Clinical Utility of SMBG: Recommendations on the Use and Reporting of SMBG in Clinical Research

Oliver Schnell,[1] Katharine Barnard,[2] Richard Bergenstal,[3] Emanuele Bosi,[4] Satish Garg,[5] Bruno Guerci,[6] Thomas Haak,[7] Irl B. Hirsch,[8] Linong Ji,[9] Sashank R. Joshi,[10] Maarten Kamp,[11] Lori Laffel,[12] Chantal Mathieu,[13] William H. Polonsky,[14] Frank Snoek,[15] and Philip Home[16]

Diabetes Care 2015;38:1627–1633 | DOI: 10.2337/dc14-2919

Quality glucose information is a core prerequisite for successful diabetes management. It enables professionals and people with diabetes to make medically relevant decisions on therapy. Details of glucose profile information beyond HbA_{1c} have been largely derived from self-monitoring of blood glucose (SMBG). Given the evidence base demonstrating the benefits of SMBG, its routine use is recommended for diabetes management and therapy by many international and regional guidelines (1–3). Today, SMBG is considered an important aspect of the management of glycemic control (3,4). Glucose information of high quality, considering the products used and the processes conducted, is also needed in clinical research in order to gain new evidence and insights on effective treatment strategies in diabetes. SMBG is widely and routinely applied in large clinical trials, where it is used to understand the glycemic state, to enhance awareness of the effects of lifestyle modification and the adaptation of treatment including insulin titration, and to enable documentation of intraday pre- and postprandial glucose excursions (glycemic variability) and the subsequent statistical analysis of this and the confirmation of hypoglycemic episodes. Examples of recent studies that used SMBG are Outcome Reduction With Initial Glargine Intervention (ORIGIN) trial, Action to Control Cardiovascular Risk in Diabetes (ACCORD), and, from earlier times, the Diabetes Control and Complications Trial (DCCT) (5–8). Indeed, SMBG is now applied in most studies of glucose-lowering agents, including glucagon-like peptide 1 (GLP-1) receptor agonist and sodium–glucose cotransporter 2 (SGLT2) inhibitor studies.

Reliable glucose information requires a clear definition as part of the study design and protocol, not least to ensure replication of the methodology. Interpretation and comparison of study results may be affected if SMBG methods and results are addressed inconsistently. With regard to the interpretation of outcomes of studies, reporting of SMBG in publications should be of the highest quality—accurate, precise, reliable, and reproducible. In many publications, however, relevant details of the SMBG measures are lacking or are incomplete. Therefore, the interpretation of study results may be hampered, reliability of study results may be compromised, and repetition of trials may become necessary.

This consensus publication not only aims to summarize learnings from previous clinical studies about the use and reporting of SMBG but also proposes recommendations for the description of the performance and reporting of SMBG in future clinical study protocols and related publications.

Clinical trials aim at expanding knowledge and evidence. One major principle of Good Clinical Practice is to conduct clinical studies at a quality standard that provides the highest level of safety for the study participants but also avoids a potentially unnecessary burden on participants by inefficient repetition of the experiments with "human beings" to answer a clinical/scientific question. In clinical trials, SMBG is performed by participants to provide information on (fluctuating) blood glucose concentrations and as a means to guide titration (as per protocol). All current tests require pricking a finger with a lancet device to obtain a small blood sample and applying a drop of blood to a test strip or tape, with the glucose concentration analyzed by a glucose meter for an automated reading. Test results are stored in the blood glucose meter's electronic memory for further use (9).

[1]*Forschergruppe Diabetes at the Helmholtz Center Munich, Munich, Germany*
[2]*Southampton General Hospital, University of Southampton, Southampton, U.K.*
[3]*International Diabetes Center at Park Nicollet, Minneapolis, MN*
[4]*Vita-Salute San Raffaele University, Milan, Italy*
[5]*Department of Internal Medicine, University of Colorado at Denver and University of Colorado Health Sciences Center, Denver, CO*
[6]*Centre Hospitalier Universitaire Nancy, Vandoeuvre-Les-Nancy, France*
[7]*Diabetes Center Mergentheim, Bad Mergentheim, Germany*
[8]*University of Washington School of Medicine, Seattle, WA*
[9]*Department of Endocrinology and Metabolism, Peking University People's Hospital, Peking, China*
[10]*Indian Academy of Diabetes, Ahmedabad, India*
[11]*Queensland University of Technology, Brisbane, Australia*
[12]*Joslin Diabetes Center, Boston, MA*
[13]*University Hospital Gasthuisberg Leuven, Leuven, Belgium*
[14]*Behavioral Diabetes Institute, University of California, San Diego, San Diego, CA*
[15]*Department of Medical Psychology, VU University Medical Center and Academic Medical Center, Amsterdam, the Netherlands*
[16]*Institute of Cellular Medicine–Diabetes, Newcastle University, Newcastle upon Tyne, U.K.*

Corresponding author: Oliver Schnell, oliver.schnell@lrz.uni-muenchen.de.

