treatment interventions.³⁵ A study of non-insulin-using patients with type 2 diabetes measured diurnal plasma glucose at 8:00 AM, 11:00 AM, 2:00 PM, and 5:00 PM.³⁸ This study concluded that glucose excursions during morning periods seem to be a permanent condition in these patients regardless of level of glycemic control, degree of residual β -cell function, or type of medication, and that mid-morning self-monitoring should be recommended for detecting these excursions. A more recent study by the same group demonstrated that glucose monitoring during the extended post-lunch period (5:00 PM) was optimal for detecting patients at risk of hypoglycemia and for assessing short-term control of diabetes.³⁹ Long-acting sulfonylureas or glitinides (glyburide, repaglinide) have been found to increase hypoglycemic rates more than thiazolidinediones or biguanides.^{7,30,40} The lowest blood glucose values have been found to occur more frequently in the evening rather than in the morning.⁴¹ Therefore, in addition to mid-morning glucose monitoring, inclusion of routine evening self-testing can be advantageous in patients taking oral agents. Considering these factors, it seems reasonable to suggest that in patients above glycemic target, managed with oral agents plus once-daily insulin, once-daily insulin alone, or oral agents plus once-daily insulin, SMBG should be performed ≥ 2 times daily. For patients who have achieved glycemic target and are managed with once-daily insulin alone or oral agents alone, self-monitoring is recommended ≥ 1 time daily. Daily testing should be accompanied by ≥ 1 weekly profile to guide nutrition and physical activity, detect postprandial hyperglycemia, and prevent hypoglycemia. A weekly profile should include both preprandial and postprandial blood glucose measurements. For patients treated with once-daily insulin plus oral agent(s) who have achieved glycemic target, the recommended frequency for self-monitoring is ≥ 1 time daily with

≥1 weekly profile. It should be noted that once-daily insulin alone, although infrequently used, is generally less effective than oral agents plus once-daily insulin or multiple daily insulin injections with or without oral agents.

Type 2 diabetes treated nonpharmacologically

Patients with type 2 diabetes not using insulin or oral hypoglycemic agents have also been shown to benefit from SMBG.³⁷ Self-monitoring can provide awareness of the effects of diet and exercise on blood glucose levels and can motivate individuals to adjust their diet or physical activity to achieve glucose goals.^{11,24,36,42} A properly implemented program of self-monitoring that incorporates patient education improves patient motivation and self-care behaviors. Pairing blood glucose testing with a meal or event may be a particularly effective strategy to explore the effects of food, exercise, or stress.^{11,27} Meal-related testing has been shown to improve overall glycemic control and lead to significant improvements in general well-being.³⁵ Several clinical studies of self-monitoring in patients managed by diet and exercise have used multiple-point profile days on ≥1 day each week.^{11,27,35,36,43} The study by Jaber and colleagues¹¹ used SMBG 4 times per day (relative to meal consumption) for 2 days per week. A study of patients with type 2 diabetes treated with oral agents or diet used a self-monitoring frequency of 6 times per day for the first month of the 44-week study.²⁷ Schwedes and associates³⁵ used meal-related self-monitoring 6 times per day on 2 days of the week. Each of these studies examining different profiling strategies showed significant decreases in HbA_{1c} for the group using SMBG. Based on these and other studies, it is reasonable to recommend that patients with type 2 diabetes who are nonpharmacologically managed can benefit from self-monitoring by performing ≥1 weekly profile whether they are at or above glycemic target. In addition to its ability to guide nutrition and physical activity, the results of frequent SMBG testing can be used to trigger the addition of pharmacologic therapy for patients who are consistently above glycemic target.

Pregnancy and gestational diabetes

Women with diabetes who become pregnant are at increased risk for congenital malformations, stillbirths, and other pregnancy-related complications. Glycemic targets are more stringent for women with diabetes who are pregnant than for nonpregnant women. Due to the ability of oral glucose-lowering drugs to cross the placenta, women with type 2 diabetes who become pregnant are commonly switched to insulin when medical nutrition therapy fails to achieve these lower targets (preprandial capillary whole-blood glucose ≤105 mg/dL (5.83 mmol/L), 2-hour postprandial levels ≤130 mg/dL (7.22 mmol/L)).²⁹ Increased

self-testing is especially important in these patients, with the ADA recommending a frequency of ≥3 times daily and the American Academy of Family Physicians (AAFP) recommending ≥4 times a day.^{13,30} In gestational diabetes, medical nutrition therapy is the first approach to management and should be monitored by self-testing of blood glucose. The ADA recommendations state that daily self-monitoring appears to be superior to intermittent (i.e., medical office) monitoring of blood glucose.²⁹ As in women with diabetes who become pregnant, self-monitoring is recommended ≥3 times daily in women with gestational diabetes who are treated with insulin.³⁰

