Association of Continuous Glucose Monitoring with Diabetes Control for Patients with Type 2 Diabetes Mellitus in an Integrated Delivery Network

Tim Reynolds, PharmD[a,b], Paul Godley, PharmD, FASHP[a]

[a]Baylor Scott & White Medical Center – Temple, [b]The University of Texas at Austin College of Pharmacy

BACKGROUND

- Patients with insulin-dependent diabetes mellitus (IDDM) have been dependent on at-home devices for the self-monitoring of blood glucose (SMBG) to make insulin dosing decisions and to understand patterns of hyperglycemia and hypoglycemia. The introduction and development of continuous glucose monitoring (CGM) has enabled more frequent and automated monitoring of glucose throughout the day and overnight. Recent improvements in the affordability of CGM products have allowed greater utilization of CGM technology across various diabetes types, including patients with non-insulin dependent type 2 diabetes mellitus (T2DM).
- As nearly all previous CGM diabetes outcomes research in type 2 diabetics has focused primarily on patients with IDDM[1-9], this project seeks to better understand utilization and outcomes associated with diabetes control for all patients with T2DM, regardless of insulin use.

PURPOSE / OBJECTIVES

Purpose:
- To determine if using CGM affects health outcomes for patients with T2DM, regardless of outpatient insulin use

Objectives:
- To evaluate the association between the use of CGM and indicators of diabetes control, including A1c and acute healthcare utilization, in patients with T2DM.
- To describe the characteristics of T2DM patients at Baylor Scott & White Health (BSWH) who utilize CGM or standard of care (blood glucose test strips) for SMBG.

DISCLOSURES

- This study was approved by the BSWH Institutional Review Board (IRB).
- The authors have no financial disclosures to report.

STUDY DESIGN / METHODS

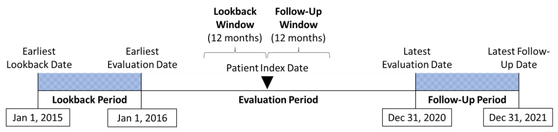
Methods:
- This is a difference-in-differences analysis evaluating change in A1c for patients just before and 6 months after initiation of CGM; compared with patients who newly initiate test strips.
- Emergency department (ED) and acute hospital use was evaluated in the 6 months before and after initiation.
- Propensity score analysis was used to reduce confounding in adjusted models.

Inclusion criteria:
- Patients received at least one outpatient order for a CGM sensor or test strip product at a BSWH facility, **and**
- Had a concurrent or previous diagnosis of T2DM, **and**
- Were aged ≥18 years, **and**
- Had distinct A1c measurements before and after initiation, **and**
- Had body mass index (BMI), blood pressure (BP), and glomerular filtration rate (GFR) measurements ≤12 months prior to initiation

Exclusion criteria:
- History of T1DM or gestational DM
- Previous history of CGM use

Statistical Analysis:
- To estimate difference-in-differences for A1c, a linear mixed-effects model for repeated measures was used, with intercepts included as a random effect.
- To estimate difference-in-differences for ED or acute hospitalization use, a generalized estimating equation was used.
- Propensity score weighting (PSW) was applied for adjusted models. Weights were determined using inverse probability of treatment weighting (IPTW) to determine the average treatment effect (ATE) for the full population. All baseline covariates (except those used directly as outcomes) were included in the propensity score analysis.

Study Timeline:



SETTING

Baylor Scott & White Health (BSWH) is an integrated health system in Texas that includes 52 hospitals and over 800 patient care sites. It is the largest not-for-profit health care system in Texas.

