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ARTICLE

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Self-monitoring of blood glucose in type 2 diabetes and long-term outcome: an epidemiological cohort study

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Abstract *Aims/hypothesis:* The aim of this study was to obtain epidemiological data on self-monitoring of blood glucose (SMBG) in type 2 diabetes and to investigate the relationship of SMBG with disease-related morbidity and mortality. *Methods:* The German multicentre Retrolective Study 'Self-monitoring of Blood Glucose and Outcome in Patients with Type 2 Diabetes' (ROSSO) followed 3,268 patients from diagnosis of type 2 diabetes between 1995 and 1999 until the end of 2003. Endpoints were diabetes-related morbidity (non-fatal myocardial infarction, stroke, foot amputation, blindness or haemodialysis) and all-cause mortality. SMBG was defined as self-measurement of blood glucose for at least 1 year. *Results:* During a mean follow-up period of 6.5 years, 1,479 patients (45.3%) began SMBG prior to an endpoint and an additional 64 patients started SMBG after a non-fatal endpoint. Interestingly, many patients used SMBG while being treated with diet or oral hypoglycaemic drugs (808 of 2,515, 32%). At baseline, the SMBG cohort had higher mean fasting blood glucose levels than the non-SMBG cohort ($p<0.001$), suggesting that insufficient metabolic control was one reason for initiating SMBG. This was associated with a higher rate of microvascular endpoints. However, the total rate of non-fatal events, micro- and macrovascular, was lower in the SMBG group than in the non-SMBG group (7.2 vs 10.4%, $p=0.002$). A similar difference was found for the rate of fatal events (2.7 vs 4.6%, $p=0.004$). Cox regression analysis identified SMBG as an independent predictor of morbidity and mortality, with adjusted hazard ratios of 0.68 (95% CI 0.51–0.91, $p=0.009$) and 0.49 (95% CI 0.31–0.78, $p=0.003$), respectively. A better outcome for both endpoints was also observed in the SMBG cohort when only those patients who were not receiving insulin were analysed. *Conclusions/interpretation:* SMBG was associated with decreased diabetes-related morbidity and all-cause mortality in type 2 diabetes, and this association remained in a subgroup of patients who were not receiving insulin therapy. SMBG may be associated with a healthier lifestyle and/or better disease management.

Keywords Blood glucose · Cohort study · Long-term outcome · Observational study · Retrospective · Self-monitoring · SMBG · Type 2 diabetes

Abbreviations HR: hazard ratio · ROSSO: Retrolective Study 'Self-monitoring of Blood Glucose and Outcome in Patients with Type 2 Diabetes' · SMBG: self-monitoring of blood glucose · UKPDS: UK Prospective Diabetes Study

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Introduction

Since the first description of regular self-monitoring of blood glucose (SMBG) [1, 2] there has been a long-standing controversy among diabetologists as to whether, and to what extent, patients with type 2 diabetes should perform self-monitoring [3, 4]. Several studies that evaluated the influence of SMBG on glycaemic control support the usefulness of SMBG for these patients [5–11]; how-

ever, other studies do not [12–16]. A position statement from the American Diabetes Association recommends daily blood glucose self-measurement for pharmacologically (insulin or oral hypoglycaemic drugs) treated patients with type 2 diabetes [17]. Two meta-analyses recently evaluated published randomised trials: Sarol et al. [18] found eight randomised controlled trials on SMBG in non-insulin-receiving patients with type 2 diabetes, while Welschen et al. [19] identified six. Both meta-analyses concluded that multi-component treatment strategies produced significantly greater reductions in HbA_1c levels when SMBG was included. The arguments for and against SMBG in patients with type 2 diabetes were recently summarised [20, 21]. Unfortunately, none of the prospective studies was extended over a period of several years, precluding analysis of clinical endpoints.

In routine patient care, the metabolic control of type 2 diabetes patients performing SMBG was worse than in patients not using SMBG, which seems to reflect the more serious disease stage of patients who undertake SMBG [22]. Nevertheless, the possibly healthier lifestyle and better treatment regimen of patients performing SMBG may reduce the risk of diabetic complications. Therefore, the Retrolective Study 'Self-monitoring of Blood Glucose and Outcome in Patients with Type 2 Diabetes' (ROSSO) was designed to document patients from diagnosis for a period of several years to obtain data on the use of SMBG and the occurrence of diabetes-related morbidity and all-cause mortality.

Subjects and methods

Subjects and protocol

The study was a retrospective, comparative, epidemiological cohort study with a parallel-group design and with statistical balancing of the baseline differences between the two cohorts. Documentation included patient demographics, history and follow-up (from the time of diagnosis of diabetes), and characteristics of the treatment centre. This information was later included in an analysis for potential confounders. Where applicable, the study was conducted according to Good Clinical Practice (GCP) guidelines.