Postprandial testing for all patients with diabetes

Postprandial glucose has been found to be a significant contributor to overall glycemic control and to correlate better with HbA_{1c} levels than fasting plasma glucose.^{44–48} Postprandial glucose excursions have been found to be greater contributors to overall hyperglycemia in fairly well-controlled patients (HbA_{1c} ≤8.4%) than in poorly controlled patients (HbA_{1c} >8.4%), in whom the contribution of fasting hyperglycemia is predominant.⁴⁶ A recent study showed that meal-related self-testing in patients with non-insulin-treated type 2 diabetes both improved overall glycemic control and significantly improved patients' general well-being.³⁵ Other studies in patients with type 1 and type 2 diabetes who were poorly controlled with insulin or oral antihyperglycemic agents, respectively,^{36,49,50} showed decreases in HbA_{1c} when postprandial self-monitoring was performed regularly, leading other researchers to suggest that postprandial glucose is a stronger reflection of the pathophysiologic process than fasting hyperglycemia.⁴⁵

In addition to the contribution of postprandial glucose to HbA_{1c} levels, data from other clinical trials reviewed earlier demonstrate a correlation between postprandial hyperglycemia and increased risk of cardiovascular events, even when glucose levels are at or below target levels.^{51,52} Therefore, postprandial SMBG should be performed by all patients to detect postprandial excursions and to indicate the need for lifestyle adjustments in order to minimize cardiovascular morbidity.

Avoiding hypoglycemic episodes

The development of hypoglycemia can increase many serious risks for patients with diabetes, including immediate and long-term complications. Therefore, avoidance of hypoglycemic episodes is critical to effective diabetes management. Hypoglycemia awareness training and education are important for patients to attain and maintain glycemic control. Episodes of severe hypoglycemia have been found to be preceded and followed by blood glucose disturbances, which—if identified—could be used to warn of imminent severe hypoglycemia.⁵³ Frequent self-testing expands awareness of the correlation of symptoms with decreases in

blood glucose, enabling patients to take early action to reverse hypoglycemic excursions.^{34,40} In all patients with diabetes, certain situations (e.g., acute illness or change in medication type or dosage) should prompt more frequent self-monitoring.

Recommendations for additional studies of self-monitoring of blood glucose

As the availability of well-designed, high-quality clinical studies of SMBG has grown, the clinical effectiveness of self-monitoring has become more apparent. Additional randomized controlled trials would be beneficial, especially if focused on determining optimal frequency and timing. Future studies should consider measures to minimize patient dropout and quantify adherence with the prescribed intervention. Data should be adjusted to control for potential confounding factors. Inclusion criteria should delineate diabetes type, baseline HbA_{1c} ranges, and prescribed treatments, as results may be applicable only to select patient strata. Additional data are also needed to determine the economic impact and cost-effectiveness of SMBG, especially in patients with non-insulin-treated type 2 diabetes. Health-economic modeling may be able to link improvements in clinical parameters with healthcare savings related to avoiding or delaying complications of diabetes. The long-term healthcare savings achieved by preventing diabetic complications would likely outweigh the short-term costs of increased use of self-monitoring.¹⁹

Summary

Controlling blood glucose levels is important to preventing serious complications of diabetes, yet evidence suggests that glycemic control is not improving. When properly implemented, SMBG is an important tool for achieving glycemic control. Barriers to effective use of self-monitoring include poor patient adherence, limited access to supplies, incomplete patient education (how to perform self-monitoring, understanding glycemic targets, actions to take based on results), and lack of specific recommendations for timing and frequency. Healthcare professionals and patients must work together to overcome these barriers.

The following statements relate to the implementation of SMBG: (1) SMBG should be initiated in all patients with diabetes as an integral part of an overall diabetes management program. (2) Recommended frequencies for SMBG are ≥ 3 to 4 times daily for patients treated with multiple daily insulin injections or using an insulin pump; ≥ 2 times daily for patients above glycemic target managed with oral agents and/or once-daily insulin; ≥ 1 time per day with a weekly profile for patients at glycemic target managed with either once-daily insulin or oral agents alone; ≥ 1 time per

day with more frequent weekly profiles for patient at glycemic target managed with oral agents plus once-daily insulin; and ≥ 1 weekly profile for patients managed nonpharmacologically whether at or above target. (3) Additional self-monitoring should be performed in certain situations, such as acute illness, intercurrent illness, changes in medication, patients with impaired awareness of hypoglycemia, and during pregnancy. (4) Postprandial SMBG testing should be used by all patients with diabetes to minimize postprandial excursions and to guide lifestyle changes. (5) In addition to its utility as a tool for evaluation of glycemic control, SMBG should be viewed as an educational tool to inform patients about the effects of lifestyle and behavioral changes.

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