Received 9 December 2014 and accepted 8 May 2015.

According to the International Diabetes Federation guideline *Self-Monitoring of Blood Glucose in Non-Insulin Treated Type 2 Diabetes*, SMBG should be performed to provide information on hypoglycemia and glucose excursions related to medications and lifestyle changes (10). Against this background, it appears purposeful to integrate SMBG into clinical trials on novel approaches of diabetes therapy. A clear need for structured approaches of glucose reporting and analysis, incorporating educational and therapeutic components, has been identified (11).

According to the Good Clinical Practice standard and the growing evidence for a structured approach of SMBG (12), a detailed and accurate description of a study's SMBG methodology is required in protocols. Consequently, all relevant findings and aspects related to SMBG should be reported in a scientific publication or its web appendices. Presenting the entire picture of SMBG is considered necessary so as to allow better interpretation of the results of clinical trials, to better predict efficacy of interventions in real-world settings, and to allow insight into glycemic outcomes including hypoglycemia beyond the dominant diabetes marker HbA_{1c}.

EVIDENCE FOR SMBG

The evidence for a benefit of SMBG both in insulin-treated and noninsulin-treated patients with diabetes has been increasing in the last decade (13,14). Laboratory-measured clinic plasma glucose may be affected by the specific circumstances under which the blood samples are drawn (15). Although statistically significant differences in HbA_{1c} have been observed between noninsulin-treated patients using SMBG or not, the potential clinically meaningful effect on management of noninsulin-treated type 2 diabetes remains to be further elucidated (16).

Potential application areas for the use of SMBG are as follows:

- Diabetes education, assessment of blood glucose response related to nutrition, physical activity, and medications
- Therapy management, including dosing and prevention of hyperglycemia/hypoglycemia

The STeP (Structured Testing Program) study in people with type 2 diabetes, as a useful example for a study on SMBG, demonstrated structured SMBG contributing significantly to the improvement in glycemic control and psychosocial functioning compared with enhanced usual care, including free blood glucose meters and strips (17,18). Also, in the recently published PRISMA (Prospective, Randomized Trial on Intensive Self-Monitoring Blood Glucose Management Added Value in Non-Insulin Treated Type 2 Diabetes Mellitus Patients) trial, performance of structured SMBG was associated with better clinical outcomes (19). An older publication demonstrated similar findings in adults with type 1 and type 2 diabetes and reinforced the importance of providing patients with the tools to perform SMBG effectively (18).

However, the performance of SMBG in the setting of a clinical trial may differ from SMBG in everyday clinical life. The trial setting might include specific educational concepts for the performance of SMBG and might also offer detailed behavioral support.

PROBLEMS/BARRIERS AND SOLUTIONS

A recently published survey of patients or parents of children with type 1 diabetes found that 58% never used a control solution for calibration (20). A systematic review of 10 trials in people with type 2 diabetes compared SMBG with no SMBG (21). An important finding was the small number of people who had ever calibrated their blood glucose meter. However, even with the use of a control solution measurement, errors are not completely eliminated (22). Inherent potential limitations of precision related to the nature of strips and monitors have to be considered (11). These may include lot variabilities in manufacturing or environmental factors potentially affecting the performance of test strips and blood glucose meters (11).

Furthermore, there was a clear and common mismatch of understanding between people with diabetes receiving the blood glucose meter and their health care professionals about how to use it. Health care professionals believed that people with diabetes were using the device to inform lifestyle decisions and to detect glucose patterns. Most people with diabetes believed, however, that they had to test their blood glucose and write down the results in a book for their health care professionals to make therapy decisions for them. Poor education on how to meaningfully interpret the numbers displayed on the device, together with lack of understanding about adequate responses to glucose levels, has been found to potentially increase anxiety and distress. Appropriate education addressing SMBG interpretation, adjustment of nutrition and physical activity according to measurements, and the response to "out-of-range" values of blood glucose—both for people with diabetes and health care providers—were identified as prerequisites for the useful performance of SMBG (18,21) and were a key recommendation. In people with type 1 diabetes, underutilization of SMBG and continuous glucose monitoring (CGM) data; lack of easy and standardized glucose data collection, analysis, and visualization; and absence of guided clinical decision making have recently been reported to be key contributors to poor glycemic control (13).

Standardizing glucose reporting and analysis is proposed to be one step toward optimizing clinical decision making in diabetes (13). Thus, with sufficient education on how to respond to the results of SMBG measurement provided, SMBG becomes an essential tool for the daily management of insulin-treated diabetes (13,23).

