

Cost Analysis of Self-Monitoring Blood Glucose in Nonintensively Managed Type 2 Diabetes

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Type 2 diabetes (T2D) poses a significant economic burden to health care systems.¹ Part of the cost associated with T2D includes the need for frequent assessment of an individual's glycemic status. Based on guidelines from the American Diabetes Association, glycemic status can be assessed using hemoglobin A_{1c} (HbA_{1c}) measurement, self-monitoring of blood glucose levels (SMBG), or continuous glucose monitoring (CGM).² Currently, most individuals with T2D use SMBG, which provides information on the prevailing glucose levels and may provide information about the impact of lifestyle and pharmacological interventions on glucose control while providing a warning system of impending dysglycemia.³

In recent years, there has been growing interest in the use of CGM to support diabetes care. One main advantage of CGM is its ability to observe glycemic excursions that cannot be captured using HbA_{1c} or traditional SMBG.⁴ Data obtained from CGM profiles include measures such as the time in range (TIR), which is the amount of time spent in the target glycemic range, or the glucose management indicator (GMI), which uses mean glucose levels over 10 to 14 days to estimate HbA_{1c}. Both TIR and GMI can be used to set glycemic targets and guide therapeutic decision-making.⁵ The use of CGM is expected to increase given recent evidence that derived measures from this technology, such as TIR, correlate with the broadly used HbA_{1c} biomarker and are also associated with the risk of long-term complications.⁶ However, most studies on CGM have focused on individuals with type 1 diabetes (T1D) or those with T2D using multiple daily injections of insulin.^{7,8} For individuals with nonintensively managed T2D (ie, those not using rapid-acting prandial insulin), there is emerging evidence on CGM use, including a recent randomized clinical trial comparing the effect of SMBG and CGM in patients with T2D using basal insulin.^{9,10} However, there is a paucity of real-world evidence on clinical outcomes and health care resource utilization (HCRU) comparing both technologies in individuals with nonintensively managed T2D. This is an important consideration given that access to diabetes-related technologies is already disproportionately low among populations bearing an excess burden of T2D and experiencing health disparities.¹¹

ABSTRACT

OBJECTIVES: To compare health care resource utilization (HCRU) and costs between self-monitoring of blood glucose (SMBG) and continuous glucose monitoring (CGM) users in adults with nonintensively managed type 2 diabetes (T2D).

STUDY DESIGN: Retrospective analysis of the MarketScan Databases.

METHODS: Adults with T2D using SMBG or initiating CGM between January 2018 and March 2019 were eligible for inclusion. Inclusion criteria were (1) 2 consecutive claims for T2D or 1 claim for T2D and a claim for glucose-lowering therapy, (2) at least 1 pharmacy claim for SMBG strips or CGM sensors, and (3) continuous enrollment for 1 year before and after the index date. Individuals with evidence of CGM in the preindex period, pregnancy, use of rapid-acting insulin or glucagon, type 1 diabetes, gestational diabetes, or secondary diabetes at any time during the study period were excluded. SMBG and CGM patients were matched using propensity score, and all-cause HCRU and costs during a 1-year period were compared.

RESULTS: A total of 3498 patients were included in each matched cohort. The per-patient per-year (PPPY) all-cause cost was \$20,542 in CGM users vs \$19,349 in SMBG users ($P < .001$). The PPPY cost of glucose-lowering medication was \$6312 in CGM users vs \$5606 in SMBG users ($P < .001$). No significant differences in the number of emergency department visits or hospitalizations were observed, but CGM users had more all-cause outpatient visits and office visits with an endocrinologist.

CONCLUSIONS: In adults with nonintensively managed T2D, SMBG appears to be less costly than CGM and is associated with lower pharmacy costs.

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The aim of this study was to compare all-cause HCRU and costs between SMBG and CGM in adults with nonintensively managed T2D in a real-world setting.