A list of more than 3,000 randomly selected primary care practices throughout Germany was generated and physicians were contacted by phone. Recruitment was stopped after information on more than 3,000 patients was contributed by 192 practices. Of these practices, 143 (74.5%) were managed by a general practitioner and 49 (25.5%) by an internist. Based on medical records, data were collected from all patients who were initially diagnosed with type 2 diabetes between 1 January 1995 and 31 December 1999. Only those patients for whom information was available on age, sex, diabetes therapy and SMBG, both for the time of diabetes diagnosis and at least one subsequent year, were included. Subjects who were diagnosed with diabetes prior to the age of 45 years were excluded.

Each enrolled patient was evaluated from the time of diagnosis of diabetes to withdrawal (e.g. following a fatal event) or to the study cut-off date, which was the end of 2003. Data were extracted from the physicians' medical records, documented in specifically designed case record forms according to standard operating procedures, and were validated for completeness and correctness by study monitors. The participating centres ensured that the patients' identities were not revealed to the monitors; therefore, no informed consent from the patient was necessary. The study protocol was presented to the Ethics Committee of the General Medical Council of North Rhine, Germany, and, due to the retrospective study design, the council indicated no responsibility. Double data entry was employed to reduce transcription errors when creating the study database. The data collection period lasted from November 2003 until June 2004.

Data from 3,275 patients were acquired. Seven of these patients did not meet the inclusion criteria and were therefore excluded from the study: two patients were less than 45 years old at diabetes diagnosis and five patients had inadequate follow-up (one patient died from a malignant tumour in the year following diabetes diagnosis and only baseline data were available for four patients). Thus, data on 3,268 patients were included in the analysis.

Predefined study endpoints were morbidity (non-fatal endpoints), defined as myocardial infarction, stroke, foot amputation, blindness (one or both eyes) or end-stage renal failure requiring haemodialysis, and all-cause mortality (fatal endpoints). All endpoints were taken as documented in the medical records. Analysis of non-fatal endpoints was based on the first event occurring in a patient during the observation period. In the mortality analysis, non-fatal events were ignored. Blood values that were used for the statistical analysis, including fasting blood glucose values, were from laboratory analysis. Since HbA_1c assays are not standardised, all values were adjusted such that 6.1% was treated as the upper limit of the normal range at each laboratory.

Statistical analysis

Differences in numeric baseline and follow-up data between patients with and without SMBG were assessed using two-sided t tests. A p value below 0.05 was considered statistically significant. Differences in the incidence of non-fatal and fatal endpoints were analysed with Fisher's exact test. Unadjusted hazard ratios (HR) were calculated. The main target variable was the time from the date of diabetes diagnosis to a non-fatal or fatal endpoint (survival time). A survival analysis was performed based on Kaplan–Meier estimates. Differences in survival distribution were tested for statistical significance using the log-rank test. To adjust for potential confounders when calculating the influence of SMBG on non-fatal and fatal endpoints, estimates of HR and associated 95% CIs were determined using the Cox proportional hazards model. SMBG was the primary covariable, and various parameters with a potential

influence on the endpoints were further covariables. Statistical analysis was undertaken with SPSS+ for Windows, versions 11.5 and 12.0 (SPSS, Chicago, IL, USA).

Results

Characteristics of the study cohort

Demographics and baseline data are provided in Table 1. Sex distribution of the complete cohort was balanced (1,609 males, 1,659 females); however, male patients were younger than female patients (mean age 60.1 vs 64.6 years, $p<0.001$). Mean follow-up time (±SD) was 6.5±1.6 years.

After diabetes diagnosis, 54.0% of the patients initially received no pharmacological treatment, and this proportion declined to 12.7% by year 8, the final year of follow-up (Fig. 1). Accordingly, the percentage of patients receiving treatment with hypoglycaemic drugs increased during the observation period. The proportion of patients receiving insulin monotherapy increased from 2.9 to 16.8%, those receiving a combination of insulin plus sulfonylurea rose from 0.7 to 4.9%, while those taking combinations of insulin with other oral hypoglycaemic drugs increased from 1.7 to 10.8%. The proportion of patients treated with metformin (alone or in combination with other hypoglycaemic drugs) rose from 18.9 to 43.2%, and the respective increase for patients on sulfonylureas was from 27.2 to 44.8%. The proportion of patients receiving monotherapy with α-glucosidase inhibitors decreased from 3.8 to 1.0%, while the total use of α-glucosidase inhibitors remained constant at 8–10% during follow-up.