An overview of problems/barriers and solutions is provided in Table 1.

SMBG IN CLINICAL TRIALS

In scientific publications of clinical trials testing different diabetes therapies, in which participants were required to perform SMBG, important and relevant details on SMBG are frequently missing or incomplete. For example, the following questions often remain unanswered (Table 2):

- Which glucose meters and test strips were used?
- Did all participants use the same glucose meters?
- Were participants provided training on how to measure capillary glucose?
- Were participants trained to use a control solution to test glucose meter accuracy?

Table 1—Key contributors to inefficient use of SMBG

Problems/barriers	Solutions
Mismatch of understanding of SMBG between patients and health care professionals	• Appropriate education addressing SMBG interpretation, adjustment of medication, nutrition, and physical activity
Lack of education on how to interpret the blood glucose readings and what to do in response to them	• Standardizing glucose reporting and analysis
Underutilization of SMBG	
Lack of easy and standardized glucose data collection, analysis, and options for visualization of glycemic levels	
Absence of guided clinical decision making	

- Were data on glucose meter accuracy during the trial reported?
- Were frequency and timing of capillary glucose measurements specified?
- Were patients provided glucose targets?
- Were study participants trained to respond to SMBG results, including hypoglycemia?
- Were glucose values documented on a paper-based diary or were they recorded electronically?
- Were SMBG data used for titrating the medications defined in the trials?
- Were SMBG results used for treatment decisions (particularly in treatment approaches using insulin) according to a defined algorithm, or were changes in diabetes treatment based on HbA_{1c} only?
- Was there an association between the frequency of SMBG and changes in HbA_{1c}?

Overall, reports of SMBG measurements in the results section are far from being standardized and often are completely missing.

The following paragraphs provide some examples of the various ways in which SMBG usage has been described in major clinical trials.

ORIGIN Trial

In the ORIGIN trial, all participants were taught to measure their own glucose levels at the beginning of the trial (6). Participants with initiation of insulin treatment with insulin glargine were instructed to perform daily fasting plasma glucose (FPG) measurement. They were given an algorithm that promoted weekly uptitration of the insulin dose (by $\geq$1 units/week) targeting a self-measured FPG concentration of 4.0–5.3 mmol/L (72–95 mg/dL) (6). Once the treatment goal had been achieved, SMBG testing was intended to be performed at least twice per week. More frequent measurements were at the discretion of the participant and investigator. Patients with type 2 diabetes receiving standard care were provided with SMBG equipment and support (6).

ACCORD

ACCORD examined the effect of standard versus intensive glucose-lowering strategy in 10,521 patients with type 2 diabetes and further cardiovascular risk factors or cardiovascular disease (7). At the beginning of the trial, all participants were provided with glucose-monitoring equipment. Patients in the intensive therapy and standard therapy arms were instructed to use SMBG to reach HbA_{1c} treatment targets of $<$6.0% and 7.0–7.9%, respectively. Predefined treatment algorithms using metformin, sulfonylureas, meglitinides, thiazolidinediones, α-glucosidase inhibitors, insulin, and insulin analogs, coupled with lifestyle intervention, have not been reported. Individuals in the intensive group receiving insulin were encouraged to take SMBG readings 4–8 times daily ($\geq$2 premeal and 2 postmeal) with an additional periodic 0300 h test, while noninsulin-treated patients were advised to perform $\geq$2 readings daily (or 4 times daily if their SMBG levels were greater than target). Patients were encouraged to adjust doses every 4 days based on SMBG readings (7).

Participants in the standard group who were treated using insulin took

Table 2—Details of SMBG published in methods and results sections of five example trials

	ORIGIN (6)	ACCORD (7)	DCCT (8)	Trial assessing GLP-1 agonist (25)	Trial assessing SGLT2 inhibitor (26)
Methods: details of SMBG					
Level of education of patients	?	?	?	?	?
Specification of SMBG meters	–	–	–	+	–
Specification of test strips	–	–	–	–	–
Accuracy of blood glucose meters (compared with laboratory)	–	–	–	–	–
Recommendations for SMBG frequency	+	+	+	–	+
Fasting blood glucose reported	+	+	+	+	+
Postprandial blood glucose reported	–	+	+	+	–
Treatment modifications based on SMBG	+	–	+	–	+ (insulin treated)
Results: details of SMBG					
Level of adherence to SMBG	–	–	–	–	–
Fasting blood glucose reported	+	–	–	+	+
Postprandial blood glucose reported	–	–	–	+	–
Frequency of treatment modifications based on SMBG	–	–	–	–	–
Discussion of SMBG results	–	–	–	+	–

SMBG readings ≤3 times daily, or ≤7 times per week (daily at different times or >1 per day on different days). Treatment doses were then adjusted according to a predetermined algorithm depending on the SMBG results obtained (15).