METHODS

Study Design and Population

This observational retrospective analysis was conducted using the Merative MarketScan Commercial and Medicare Databases. The target population consisted of patients with 1 pharmacy claim for either an SMBG strip or a CGM sensor between January 1, 2018, and March 31, 2019. The date of the first claim of an SMBG strip or CGM sensor was designated as the index date. To be included, patients were required to have at least 2 primary or secondary diagnoses of T2D (*International Classification of Diseases, Tenth Revision, Clinical Modification* code E11) or 1 primary or secondary diagnosis of T2D and 1 antidiabetes medication within 12 months. Patients were also required to be 18 years or older at the index date, to be continuously enrolled in the health plan for 12 months prior to and following the index date, and to have no claims for rapid-acting insulin or glucagon medication prior to and after the index date. Patients with evidence of CGM use during the preindex period, pregnancy, or gestational or secondary diabetes at any time during the study period were excluded. Patients with claims for both T1D and T2D were reclassified using a modified version of the Klompas algorithm.¹²

Demographic and Clinical Characteristics

Patient demographic and clinical characteristics were obtained during the preindex period and included age at index, gender, geographic region, health plan coverage, comorbidities and diabetes complications, Charlson Comorbidity Index (CCI) score, and types of antidiabetic medications (Table 1).

Outcomes Definition

Outcomes included all-cause HCRU and costs and were stratified by outpatient services, emergency department (ED) visits, inpatient (IP) stays, and pharmacy prescriptions. Costs related to antidiabetic therapy and glucose monitoring devices were also calculated. All-cause HCRU and costs were measured during the 12-month follow-up period, and costs were calculated as the health plan–paid amounts per user adjusted to 2020 US\$ using the annual medical care component of the Consumer Price Index.¹³ HCRU and costs were reported as annualized means.

Statistical Analysis

To adjust for imbalances in baseline characteristics and enable comparisons between the 2 cohorts, a propensity score matching approach was used. The propensity score was estimated using logistic regression that included potential predictors of SMBG/CGM

TAKEAWAY POINTS

This study sought to compare resource utilization and costs among patients with nonintensively managed type 2 diabetes (T2D) using self-monitoring of blood glucose (SMBG) vs continuous glucose monitoring (CGM).

- ▶ Analysis of claims data suggests that in adults with nonintensively managed T2D, SMBG users appear to have lower all-cause costs compared with CGM users.
- ▶ Adults with nonintensively managed T2D using SMBG seem to have similar frequency of emergency department visits and hospitalizations as CGM users, whereas the latter appear to have more all-cause outpatient visits and office visits with an endocrinologist.

TABLE 1. Patients' Demographic Characteristics and Baseline HCRU and Costs After Propensity Score Matching