SMBG and non-SMBG cohorts

Patients were allocated to the SMBG group if SMBG was documented in the medical records for at least 1 year during the observation period and prior to a non-fatal endpoint. The baseline characteristics of patients without SMBG (n=1,789) and those with SMBG (n=1,479) are provided in Table 1.

SMBG was initiated in 29.2% of the total SMBG cohort in the year of diagnosis, in 15.9% in the year after diagnosis, in 11.0% in the second year after diagnosis, in 11.8% in the third year after diagnosis, in 10.8% in the fourth year after diagnosis, in 8.3% in the fifth year after diagnosis, in 6.7% in the sixth year after diagnosis, and in 6.4% in the seventh and eighth year together. The mean time before the first event was 2.5±2.3 years. An additional 64 patients started SMBG after a non-fatal endpoint. Of those patients who did not receive insulin over the complete observation period, 32% (808 out of 2,515) used SMBG, while 11% (66 out of 603) of those who did not receive any pharmaceutical treatment used SMBG. Pharmacological therapy for glycaemic control occurred more often in the SMBG cohort than in the non-SMBG cohort ($p<0.001$). The percentages of patients in the SMBG and non-SMBG

Table 1 Baseline characteristics of the study cohort and subgroups

Characteristic	All patients	Patients		
	n=3,268	Without SMBG (n=1,789)	With SMBG[a] (n=1,479)	p value[b]
Male, n (%)	1,609 (49.2)	831 (46.5)	778 (52.6)	0.001
Age (years)	62.4±9.6	64.0±9.7	60.5±9.1	<0.001
	n=3,268	n=1,789	n=1,479	
BMI (kg/m^2)	29.8±5.1	29.8±5.2	29.9±5.0	0.604
	n=2,460	n=1,336	n=1,124	
Systolic blood pressure (mmHg)	149±20.3	150±19.8	148±20.9	0.013
	n=2,696	n=1,490	n=1,206	
Diastolic blood pressure (mmHg)	87±10.9	87±10.5	87±11.3	0.484
	n=2,697	n=1,491	n=1,206	
Fasting blood glucose (mmol/l)	9.26±3.78	8.66±3.25	10.05±4.24	<0.001
	n=2,868	n=1,622	n=1,246	
HbA_1c (adjusted) (%)[c]	7.7±2.1	7.2±1.7	8.1±2.4	<0.001
	n=1,486	n=779	n=707	
Total cholesterol (mmol/l)	6.11±1.29	6.12±1.23	6.09±1.37	0.501
	n=2,352	n=1,327	n=1,025	
LDL-cholesterol (mmol/l)	3.85±1.10	3.87±1.10	3.83±1.10	0.628
	n=783	n=447	n=336	
HDL-cholesterol (mmol/l)	1.24±0.59	1.24±0.43	1.24±0.75	0.945
	n=986	n=556	n=430	
Triglycerides (mmol/l)	2.63±2.16	2.45±1.80	2.86±2.54	<0.001
	n=1,906	n=1,084	n=822	

[a]Comprises patients with SMBG (documented for at least 1 year) during the observation period and prior to a non-fatal endpoint
[b]p value for difference between the two subgroups (male sex distribution: Fisher's exact test; other variables: two-sided t test)
[c]HbA_1c adjusted to 6.1% as upper limit of normal range using the following formula: (HbA_1c/6.1) × upper limit of normal range

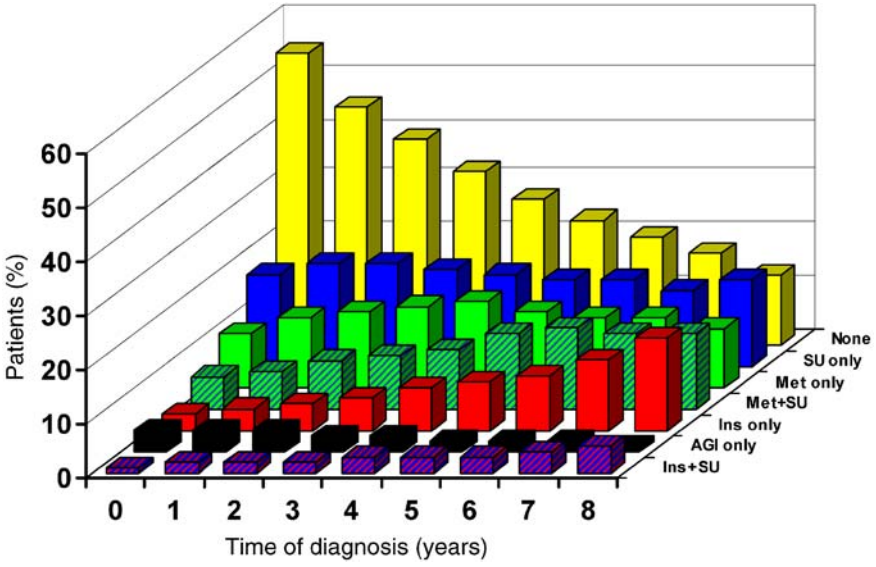

Fig. 1 Percentage of patients with specific diabetes treatment in each year of the follow-up period. Year 0 denotes the year of diabetes diagnosis. *AGI* α-glucosidase inhibitors, *Ins* insulin, *Met* metformin, *SU* sulfonylureas