DCCT

The results of DCCT, published in 1993, contributed significantly to the understanding of the principles of blood glucose optimization modification and therapy management supported by SMBG (24). Results of SMBG, although recorded in structured form, are not described in detail. DCCT demonstrated the beneficial impact of near-normal glycemic control on the development and progression of microvascular and neurological complications in patients with type 1 diabetes (8). Participants on intensive therapy used SMBG to adjust their insulin dosage. Readings were taken ≥4 times daily to meet target preprandial glucose levels of 70–120 mg/dL, postprandial levels of <180 mg/dL, one weekly 3 A.M. measurement of >65 mg/dL, and monthly HbA_{1c} measurements of <6.05%. Conventional therapy included daily self-monitoring of urine or blood glucose but did not usually include daily adjustment of insulin dosage (8).

Example of a Trial With GLP-1–Based Treatment

The Liraglutide Effect and Action in Diabetes (LEAD-2) study was conducted to examine the efficacy and safety of adding the GLP-1 receptor agonist liraglutide to metformin versus the addition of placebo or glimepiride to metformin in people previously treated with oral glucose-lowering agents (25). Secondary end points included, among others, changes in FPG and 7-point plasma glucose profiles (before each meal; 90 min after breakfast, lunch, and dinner; and at bedtime). The study also aimed at the detection of hypoglycemic episodes with definitions dependent on SMBG. Patients were provided with a glucose meter and were encouraged to perform SMBG and to record self-measured plasma glucose values in their diaries (25).

Example of a Trial With SGLT2 Inhibition–Based Treatment

Wilding et al. (26) demonstrated the ability of the SGLT2 inhibitor dapagliflozin to lower hyperglycemia in people with type 2 diabetes who are poorly controlled with high insulin doses plus oral antidiabetes agents. The end points included, among others, HbA_{1c}, FPG, and postprandial blood glucose. SMBG was performed five times daily during the 3–5 days before clinic visits at weeks 1, 2, 4, 6, 8, 10, and 12 and used to support confirmation of hypoglycemia. Due to the potentially increased risk of hypoglycemia, insulin could be downtitrated in the case of SMBG levels <54 mg/dL or mean daily glucose <100 mg/dL (26). In case of FPG levels >240 mg/dL at weeks 4 and 6, >220 mg/dL at week 8, or >200 mg/dL at week 10, the insulin dose could be increased after a retest.

Lessons From the Studies

The use of SMBG was thus an important element in the above-mentioned clinical trials. However, the levels of the description of the performance of SMBG and the use of results differ. Table 2 provides an overview of the details of SMBG reported in publications of the trials.

All in all, information on SMBG utilization and the presentation of results are handled on a highly nonuniform basis (Table 2) (5,25,27,28). Some factors potentially influencing the SMBG performance remain unconsidered. In particular, there are often gaps in information on the performance of structured testing, the level of SMBG education and support, accuracy of blood glucose meters, and glycemic variability.

With regard to an optimized efficacy, SMBG should be implemented in a structured and standardized approach. Education on how to respond to the results of SMBG measurement for patients and health care providers has been identified as a key issue. Accuracy of blood glucose meters and strip-to-strip variations of test strips have been shown to potentially impact long-term glycemic control and the risk for hypoglycemia (29,30). In addition, improvements in the accuracy of SMBG meters have been reported to lower complication-related costs (31). Within-day glycemic variability, which can be assessed by SMBG (31,32) and particularly by CGM, has been hypothesized to be associated with diabetes complications independently of HbA_{1c} levels (33–35).

Interpretation and comparison of study results may be affected if SMBG methods and results are not addressed consistently. It is conceivable that a more systematic presentation of SMBG methods and results in publications of studies may improve the comparability of study results.

RECOMMENDATIONS

To improve the implementation of SMBG in clinical trials and the reporting of SMBG data in scientific publications, we provide the following recommendations (Table 3).

Study Protocol/Method Section

Monitoring of capillary glucose has the potential to affect glucose control depending on the training of both patients and diabetes care team on how to respond to glucose levels that are not on target, through either lifestyle changes or adjustment of diabetes medications. A need to incorporate an educational component for patients with diabetes starting SMBG has been emphasized (12). Less obvious is the need for training the diabetes care team on how to respond to capillary glucose levels. Furthermore, to maximize the efficacy of measuring capillary glucose, SMBG should be performed according to a structured approach, with defined frequency and timing of the measurements (11,12,36).