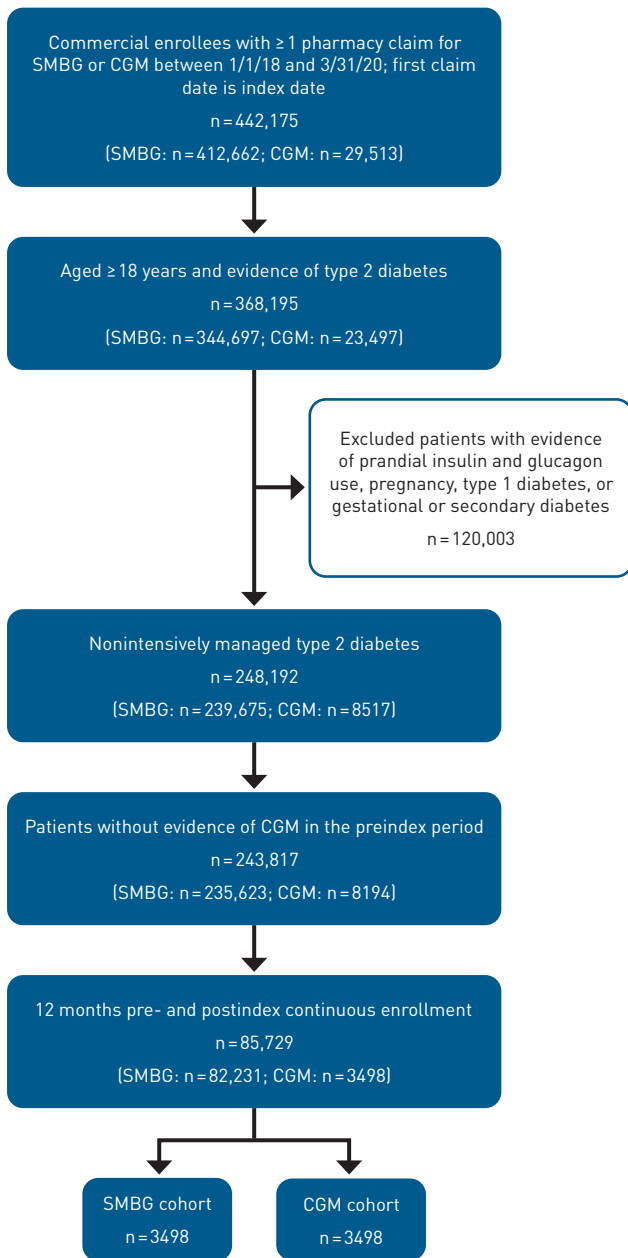
Characteristics and HCRU	SMBG n = 3498	CGM n = 3498	SMD
Age in years, mean (SD)	52.8 (8.9)	52.8 (8.9)	0.007
Male, n (%)	1826 [52.2]	1813 [51.8]	0.007
Region, n (%)			
Northeast	580 [16.6]	592 [16.9]	0.009
North Central	448 [12.8]	447 [12.8]	0.001
South	2098 [60.0]	2088 [59.7]	0.006
West	363 [10.4]	362 [10.3]	0.001
Unknown	9 [0.3]	9 [0.3]	0.00
Health care plan, n (%)			
Comprehensive	104 [3.0]	99 [2.8]	0.009
Exclusive provider organization	34 [1.0]	25 [0.7]	0.028
Health maintenance organization	442 [12.6]	428 [12.2]	0.012
Point of service	103 [2.9]	115 [3.3]	0.02
Preferred provider organization	1692 [48.4]	1714 [49.0]	0.013
Capitated point of service	1 [0.0]	1 [0.0]	0
Consumer-driven health plan	675 [19.3]	671 [19.2]	0.003
High-deductible health plan	372 [10.6]	366 [10.5]	0.006
Unknown	75 [2.1]	79 [2.3]	0.008
All-cause HCRU, mean (SD)			
Number of ED visits	0.49 [1.47]	0.48 [1.19]	0.008
Number of endocrinologist visits	0.74 [1.65]	0.84 [1.54]	0.06
Number of ICU visits	0.03 [0.20]	0.03 [0.21]	0.003
All-cause cost in US\$, mean (SD)	17,088 (40,338)	17,296 (30,017)	0.006

CGM, continuous glucose monitoring; ED, emergency department; HCRU, health care resource utilization; ICU, intensive care unit; SMBG, self-monitoring of blood glucose; SMD, standardized mean difference.

use as independent variables. Covariates for the logistic regression model included age, gender, geographic region, health plan coverage, baseline comorbidity, CCI score, presence of certain comorbidities and complications, antidiabetes medication types, frequency of SMBG testing in the preindex period, baseline all-cause cost, and baseline HCRU (visits to the ED, visits to the endocrinologist, and admissions to the intensive care unit).

Patients were matched in a 1:1 ratio using nearest neighbors without replacement with a caliper of 0.2. A standardized mean

FIGURE 1. Attrition Flowchart



CGM, continuous glucose monitoring; SMBG, self-monitoring of blood glucose.

difference of greater than 10% was used to indicate imbalance in baseline characteristics between the 2 cohorts. After matching, descriptive analyses were performed. For categorical variables, numbers and percentages were reported, and the χ^2 test was used to detect differences. For continuous variables, means and SDs were reported. The Wilcoxon signed-rank test was used to detect differences in costs, and a paired *t* test was used to detect differences in other continuous variables.