groups who received hypoglycaemic medication for at least 1 year were as follows: 46.6 vs 7.0% for insulin, 65.7 vs 47.9% for metformin, 66.9 vs 49.3 % for sulfonylurea, and 23.2 vs 14.6% for α-glucosidase inhibitor. There was no interaction between SMBG and the type of oral hypoglycaemic medication chosen.

Significant baseline differences were observed between the two groups with respect to some parameters: patients undertaking SMBG during follow-up were younger, had inferior metabolic control (higher HbA_1c, fasting blood glucose and triglyceride values) and a lower systolic blood pressure. There was a higher proportion of men in the SMBG group (Table 1).

For all patients, after an initial reduction (between the time of diabetes diagnosis and 1 year later), mean fasting blood glucose and HbA_1c remained unchanged for the remainder of the observation period (Fig. 2). However, for each year, fasting blood glucose and HbA_1c remained significantly higher ($p<0.001$, t test) in the SMBG group than in the group without SMBG (Fig. 2). Using the Bonferroni correction, a significant difference was found for multiple comparison of all years. Patients in the SMBG cohort had significantly more visits to the treating physician (mean number of visits per year 18±12 in the SMBG cohort vs 16±18 in the non-SMBG cohort, $p<0.001$). During follow-up after diabetes diagnosis there were no significant differences between the two cohorts with regard to mean serum levels of triglycerides, total cholesterol or mean blood pressure values. A comparison of the percentage of patients treated with thrombocyte aggregation inhibitors, lipid-lowering drugs or blood pressure-lowering drugs for each year revealed no indication of more aggressive treatment in the SMBG cohort. The percentage of smokers was similar in the two groups (data not shown).

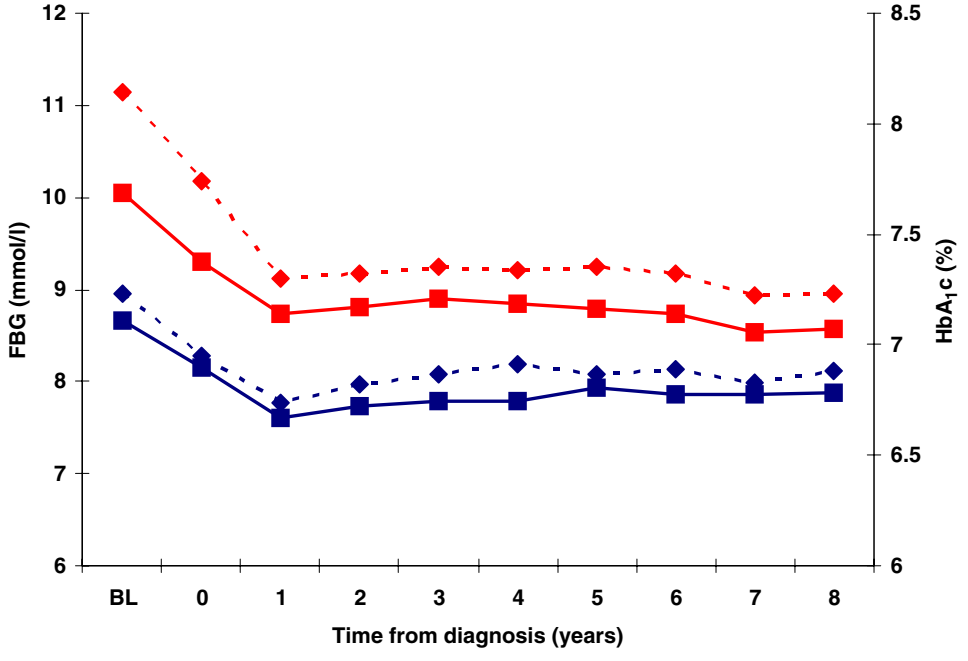

Fig. 2 Fasting blood glucose (FBG) and HbA_1c at baseline (BL) and during follow-up. The SMBG cohort comprises patients with SMBG documented for at least 1 year during the observation period and prior to a non-fatal endpoint. The data show arithmetic means. *Red symbols*, SMBG cohort; *blue symbols*, non-SMBG cohort; *continuous lines*, FBG; *dashed lines*, HbA_1c. HbA_1c adjusted to 6.1% as upper limit of normal range. Year 0 denotes the year of diagnosis of diabetes. If more than one measurement was available for a given patient for any year, the arithmetic mean was calculated