To collect quality SMBG data during clinical trials, the study protocol should detail different aspects of the measurement of capillary glucose in the daily life of study participants:

- The glucose meter and strips used in the trial, as well as provisions for substituting the glucose meter in case of malfunction, and the strip lot number, if relevant. In general, capillary or venous blood is used for glucose measurement. The terms plasma or capillary whole-blood calibration, however, are sometimes not clearly specified (37). The International Federation of Clinical Chemistry and Laboratory Medicine (IFCC) recommends reporting all results as glucose concentration in plasma to avoid misunderstanding (38). Blood glucose systems used in clinical trials should have been demonstrated to meet the requirements of the International Organization for Standardization (ISO) 15197:2013, which state that 95% of the blood glucose

Table 3—Recommendations on the use and reporting of SMBG in clinical research

	Characteristics
Study protocol/methods	• Type of blood glucose meter and test strips that were used in the trial; SMBG should be performed in a structured approach (frequency and timing) • Blood glucose results should be reported as glucose concentration in plasma • Level and details of education of patients included in studies on how to perform and interpret SMBG (e.g., algorithms for modification of treatment) • Blood glucose targets in the study • Definition of hypoglycemia
Results	• Adherence to study protocol • Pre- and postprandial blood glucose levels • Glycemic excursions (e.g., mean amplitude of glycemic excursions) • Modification of treatment based on SMBG results
Discussion	• Results of SMBG • Effects of results on SMBG on treatment modifications • Hypoglycemic episodes • Relationship between SMBG and HbA_{1c} • Compliance with SMBG regimen and its impact on outcomes
Minimum set of data required for reporting	• Type of blood glucose meter and test strips that were used • Blood glucose goals during the study • Definition and frequencies of hypoglycemia • Pre- and postprandial blood glucose levels • Glycemic variability

results shall fall within ±15 mg/dL of the reference method at blood glucose concentrations <100 mg/dL and within ±15% at blood glucose concentrations ≥100 mg/dL (39). The use of blood glucose systems, which do not need calibration, is associated with a reduced risk of handling errors (39). It may also be necessary to describe which test strips are used (37). It should be noted that accuracy may be affected even by small strip-to-strip variations (e.g., in the size or enzyme coverage of reaction wells) (30). Test strip performance may also be compromised by various environmental conditions (40)

- The training of participants in performing capillary glucose measurements
- The training of participants on using a control solution to document glucose meter accuracy
- Frequency and timing of capillary glucose measurements for study purposes when a structured SMBG regimen is used. According to current recommendations and guidelines, postprandial glucose measurements should be conducted 1–2 h after the beginning of a meal (1,41)
- Recording (diary or glucose meter memory or both), storage, and retrieval of SMBG data (download on a computer through a cable or wireless transmission, transfer to a remote server or cloud, and access to SMBG data by the patient and the diabetes team). In order to reduce potential data entry errors, the use of software for downloading blood glucose measurement results from the glucose meter may be preferred
- Glucose control targets for participants during the study
- The intended use of SMBG data by the patient and the diabetes team
- The training of participants (changes in lifestyle or insulin dose) and the diabetes team (adjustment of treatment with insulin and to a limited degree with GLP-1 analogs and oral medications) and the algorithm(s) used
- What to do in case of low (defined) and high (defined) capillary glucose values (treatment and reporting to the diabetes team)
- The need to avoid judgmental responses to glucose levels out of range with the aim to use the glucose data to direct management

Varying definitions of hypoglycemia are given in the literature, particularly in trials assessing glucose-lowering therapies (42). Using a blood glucose cutoff of ≤3.9 mmol/L [70 mg/dL], more than 40% of patients with type 2 diabetes starting insulin treatment have been found to experience hypoglycemia (42). The cutoff reflects the understanding that many of these events may be asymptomatic. This cutoff of ≤3.9 mmol/L [70 mg/dL] is widely accepted (41,43). In the framework of clinical trials, we recommend the use of a definition that focuses on clinical relevance. Implausible and confusing measurement readings, particularly with discrepancies between the blood glucose value and clinical signs, should be verified by one or more retests. In this regard, the limitations in precision and accuracy of glucose meters have to be considered (11).

In case of clinical trials lasting several months or longer, the study protocol should incorporate strategies for how to encourage patients to continue to comply with the planned SMBG schedule over time.

If SMBG data are an outcome of the trial (usually secondary), the statistical section of the study protocol and analysis protocol should detail the following:

- Which SMBG data points (all or specific measurements, e.g., fasting glucose, postprandial, postprandial excursions, nocturnal) and which period (e.g., SMBG of the month or week prior to the visit) will be analyzed
- The percentage of capillary glucose measurements required by the study protocol that defines participants as sufficiently compliant with SMBG
- How to handle extra capillary glucose measurements, i.e., measurements performed in addition to those required by the study protocol

An important issue, although still underestimated, is reporting the compliance of the diabetes team to the study protocol when responding to the participants' SMBG data.