TABLE 2. Patients' Clinical Characteristics After Propensity Score Matching

Characteristics	SMBG n = 3498	CGM n = 3498	SMD
Comorbid conditions, n [%]			
Cardiovascular	430 [12.3]	391 [11.2]	0.03
Hyperlipidemia	2523 [72.1]	2550 [72.9]	0.02
Hypertension	2468 [70.6]	2451 [70.1]	0.01
Renal disease	156 [4.5]	152 [4.3]	0.01
Obesity	1083 [31.0]	1050 [30.0]	0.02
Microvascular and macrovascular complications	1055 [30.2]	1068 [30.5]	0.01
CCI score, n [%]			
0	80 [2.3]	72 [2.1]	0.016
1	1660 [47.5]	1640 [46.9]	0.011
2	837 [23.9]	896 [25.6]	0.039
≥3	921 [26.3]	890 [25.4]	0.02
Antidiabetes medication, n [%]			
Injectables alone	28 [0.8]	27 [0.8]	0.003
OAD + injectables	670 [19.2]	664 [19]	0.004
OAD alone	1455 [41.6]	1449 [41.4]	0.003
OAD + insulin	1028 [29.4]	1044 [29.8]	0.01
Injectables + insulin	495 [14.2]	516 [14.8]	0.017
Insulin alone	452 [12.9]	477 [13.6]	0.021
No treatment	78 [2.2]	74 [2.1]	0.008
Frequency of SMBG testing per day, mean [SD]	1.35 [1.62]	1.34 [1.58]	0.007

CCI, Charlson Comorbidity Index; CGM, continuous glucose monitoring; OAD, oral antidiabetic drug; SMBG, self-monitoring of blood glucose; SMD, standardized mean difference.

RESULTS

Patients' Demographics and Clinical Characteristics

A total of 6996 eligible patients were included in the matched overall analysis (3498 patients each in the SMBG and CGM cohorts) (Figure 1). Baseline clinical and demographic patient characteristics for the propensity score–matched SMBG and CGM cohorts are summarized in Table 1 and Table 2. The mean patient age was 52.8 years in both cohorts. Both cohorts had a slightly higher proportion of men (51.8% and 52.2% in the CGM and SMBG cohorts, respectively) (Table 1). A substantial proportion of patients were treated at baseline with oral antidiabetes medications (41%), were residing in the South (~60%), and had a CCI score of 1 (47%) (Table 2).

HCRU

During the 12-month follow-up period, 34% of SMBG users and 37% of CGM users were on insulin-based regimens, and 1034 (30%) CGM users had evidence of SMBG use. A total of 249 (7.1%) CGM users and 235 (6.7%) SMBG users had an IP admission (*P* = .54), whereas 23% of patients in the CGM cohort and 21% of those in the SMBG cohort had an ED visit (*P* = .02). However, the mean per-patient per-year (PPPY) numbers of IP admissions and ED visits were similar

TABLE 3. Health Care Resource Utilization

Utilization	SMBG n = 3498	CGM n = 3498	P
Patients with an IP stay, n (%)	249 (7.1%)	235 (6.7%)	.54
Number of IP admissions, mean (SD)	0.1 (0.4)	0.09 (0.4)	.33
Patients with an ED visit, n (%)	732 (20.9%)	811 (23.2%)	.02
Number of ED visits, mean (SD)	0.41 (1.2)	0.41 (1.0)	.75
Patients with an OP visit, n (%)	3444 (98.5%)	3460 (98.9%)	.12
Number of OP visits, mean (SD)	12.77 (12.1)	13.98 (13.0)	<.001
Patients with an OP endocrinologist visit, n (%)	791 (22.6%)	1254 (35.9%)	<.001
Number of OP endocrinologist visits, mean (SD)	0.64 (1.5)	1.04 (1.7)	<.001

CGM, continuous glucose monitoring; ED, emergency department; IP, inpatient; OP, outpatient; SMBG, self-monitoring of blood glucose.

between the 2 cohorts, whereas CGM users had more all-cause outpatient visits compared with SMBG users (Table 3). A total of 1254 (35.8%) CGM users and 791 (22.6%) SMBG users had an office visit with an endocrinologist ($P < .001$) (Table 3). The PPPY mean number of visits to an endocrinologist was higher in CGM users (1.04 vs 0.64; $P < .001$) (Table 3).