Influence of SMBG on non-fatal and fatal endpoints

During the observation period, 293 patients (9.0%) experienced a non-fatal endpoint. Of these patients, 186 had not undertaken SMBG prior to the event, while 107 patients had. The resulting incidence of non-fatal endpoints in the two cohorts was 10.4 and 7.2%, respectively (p=0.002). Kaplan–Meier analysis (Fig. 3a) demonstrated superior survival (in terms of freedom from a non-fatal endpoint) for patients with SMBG than for patients without SMBG over the entire observation period (p<0.001, unadjusted HR=0.63, 95% CI 0.50–0.80). Of the 120 patients (3.7%) who died during the follow-up period, 79 had not performed SMBG and 41 had performed SMBG, resulting in incidence rates of 4.6 and 2.7% for fatal endpoints in the two groups, respectively (p=0.004). Kaplan–Meier analysis (Fig. 3b) revealed superior survival of patients with SMBG for all time points investigated (p<0.001, unadjusted HR=0.52, 95% CI 0.36–0.76).

Of the subgroup of 2,515 patients who did not receive insulin during the observation period or prior to an event, 231 patients (9.2%) experienced a non-fatal endpoint and 93 patients (3.7%) died. The incidence of non-fatal endpoints was 10.4% (177 of 1,707) for patients without and 6.7% (54 of 808) for patients with SMBG prior to the event (p=0.002). Furthermore, 4.3% (71 of 1,649) of patients without and 2.5% (22 of 866) of patients with SMBG (p=0.026) died. Kaplan–Meier analyses demonstrated that SMBG was associated with a reduced risk of non-fatal (p<0.001, HR=0.60, 95% CI 0.44–0.82) (Fig. 3d) and fatal endpoints (p=0.010, HR=0.54, 95% CI 0.33–0.87) (Fig. 3d).

This reduction in the risk of non-fatal endpoints was mainly due to a decreased risk of macrovascular endpoints