Results Section

In many clinical trials, the main purpose of SMBG performance is to guide changes in the adjustment of diabetes medications. In these cases, SMBG readings are a "dynamic" measure, thus difficult to report in detail, rather than just as an end point. Nevertheless, it has to

be remembered that SMBG is not a therapeutic tool but rather a diagnostic and monitoring tool and should be performed with a structured educational and therapeutic format in response to SMBG data (11,36). With the view of better comparability of clinical studies, the following topics are recommended to be addressed in the results section:

- Number (percent) of patients who performed SMBG throughout the entire study in each study arm
- Percent of participants in each study arm performing SMBG according to the study protocol
- Evaluation of the performance of the blood glucose systems
- Preprandial, postprandial, and nocturnal glucose levels (point of time of measurement)
- Postprandial glycemic excursions (e.g., the difference between post- and preprandial glucose values, data generated by 7–10 point blood glucose profiles can be used for the determination of the mean amplitude of glycemic excursions or other measures of within-day variation)
- Within-person between-day variation at any point of time
- Details on how diabetes treatment was modulated based on SMBG data
- Differences in SMBG between the groups

Discussion/Conclusions Section

A discussion of aspects of SMBG is warranted in any study in which participants are required to perform SMBG. This may include the effects of SMBG on diabetes management (either lifestyle changes or adjustment of medication), detection of asymptomatic hypoglycemia, outcomes and variation at particular times of day, and correlation with HbA_{1c}. Furthermore, compliance with the SMBG regimen and the overall effect of SMBG on study outcomes should be discussed.

SUMMARY AND CONCLUSION

SMBG is widely used in clinical trials. Researchers recognize the importance of documenting glycemic variability, postprandial glucose excursions, and symptomatic and asymptomatic hypoglycemic episodes in their study participants. Furthermore, SMBG data are often used in clinical trials to guide the prescription and dosage of diabetes medications according to specific algorithms. Looking ahead, data-management technology, which appears to facilitate daily diabetes management (44), may gain increasing relevance in studies.

In the scientific literature, however, information on the implementation of SMBG in clinical trials and reporting of SMBG data are often lacking or incomplete. We, therefore, recommend a more standardized approach for SMBG in trial protocols as well as in publications where applicable. That may improve the comparability and scientific force of clinical studies. Research should aim at being highly efficient, being meaningful to the community, and avoiding the need for renewed examination. Therefore, an accurate description of how SMBG should be performed and applied in study protocols is required. Subsequently, all relevant findings and aspects related to SMBG should be reported. As a result, we expect that the comparability and scientific force of clinical studies will be enhanced and that it will become much easier to compare SMBG data across studies.

Duality of Interest. The medical writing of the manuscript was supported by an unrestricted research grant from Roche Diagnostics Germany GmbH. The idea to write the manuscript originates solely from the authors. None of the authors was compensated for writing the manuscript. O.S., K.B., R.B., E.B., S.G., B.G., T.H., I.B.H., L.J., S.R.J., M.K., L.L., C.M., W.H.P., F.S., and P.H., or institutions with which they are associated, all receive funding from manufacturers of blood glucose monitoring systems, including Roche Diagnostics, for their advisory, lecturing, and/or research activities. No other potential conflicts of interest relevant to this article were reported.

Author Contributions. O.S. was responsible for conception and design, drafting of the manuscript, critical revision of the manuscript for important intellectual content, and the final approval of the version to be published. K.B., R.B., E.B., S.G., B.G., T.H., I.B.H., L.J., S.R.J., M.K., L.L., C.M., W.H.P., and F.S. contributed input especially regarding their specialist field and critically revised the manuscript for important intellectual content. P.H. critically revised the manuscript for important intellectual content and conducted the final review.

