

## Benefits and Limitations of Self-Monitoring of Blood Glucose

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### Introduction

**S**elf-monitoring of blood glucose (SMBG) provides significant benefits to patients with diabetes and their healthcare providers. SMBG is increasingly recognized as an integral part of intensive therapy for all forms of diabetes. This article discusses the clinical utility of SMBG in type 1 (T1DM) and type 2 diabetes (T2DM) and looks at the relationship between SMBG and improved overall glycemic control as measured by A1c.

### Why SMBG is Helpful for Patients with Diabetes

SMBG is helpful to patients with diabetes in four distinct ways. First, it allows patients and clinicians to detect high or low blood glucose levels, thereby facilitating therapeutic adjustments to achieve long-term A1c goals. Second, SMBG helps protect patients by allowing them to immediately confirm acute hypoglycemia or hyperglycemia. Third, the technology facilitates patient education about diabetes and its management by giving patients more self-care responsibilities. Fourth, SMBG helps motivate people toward healthier behavior.

#### *SMBG Facilitates Improved A1c*

Many published studies have demonstrated that regular and frequent SMBG improves glycemic control in T1DM and T2DM patients on insulin treatment. There is also very strong evidence that SMBG improves control in T2DM patients who are not on insulin therapy.

#### *T1DM and Insulin-Treated T2DM patients*

Davidson and colleagues showed that there is an inverse correlation between frequency of SMBG and A1c values

in T1DM patients.<sup>1</sup> Patients using SMBG have lower A1c than those who do not. The authors found that the more times per day that people check their blood glucose levels, the lower their A1c. However, after reaching a frequency of 6-7 tests per day, the improvement levels off.

Stowig and colleagues showed similar results, reporting a 0.25% decrease in A1c for each blood glucose test per day.<sup>2</sup> Again, there was a point of diminishing returns; improvements in A1c leveled off at approximately 8 tests per day. Studies of pediatric T1DM patients have demonstrated similar findings.<sup>3, 4</sup>

In a retrospective study of more than 24,000 patients, Karter and colleagues found that increased frequency of SMBG correlated strongly with improved A1c regardless of the type of diabetes or therapy used.<sup>5</sup>

#### *Non-Insulin-Treated T2DM patients*

There has been much debate on the impact of SMBG on A1c in T2DM patients who are not treated with insulin. Skeptics of the benefits of SMBG use in this patient group often cite small or poorly designed studies that demonstrate no A1c benefit. This perspective often overlooks the fact that many T2DM patients are not adequately trained to interpret and respond to their test results. Utilization of SMBG involves more than simply documenting test results in a logbook; patients must understand and be able to make appropriate changes in therapy or activity based upon those results. SMBG testing in T2DM patients has also been hampered by a lack of consensus on the timing and frequency with which testing should be performed. Most patients who do perform blood glucose monitoring

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**Abbreviations:** (SMBG) self monitoring of blood glucose, (T1DM) type 1 diabetes mellitus, (T2DM) type 2 diabetes mellitus

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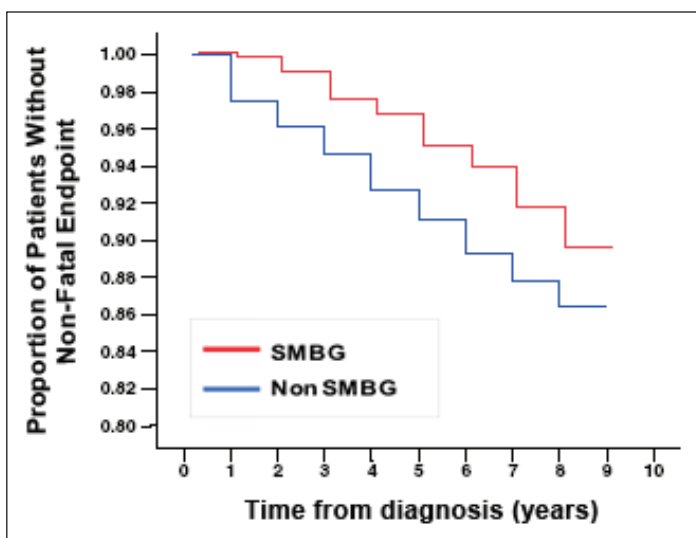
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seldom test postprandial glucose. Other factors that inhibit testing frequency include the cost, pain, and inconvenience. All of these factors work against seeing a benefit in T2DM patients.