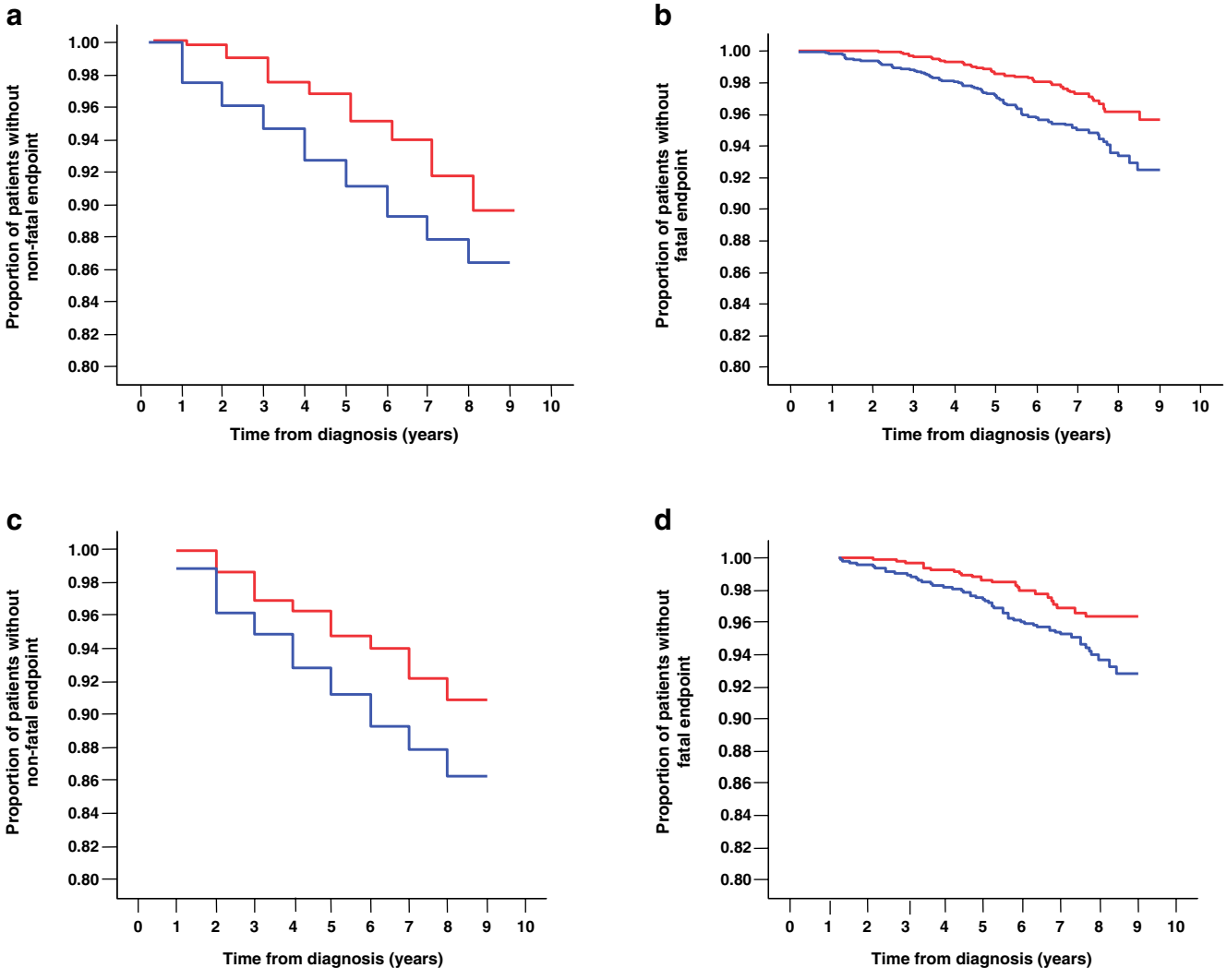

Fig. 3 Kaplan–Meier survival curves for non-fatal and fatal endpoints in patients with and without SMBG. The values shown in **(a)** and **(b)** are from analyses including all patients, while those presented in **(c)** and **(d)** are from analyses excluding patients with insulin treatment. *Red symbols*, SMBG group; *blue symbols*, non-SMBG group. Only patients with SMBG for at least 1 year prior to the event were included in the SMBG group. Patients with SMBG showed better survival with respect to non-fatal and fatal endpoints (both p<0.001, log-rank test). The effect of SMBG on survival was also evident in the subgroup of patients who did not receive insulin treatment (p<0.001 for non-fatal and fatal endpoints, log-rank test)