References

1. International Diabetes Federation. *Guideline for Management of PostMeal Glucose in Diabetes* (Internet), 2011. Available from http://www.idf.org. Accessed April 2014
2. Rydén L, Grant PJ, Anker SD, et al.; ESC Committee for Practice Guidelines (CPG); Document Reviewers. ESC guidelines on diabetes, prediabetes, and cardiovascular diseases developed in collaboration with the EASD: the Task Force on Diabetes, Pre-Diabetes, and Cardiovascular Diseases of the European Society of Cardiology (ESC) and developed in collaboration with the European Association for the Study of Diabetes (EASD). Eur Heart J 2013;34:3035–3087
3. American Diabetes Association. Standards of medical care in diabetes—2013. Diabetes Care 2013;36(Suppl. 1):S11–S66
4. Breland JY, McAndrew LM, Burns E, Leventhal EA, Leventhal H. Using the Common Sense Model of Self-regulation to review the effects of self-monitoring of blood glucose on glycemic control for non-insulin-treated adults with type 2 diabetes. Diabetes Educ 2013;39:541–559
5. Gerstein HC, Bosch J, Dagenais GR, et al.; ORIGIN Trial Investigators. Basal insulin and cardiovascular and other outcomes in dysglycemia. N Engl J Med 2012;367:319–328
6. Gerstein H, Yusuf S, Riddle MC, Ryden L, Bosch J; ORIGIN Trial Investigators. Rationale, design, and baseline characteristics for a large international trial of cardiovascular disease prevention in people with dysglycemia: the ORIGIN Trial (Outcome Reduction with an Initial Glargine Intervention). Am Heart J 2008;155:26–32, 32.e1–6
7. Gerstein HC, Riddle MC, Kendall DM, et al.; ACCORD Study Group. Glycemia treatment strategies in the Action to Control Cardiovascular Risk in Diabetes (ACCORD) trial. Am J Cardiol 2007;99:34i–43i
8. The Diabetes Control and Complications Trial Research Group. The effect of intensive treatment of diabetes on the development and progression of long-term complications in insulin-dependent diabetes mellitus. N Engl J Med 1993;329:977–986
9. Benjamin EM. Self-monitoring of blood glucose: the basics. Clin Diabetes 2002;20:45–47
10. International Diabetes Federation. *Guideline on Self-Monitoring of Blood Glucose in Non-Insulin Treated Type 2 Diabetes* [Internet], 2009. Available from http://www.idf.org/guidelines/self-monitoring. Accessed April 2014
11. Klonoff DC, Blonde L, Cembrowski G, et al.; Coalition for Clinical Research-Self-Monitoring of Blood Glucose Scientific Board. Consensus report: the current role of self-monitoring of blood glucose in non-insulin-treated type 2 diabetes. J Diabetes Sci Tech 2011;5:1529–1548
12. Schnell O, Alawi H, Battelino T, et al. Self-monitoring of blood glucose in type 2 diabetes: recent studies. J Diabetes Sci Tech 2013;7:478–488
13. Bergenstal RM, Ahmann AJ, Bailey T, et al. Recommendations for standardizing glucose reporting and analysis to optimize clinical decision making in diabetes: the ambulatory glucose profile. J Diabetes Sci Tech 2013;7:562–578
14. Guerci B, Drouin P, Grangé V, et al.; ASIA Group. Self-monitoring of blood glucose significantly improves metabolic control in patients with type 2 diabetes mellitus: the Auto-Surveillance Intervention Active (ASIA) study. Diabetes Metab 2003;29:587–594
15. Sacks DB. A1C versus glucose testing: a comparison. Diabetes Care 2011;34:518–523