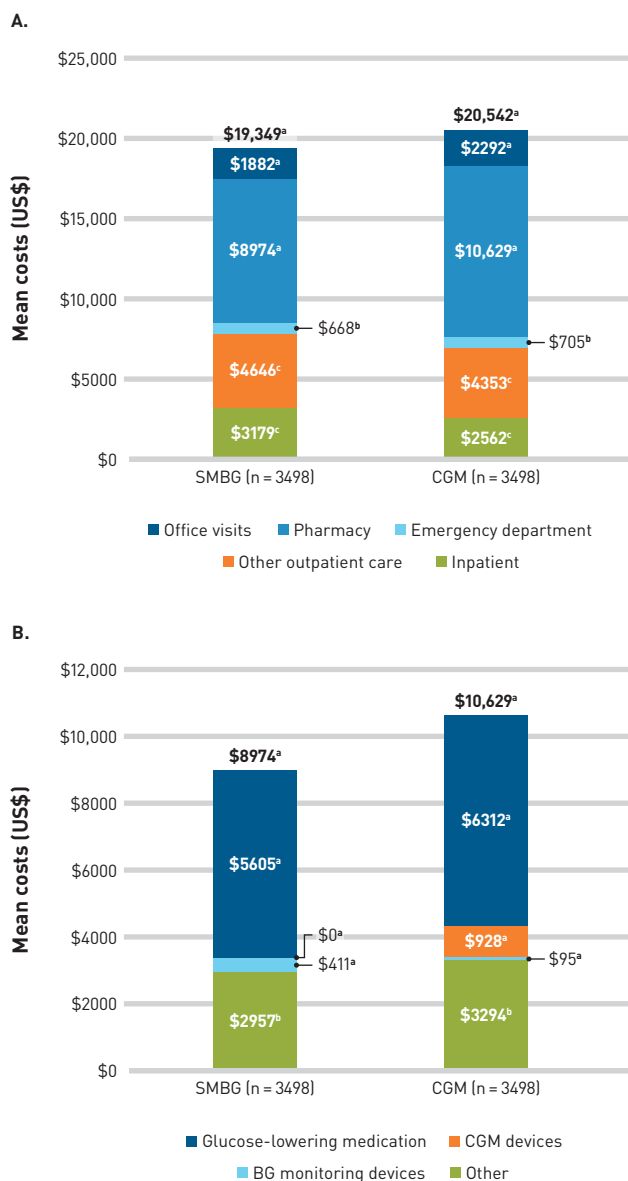
All-Cause Health Care Costs

During the 1-year follow-up period, total all-cause cost was lower in the SMBG cohort compared with the CGM cohort (\$19,349 vs \$20,542; $P < .001$) (Figure 2). Compared with CGM users, SMBG users had lower outpatient office visit costs (\$1882 vs \$2292; $P < .001$) and similar IP costs (Figure 2 [A]). Total pharmacy cost was also lower in the SMBG cohort (\$8974 vs \$10,629; $P < .001$). Additionally, the SMBG cohort had lower costs of glucose-lowering medication (\$5606 vs \$6312; $P < .001$) and glucose monitoring devices (\$411 vs \$928; $P < .001$) (Figure 2 [B]).

DISCUSSION

Glucose monitoring technologies are an essential component of diabetes management. For adults and children with T1D and individuals with T2D using multiple daily injections of insulin, there is a growing consensus that CGM systems should be the first-line approach to glucose monitoring.² However, there is insufficient evidence to guide the best cost-benefit approach on glucose monitoring for individuals with T2D who do not use intensive insulin regimens, such as those using basal insulin with or without oral agents. This real-world data study used claims data to compare the health care costs among CGM vs SMBG users in adults with nonintensively managed T2D. The total all-cause cost was lower in the SMBG cohort, mainly related to lower outpatient office visit costs and pharmacy costs. Over the 12-month follow-up period, the mean PPPY numbers of IP admissions and ED visits were similar between the 2 cohorts,

FIGURE 2. Breakdown of (A) All-Cause Costs and (B) Pharmacy Costs



CGM, continuous glucose monitoring; SMBG, self-monitoring of blood glucose.