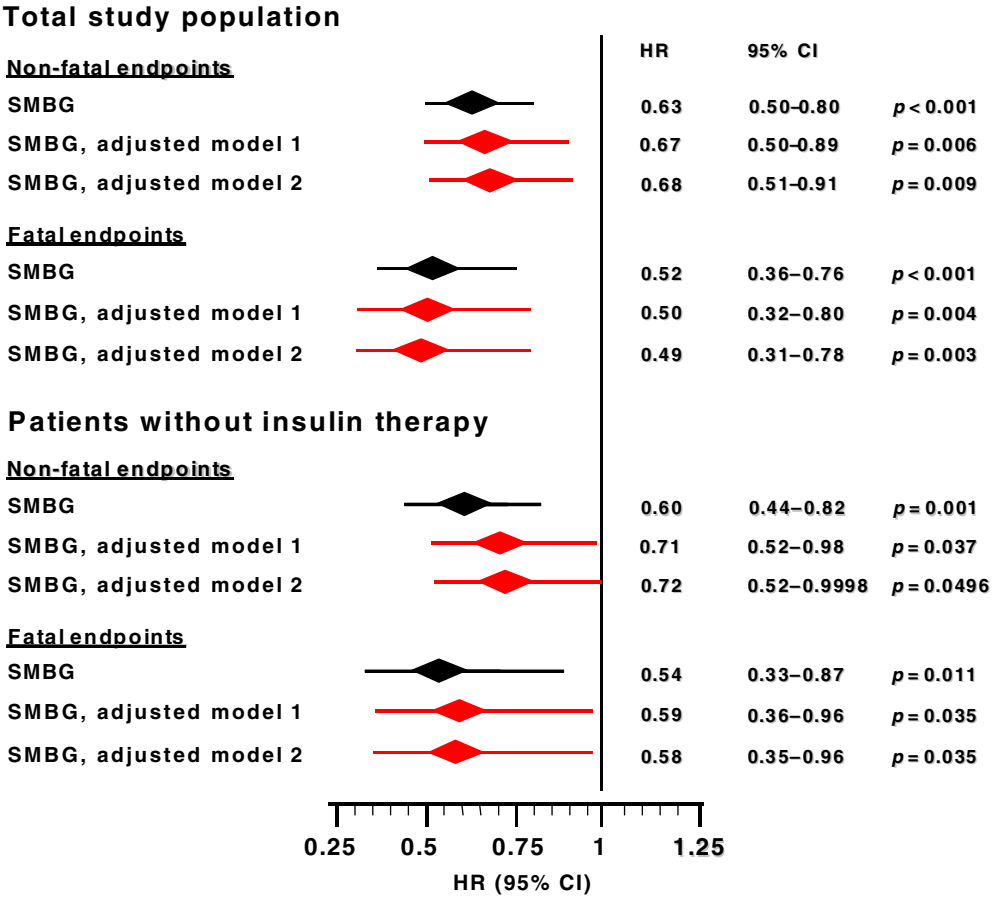

Fig. 4 Cox regression analysis: unadjusted and adjusted HR for fatal and non-fatal endpoints for patients using SMBG. Estimates were obtained by Cox regression using a proportional HR model. Adjustments: in Model 1, the factors SMBG, age, sex, concomitant diseases at diabetes diagnosis (hypertension, CHD, history of stroke), laboratory values (fasting blood glucose, triglycerides) and treatment are considered. Model 2 comprises the factors of Model 1 and additional non-disease-related potential confounders, such as qualification of the treating physician (general practitioner, internist), centre size (number of newly diagnosed patients with type 2 diabetes during 1995–1999), centre location (small town, city), patient's habitation (small town, city) and patient's health insurance (public, private). After adjustment for the mentioned confounders, use of SMBG resulted in reduced HR for non-fatal and fatal endpoints

(myocardial infarction and stroke, incidence 5.7 vs 10.0%, $p<0.001$), whereas microvascular endpoints (foot amputation, loss of eyesight, dialysis) occurred almost twice as often in the SMBG group (incidence 2.5 vs 1.5%, $p<0.03$).

Cox regression analysis for potential confounders was undertaken for all patients as well as for the subgroup of patients who did not receive insulin treatment (Fig. 4). In Model 1, in addition to SMBG, adjustments were made for baseline differences in age, sex, concomitant diseases at diabetes diagnosis (hypertension, CHD, history of stroke), laboratory values (fasting blood glucose, triglycerides) and treatment. As well as these factors, Model 2 was adjusted for additional non-disease-related potential confounders. These included the qualification of the treating physician (general practitioner, internist), the centre size (number of newly diagnosed patients with type 2 diabetes during 1995–1999), centre location (small town, city), patient's habitation (small town, city), and patient's health insurance (public, private). According to Model 1, Cox regression analysis of non-fatal endpoints in all patients yielded an adjusted HR=0.67 (p=0.006, 95% CI 0.50–0.89) for SMBG and 0.50 (p=0.004, 95% CI 0.32–0.80) for fatal endpoints (Fig. 4).

The adjusted HR changed only slightly using Model 2 (non-fatal endpoints: HR=0.68, 95% CI 0.51–0.91, p=0.009; fatal endpoints: HR=0.49, 95% CI 0.31–0.78, p=0.003). In both models, adjustment to equal baseline and treatment conditions resulted in only slight changes compared with the unadjusted HR. Thus, after accounting for the inhomogeneities between the patient characteristics, SMBG reduced the HR for a non-fatal endpoint by about one-third and that for a fatal endpoint by about one-half. In the subgroup of patients who did not receive insulin treatment, SMBG significantly reduced the HR for a non-fatal endpoint by approximately one-third and the HR for a fatal endpoint by more than 40% (Fig. 4) according to analysis using either model, with or without adjustment for confounders.

Discussion

This epidemiological cohort study observed a different clinical outcome in patients with type 2 diabetes mellitus using SMBG vs those who did not perform SMBG. After adjustment for potential confounders, HR indicated that SMBG was associated with a 32% reduction in combined non-fatal endpoints, despite an increase of microvascular events, and a 51% reduction in mortality over the observation period. This substantial difference remained when we analysed only those patients who did not receive insulin therapy, or when statistical adjustments were performed for the type of hypoglycaemic treatment received by patients in the two cohorts.

In our study we observed reasonably acceptable values for fasting blood glucose and HbA_1c levels in the first year

after diabetes diagnosis in the two groups, and these did not change during follow-up. This is in contrast to the UK Prospective Diabetes Study (UKPDS), which demonstrated a significant worsening of metabolic control during the course of the study [23]. These discrepancies might be related to differences in the study population. Mean age and BMI were considerably lower in the UKPDS population than in the ROSSO population. The latter population exhibited baseline characteristics comparable with those reported in a recent population-based German diabetes survey [24]. The available data will allow a detailed comparison of the natural course of type 2 diabetes in the two studies, including the nature and incidence of diabetic complications.

The epidemiological data described here show that the SMBG cohort had worse metabolic control at baseline than the non-SMBG cohort. In a cross-sectional study, patients who undertook SMBG also exhibited higher HbA_1c levels, and it has been suggested that SMBG was used in response to insufficient metabolic control [22]. Early signs of microvascular complications may also play a part. In line with data from the UKPDS [23], the higher HbA_1c level in the SMBG cohort was associated with a higher incidence of non-fatal microvascular endpoints, while non-fatal macrovascular endpoints were lower in this group. Because macrovascular endpoints occurred about three times as often as microvascular endpoints, the overall rate of combined non-fatal endpoints was significantly lower in the SMBG cohort.