16. Farmer AJ, Perera R, Ward A, et al. Meta-analysis of individual patient data in randomised trials of self monitoring of blood glucose in people with non-insulin treated type 2 diabetes. BMJ 2012;344:e486
17. Polonsky WH, Fisher L, Schikman CH, et al. Structured self-monitoring of blood glucose significantly reduces A1C levels in poorly controlled, noninsulin-treated type 2 diabetes: results from the Structured Testing Program study. Diabetes Care 2011;34:262–267
18. Moreland EC, Volkening LK, Lawlor MT, Chalmers KA, Anderson BJ, Laffel LM. Use of a blood glucose monitoring manual to enhance monitoring adherence in adults with diabetes: a randomized controlled trial. Arch Intern Med 2006;166:689–695
19. Bosi E, Scavini M, Ceriello A, et al.; PRISMA Study Group. Intensive structured self-monitoring of blood glucose and glycemic control in noninsulin-treated type 2 diabetes: the PRISMA randomized trial. Diabetes Care 2013;36:2887–2894
20. Chaudhry T, Klonoff DC. SMBG out of control: the need for educating patients about control solution. Diabetes Educ 2013;39:689–695
21. Clar C, Barnard K, Cummins E, Royle P, Waugh N; Aberdeen Health Technology Assessment Group. Self-monitoring of blood glucose in type 2 diabetes: systematic review. Health Technol Assess 2010;14:1–140
22. Solnica B, Naskalski JW. Quality control of self-monitoring of blood glucose: why and how? J Diabetes Sci Tech 2007;1:164–168
23. Blevins T. Value and utility of self-monitoring of blood glucose in non-insulin-treated patients with type 2 diabetes mellitus. Postgrad Med 2013;125:191–204
24. Goldstein DE, Little RR, Lorenz RA, Malone JI, Nathan DM, Peterson CM; American Diabetes Association. Tests of glycemia in diabetes. Diabetes Care 2003;26(Suppl. 1):S106–S108
25. Nauck M, Frid A, Hermansen K, et al.; LEAD-2 Study Group. Efficacy and safety comparison of liraglutide, glimepiride, and placebo, all in combination with metformin, in type 2 diabetes: the LEAD (Liraglutide Effect and Action in Diabetes)-2 study. Diabetes Care 2009;32:84–90
26. Wilding JP, Norwood P, T'joen C, Bastien A, List JF, Fiedorek FT. A study of dapagliflozin in patients with type 2 diabetes receiving high doses of insulin plus insulin sensitizers: applicability of a novel insulin-independent treatment. Diabetes Care 2009;32:1656–1662
27. Writing Team for the Diabetes Control and Complications Trial/Epidemiology of Diabetes Interventions and Complications Research Group. Effect of intensive therapy on the microvascular complications of type 1 diabetes mellitus. JAMA 2002;287:2563–2569
28. Hirsch IB. Home blood glucose monitoring in type 2 diabetes: broken health care system undermines study's impact. Diabetes Care 2011;34:527–528
29. Breton MD, Kovatchev BP. Impact of blood glucose self-monitoring errors on glucose variability, risk for hypoglycemia, and average glucose control in type 1 diabetes: an in silico study. J Diabetes Sci Tech 2010;4:562–570
30. Ginsberg BH. Factors affecting blood glucose monitoring: sources of errors in measurement. J Diabetes Sci Tech 2009;3:903–913
31. Hirsch IB, Bode BW, Childs BP, et al. Self-monitoring of blood glucose (SMBG) in insulin- and non-insulin-using adults with diabetes: consensus recommendations for improving SMBG accuracy, utilization, and research. Diabetes Technol Ther 2008;10:419–439
32. Welschen LM, Bloemendal E, Nijpels G, et al. Self-monitoring of blood glucose in patients with type 2 diabetes mellitus who are not using insulin. Cochrane Database Syst Rev 2005;2:CD005060
33. Monnier L, Mas E, Ginet C, et al. Activation of oxidative stress by acute glucose fluctuations compared with sustained chronic hyperglycemia in patients with type 2 diabetes. JAMA 2006;295:1681–1687
34. Nalysnyk L, Hernandez-Medina M, Krishnarajah G. Glycaemic variability and complications in patients with diabetes mellitus: evidence from a systematic review of the literature. Diabetes Obes Metab 2010;12:288–298
35. Kohnert KD, Augstein P, Heinke P, et al. Chronic hyperglycemia but not glucose variability determines HbA1c levels in well-controlled patients with type 2 diabetes. Diabetes Res Clin Pract 2007;77:420–426
36. Martin S, Schneider B, Heinemann L, et al. Self-monitoring of blood glucose in type 2 diabetes and long-term outcome: an epidemiological cohort study. Diabetologia 2006;49:271–278
37. Schnell O, Hinzmann R, Kulzer B, et al. Assessing the analytical performance of systems for self-monitoring of blood glucose: concepts of performance evaluation and definition of metrological key terms. J Diabetes Sci Tech 2013;7:1585–1594
38. D'Orazio P, Burnett RW, Fogh-Andersen N, et al.; International Federation of Clinical Chemistry Scientific Division Working Group on Selective Electrodes and Point of Care Testing. Approved IFCC recommendation on reporting results for blood glucose (abbreviated). Clin Chem 2005;51:1573–1576
39. International Organization for Standardization. In vitro diagnostic test systems–requirements for blood-glucose monitoring systems for self-testing in managing diabetes mellitus. EN ISO/DIS 15197 [Internet], 2013. Available from http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=54976. Accessed 13 July 2015
40. Tonyushkina K, Nichols JH. Glucose meters: a review of technical challenges to obtaining accurate results. J Diabetes Sci Tech 2009;3:971–980
41. American Diabetes Association. Standards of medical care in diabetes: introduction. Diabetes Care 2015;38(Suppl. 1):S1–S2
42. Swinnen SG, Mullins P, Miller M, Hoekstra JB, Holleman F. Changing the glucose cut-off values that define hypoglycaemia has a major effect on reported frequencies of hypoglycaemia. Diabetologia 2009;52:38–41
43. European Medicines Agency. Guideline on clinical investigation of medicinal products in the treatment or prevention of diabetes mellitus [Internet], 2012. Available from http://www.ema.europa.eu/docs/en_GB/document_library/Scientific_guideline/2012/06/WC500129256.pdf. Accessed 26 February 2015
44. Rao A, Hou P, Golnik T, Flaherty J, Vu S. Evolution of data management tools for managing self-monitoring of blood glucose results: a survey of iPhone applications. J Diabetes Sci Tech 2010;4:949–957