^a $P < .001$.

^b $P \leq .05$.

^c $P > .05$.

whereas CGM users had more outpatient visits compared with SMBG users.

For individuals with T2D who are not using insulin, unstructured SMBG may be of limited clinical benefit.² However, the use of structured SMBG, which incorporates educational components, has been reported to be associated with clinical benefits in individuals not treated with insulin.¹⁴ The American Diabetes Association Standards of Care recommend that individuals who are taking insulin should

be encouraged to use SMBG to check their blood glucose levels at fasting, prior to meals and snacks, at bedtime, prior to exercise, when low blood glucose level is suspected, after managing low blood glucose levels, and prior to and while performing critical tasks such as driving.² Alternatively, real-time or intermittently scanned CGM can also be used for diabetes management in adults with diabetes taking basal insulin who are capable of using devices safely (either by themselves or with a caregiver). There is growing evidence of beneficial clinical outcomes with CGM use in T2D that is not intensively managed, but the cost of this type of technology is also an important factor to guide cost-benefit decision-making related to the choice of glucose monitoring technologies.¹⁰ In this study that leveraged a propensity score–matching approach, the costs associated with CGM compared with SMBG were higher, predominantly due to pharmacy costs. From an HCRU perspective, these differences in costs were related to more visits to outpatient clinics and endocrinologists. The increased use of specialist endocrine services by CGM users may likely reflect the high level of knowledge of and enthusiasm for CGM among these specialists compared with nonspecialist providers.⁷

In this study, insurance claims information reflecting real-world use of 2 glucose monitoring technologies was used. Claims data are a source of real-world data that provide longitudinal information from medical encounters submitted by health care providers to payers. The potential sample sizes of studies using claims data are often large, and the data sources capture a relatively diverse group of enrollees receiving care in various settings across geographic regions. Claims data can also assess the temporal relationships among different conditions, procedures, devices, or medications.¹⁵ Real-world data also have the potential advantage of assessing clinical efficacy in populations with few predefined restrictions and who are often excluded from randomized controlled clinical trials. An additional advantage of using real-world evidence is that the data are also more likely to reflect persistence with use of a device or treatment over time. However, the value of using insurance claims data may be limited by incomplete, inaccurate, or missing data and the lack of specific billing codes for some conditions.¹⁵

Limitations

The study is subject to several limitations, including those inherent to retrospective analysis of claims data. Longitudinal claims data gave an overview of patients' HCRU, including clinical conditions, procedures, and medications across the continuum of care, which allowed for propensity score matching on important confounding variables. Although the propensity score matching strengthened the comparability between the 2 cohorts, residual confounding may still remain, as potential unknown and unmeasured confounders could not be accounted for. Indeed, specific clinical outcomes such as the achieved level of glycemic control and development of acute and long-term diabetes-related complications are not available in claims data sets and could not be accounted for. Further, due to data availability, the study did not take into consideration social determinants

of health such as race and ethnicity, patient-reported outcomes such as quality of life, and changes in psychosocial variables; nor did it consider the contribution of clinician reasoning as part of the choice of a specific glucose monitoring device. Although implicit bias in clinician decision-making may be unintended, research suggests that these biases may contribute to various health care disparities.¹⁶

CONCLUSIONS

This study is the first to leverage information from a large insurance claims data set to compare HCRU and costs between SMBG and CGM users in adults with nonintensively managed T2D. Although the present study used propensity score matching to reduce the imbalances between the 2 cohorts and strengthen the comparability, the results should be interpreted while taking into consideration the limitations. Findings suggest that the use of SMBG is less costly than CGM in this patient population mainly because of lower pharmacy costs, including costs for glucose-lowering medications. Furthermore, no significant differences in the number of ED visits or hospitalizations were seen between SMBG and CGM users.

Overall, and given the absence of head-to-head comparisons of SMBG and CGM for individuals with nonintensively managed T2D, costs may be another factor in treatment choice alongside clinical goals. Patient and provider preferences should be considered in the decision-making process when selecting the most appropriate glucose monitoring approach in T2D. ■

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