However, the difference in clinical outcome between the SMBG and non-SMBG cohorts remained even when no adjustment was made for metabolic control at baseline. In this context it is important to note that SMBG is a diagnostic procedure and that diagnostic measures themselves do not have a direct impact on the course of a disease. The apparent association of SMBG with better clinical outcome is probably complex in nature. For one, in diabetes management, compliance, disease awareness and empowerment of the patient play an important role. While lifestyle changes such as improved diet and exercise alone may have limited sustainability [25], the immediate feedback on the effects of diet and exercise that SMBG may provide could enhance patient empowerment. The consequences of type 2 diabetes are commonly downplayed by doctors, especially to those patients not receiving insulin therapy. Interestingly, it has been shown that patients who are not receiving insulin but who are using SMBG have an increased psychological burden [22]. In these patients, an SMBG frequency of at least once per day was related to significantly higher levels of distress and worries. In other studies, increased use of SMBG has been shown to be associated with improved medication compliance [8, 26]. We found that patients in the SMBG group visited the treating physician more frequently. These observations demonstrate that SMBG has the potential to change patients' attitudes to their disease.

Second, the physicians' attitudes to patients using SMBG may be altered. It may strengthen their ability to teach self-management skills and to motivate patients to make behavioural changes [27]. Clinical trials have demonstrated that intensive patient care by non-physician personnel, such as case managers or telephone-based contact, are efficacious in improving glycaemic control and cardiovascular risk parameters [28–30]. This underlines the importance of analysing the association of SMBG with long-term outcome using an observational study design. Thus, SMBG appears to be not only a diagnostic tool, but also a form of psychological intervention, as recently demonstrated in a meta-analysis on improvement in long-term glycaemic control in type 2 diabetes [31].

Third, SMBG may not be causally linked to better clinical outcome but, instead, act as a marker of persons of higher socioeconomic and educational status – since the cost of test strips is not reimbursed in Germany in the absence of insulin treatment – who have a healthier lifestyle and live in a healthier environment. This argument would lead to the conclusion that higher socioeconomic status is associated with worse metabolic control, which has not been observed [32]. When we tested subcohorts defined by parameters with some socioeconomic impact (age, sex, area of residency), the difference between SMBG and non-SMBG in terms of outcome remained.

There was no indication that the SMBG cohort received more aggressive treatment with thrombocyte aggregation inhibitors or lipid- or blood pressure-lowering drugs, or that the percentage of smokers was lower in this cohort. This was also illustrated by comparable mean values for serum lipids and blood pressure.

This study is limited by the fact that patients were not randomised, i.e. the data cannot provide formal proof of a benefit of SMBG or, rather, of SMBG-induced adaptations of disease treatment and lifestyle. Furthermore, there was insufficient information on the frequency of blood glucose measurements available from the medical records to analyse the impact of the frequency of SMBG on outcome, and no information was provided on how the decision to start SMBG was made. Another possibility that should be considered is that the SMBG cohort is enriched with a pathogenetic subtype with less macrovascular risk but more difficult mean glycaemic control.

Unfortunately, the benefit of SMBG cannot be probed in a placebo-controlled randomised trial. A placebo SMBG procedure is hardly feasible and is ethically questionable, particularly when considering a trial duration of several years to reach a sufficient number of non-fatal and fatal endpoints. The selection of compliant patients, specialised doctors and medical personnel for participation in an open but randomised controlled trial over several years would also be difficult, as has been pointed out recently [33]. In such circumstances, epidemiological studies provide valuable information that helps to assess the putative benefit of SMBG in type 2 diabetes under conditions of routine care.

In conclusion, the results of this retrospective cohort study demonstrate that SMBG is a marker of better clinical outcome. The differences between the SMBG and non-SMBG groups remained after adjustment for patients' or doctors' characteristics and when non-insulin-receiving patients alone were analysed.

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Duality of interest statement S. Martin and H. Kolb report having received lecture fees from speaking at the invitation of Roche Diagnostics. B. Schneider reports having received consulting fees from Roche Diagnostics. W.A. Scherbaum stated having received grant support from the Bundesministerium für Bildung und Forschung BMBF (German Ministry of Research) for a separate study investigating the role of SMBG in type 2 diabetes. V. Lodwig reports to be employed by the commercial entity that sponsored the study (Roche Diagnostics). L. Heinemann and H.-J. Kurth report that they are employees of the "Profil Institute for Metabolic Research GmbH" that received grant support for the ROSSO study. L. Heinemann is one of the shareholders of Profil.

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