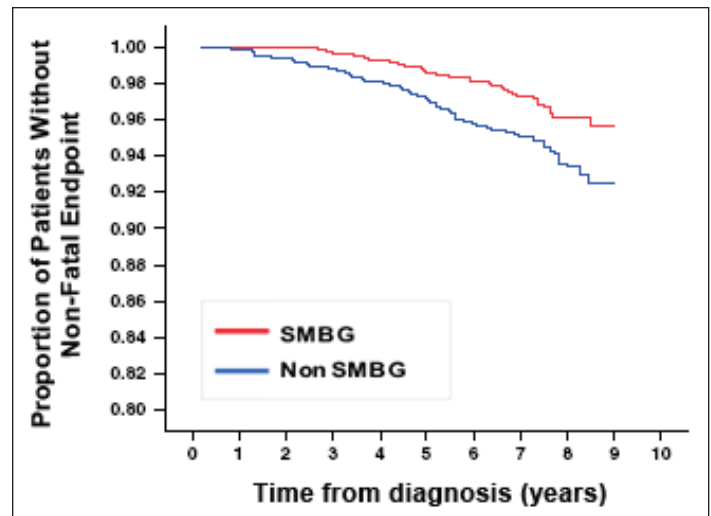
Despite these factors, there is strong evidence that SMBG is, in fact, an effective method for lowering A1c in this patient group. A meta-analysis by Sarol and colleagues found an overall A1c improvement of 0.4% in non-insulin-treated T2DM patients who use SMBG compared with those who do not monitor.<sup>6</sup> To counter potential criticism of their report, the authors critiqued the studies included in their meta-analysis and found no publication bias in their selection.

A second meta-analysis conducted by Welschen *et al.* found similar results: an overall 0.39% improvement in A1c in type 2 patients not on insulin.<sup>7</sup> The authors concluded that SMBG lowers A1c levels. Another review of the literature by Saudek in 2006 yielded similar findings.<sup>8</sup>

In a recent epidemiologic, non-randomized retrospective study, Martin and colleagues looked at disease-related fatal and non-fatal events in approximately 3,200 T2DM patients.<sup>9</sup> Unlike the meta-analyses cited above, this study directly assessed clinical outcomes relative to SMBG utilization. As shown in **Figure 1**, fewer patients who used SMBG experienced fatal or non-fatal events than patients who did not monitor their glucose (7.2 versus 10.4%,  $p=0.002$ ). The authors concluded that SMBG may be associated with a healthier lifestyle and/or better disease management. Significantly, this study did not simply show that SMBG correlates with improved A1c; it demonstrated that SMBG is actually linked to better clinical outcomes.



**Figure 1a.** Self-monitoring of blood glucose in type 2 diabetes and long-term outcomes.



**Figure 1b.** Self-monitoring of blood glucose in type 2 diabetes and long-term outcomes.

## Frequency of SMBG

A major obstacle to increased SMBG utilization is the lack of clear guidelines for testing frequency. A global consensus conference was convened in 2004 to address this issue. The results of that conference were published as a supplement in the *American Journal of Medicine*.<sup>10</sup> **Table 1** shows a summary of the recommendations presented.

**Table 1.** Specific recommendations for SMBG frequency.

Treatment Regimen	SMBG Frequency
Insulin Therapy (Multiple Daily Injections or Insulin Pump)	> 3-4x/day
Patients above target on other regimens (orals and/or QD insulin)	> 2x/day
Patients at target on oral agents or QD insulin	> 1x/day + 1 profile*/week
Patients at target on orals agents plus QD insulin	> 1x/day + frequent profiles
Patients on non-pharmacologic therapy	> 1profile/week

\* A collection of pre- and post-meal glucose test results over a 7-day period.

## Economic Benefits of SMBG

As described earlier, frequent SMBG results in a statistically and clinically significant improvement in A1c which can range up to reductions of 2.5-4.0%. To determine whether this reduction results in economic benefits, Neeser and colleagues performed a cost-effectiveness analysis of SMBG using a Markov state model of diabetes to assess the clinical impact and related costs when SMBG is provided to patients not on insulin therapy.<sup>11</sup> They assumed an improvement in A1c of 0.39%. The results of the analysis showed a slight increase in life expectancy and a reduced cost of complications, 70% of which was attributable to reductions in microvascular events. The cost per life-year gained was approximately \$39,650, which is considered to be an acceptable cost-effective intervention from a health insurance perspective.

## Accuracy

Another important issue is patient accuracy. Alto and colleagues conducted a study of 111 patients in two family practice settings to determine the technical skill and accuracy of SMBG in an outpatient population.<sup>12</sup> The patients were observed using a 13-point checklist of critical steps in the calibration and operation of their glucose monitor. Overall, 53% of patient glucose values were within 10% of the control value, 84% were within 20% of the control value and 16% varied 20% or more from the control value. In short, the study showed that despite multiple technical errors when using SMBG, most patients obtained clinically useful values.

A study reported by Bergenstal and colleagues found that 19% percent of patients had inaccuracy rates of more than 15% in blood glucose monitoring.<sup>13</sup> Some of the most common causes of inaccurate readings included: lack of periodic meter technique evaluation, difficulty using wipe meters, incorrect use of control solutions, lack of hand washing (even when under clinical observation), and using unclean meters.

These studies demonstrate the need for healthcare providers to monitor patient use of SMBG to help improve the accuracy of test results.

## Conclusions

Studies clearly demonstrate that frequent SMBG improves A1c and related outcomes in T1DM and T2DM regardless of the therapy used. SMBG helps protect patients by allowing them to immediately confirm hypoglycemia and hyperglycemia. Further, SMBG facilitates diabetes self-

management education and motivates patients to live healthier lives. SMBG is an integral part of all intensive regimens. There will undoubtedly be greater use of SMBG as more consensus standards are published regarding frequency of testing and utilization of test results.

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