PATIENT CHARACTERISTICS

Baseline Characteristics	Unadjusted Groups: CGM (n = 5,297)	Unadjusted Groups: Test Strips (n = 8,865)	Unadjusted Groups: Standardized Differences	ATE Weighted Groups: CGM (n = 5,297)	ATE Weighted Groups: Test Strips (n = 8,865)	ATE Weighted Groups: Standardized Differences
Sex, %						
Female	48.4	51.4	- 0.060	50.4	50.2	0.002
Male	51.6	48.6	0.060	49.6	49.8	-0.002
Age, years - mean (SD)	62.0 (12.4)	65.7 (12.0)	**- 0.299**	64.5 (12.5)	64.5 (12.1)	-0.005
Race, %						
Asian	4.3	5.0	- 0.035	4.7	4.6	0.007
Black	18.1	16.7	0.039	17.7	17.5	0.004
White	71.1	71.7	- 0.015	71.2	71.5	-0.007
Other/unknown	6.5	6.6	- 0.003	6.4	6.4	0.001
Ethnicity, %						
Hispanic or Latino	16.6	16.4	0.006	17.0	16.7	0.010
Not Hispanic or Latino	81.2	81.1	0.004	80.7	80.9	-0.006
Unknown	2.2	2.5	-0.025	2.3	2.4	-0.009
Primary language, %						
English	96.8	94.6	**0.107**	95.0	95.3	-0.013
Spanish	2.3	4.0	-0.097	3.6	3.5	0.010
Other/unknown	0.9	1.4	-0.045	1.4	1.3	0.009
Marital status, %						
Divorced/Widowed	14.3	16.7	-0.065	16.5	16.0	0.013
Married	65.9	63.0	0.061	63.2	63.6	-0.008
Single	14.7	14.7	-0.001	15.0	15.0	0.002
Other/unknown	5.1	5.6	-0.024	5.3	5.4	-0.008
Smoking status, %						
Former smoker	29.7	28.8	0.020	28.8	29.2	-0.008
Never smoker	63.2	63.2	0.001	63.4	63.1	0.006
Smoker	7.0	7.8	-0.032	7.6	7.5	0.004
Other/unknown	0.1	0.2	-0.032	0.2	0.2	-0.004
Hemoglobin A1c, mean (SD)	8.73 (1.92)	8.04 (1.78)	**0.373**	8.53 (1.89)	8.16 (1.82)	**0.198**
BMI, kg/m² - mean (SD)	33.9 (7.1)	33.0 (7.3)	**0.124**	33.3 (7.1)	33.3 (7.4)	-0.006
GFR, mL/min - mean (SD)	79.6 (29.1)	80.4 (26.8)	-0.028	79.9 (27.6)	79.9 (27.6)	< 0.001
SBP, mmHg - mean (SD)	128.2 (15.0)	128.4 (14.9)	-0.014	128.3 (15.2)	128.3 (15.0)	0.005
DBP, mmHg - mean (SD)	74.9 (10.0)	75.1 (9.8)	-0.013	75.0 (10.0)	75.0 (9.9)	0.006
Recent uACR, %	5.8	2.7	**0.156**	4.0	3.9	0.006
Uses insulin, %	59.7	24.8	**0.753**	37.9	37.6	0.005
Takes a statin, %	79.2	75.5	0.089	76.5	76.7	-0.004
Takes antihypertensives, %	86.4	85.4	0.029	85.8	85.8	0.002
Recent ED visit, %	11.6	10.0	0.054	10.6	10.6	-0.001
Recent hospitalization, %	6.2	5.8	0.019	5.6	6.5	-0.041
Primary insurance, %						
Commercial	56.0	42.6	**0.269**	47.0	46.8	0.004
Medicaid	0.7	0.6	0.015	0.6	0.6	0.001
Medicare	43.0	56.4	**-0.272**	52.0	52.3	-0.005
Other	0.4	0.4	0.005	0.3	0.3	0.001
Has Medicaid, %	3.4	3.5	-0.004	3.6	3.6	0.001
Has Medicare, %	44.8	57.7	**-0.262**	53.5	53.8	-0.005
Patient EHR portal active, %	84.8	79.8	**0.129**	80.8	81.4	-0.016
Prescriber region, %						
Central Texas	35.9	33.1	0.059	34.7	34.5	0.003
North Texas	64.1	66.9	-0.059	65.3	65.5	-0.003
Prescriber type, %						
APP	17.2	12.8	**0.126**	14.0	14.0	< 0.001
Physician	82.8	87.2	**-0.126**	86.0	86.0	< -0.001
Prescriber department, %						
Endocrinology	36.4	8.2	**0.719**	18.5	18.1	0.010
Primary Care	61.9	89.0	**-0.665**	78.9	79.4	-0.012
Other	1.8	2.8	-0.066	2.6	2.5	0.008
Resident prescriber, %	0.8	0.9	-0.020	0.7	0.8	-0.009

ABBREVIATIONS

Abbreviation	Meaning	Abbreviation	Meaning
APP	Advanced practice provider	**IDDM**	Insulin-dependent diabetes mellitus
ATE	Average treatment effect	**IPTW**	Inverse probability of treatment weighting
BMI	Body mass index	**IRB**	Institutional review board
BP	Blood pressure	**PSW**	Propensity score weighting
BSWH	Baylor Scott & White Health	**SBP**	Systolic blood pressure
CGM	Continuous glucose monitoring	**SD**	Standard deviation
DBP	Diastolic blood pressure	**SMBG**	Self-monitoring of blood glucose
DM	Diabetes mellitus	**T1DM**	Type 1 diabetes mellitus
ED	Emergency department	**T2DM**	Type 2 diabetes mellitus
EHR	Electronic health record	**uACR**	Urine albumin-to-creatinine ratio
GFR	Glomerular filtration rate		

RESULTS

- After applying inclusion and exclusion criteria, (**n = 5,297**) patients were included in the CGM group, and (**n = 8,865**) patients were included in the test strip group.
- CGM initiating patients tended to be younger, speak English primarily, have a higher A1c, use insulin, have primary commercial insurance, use the patient EHR portal, and be managed by endocrinology.
- After propensity score weighting with all available covariates, the CGM group still had a higher A1c at baseline.
- After 6 months, **A1c decreased by an additional 0.15 points** in the CGM group when compared with the test strip group. After PSW adjustment, this was a **0.08-point decrease**.

A1c: After 6 Months	Unadjusted Model		Adjusted Model	
Least Squares Means	**Estimate**	**Std. Error**	**Estimate**	**Std. Error**
Test Strips				
Baseline A1c	8.04	0.02	8.09	0.02
A1c at 6 months	7.39	0.02	7.42	0.02
CGM				
Baseline A1c	8.73	0.02	8.65	0.02
A1c at 6 months	7.92	0.02	7.91	0.02
Mean Difference	**-0.15**	**0.03**	**-0.08**	**0.03**

- Absolute risk of ED use increased insignificantly by 1.1% with CGM. After PSW adjustment, this was a significant **2.0% increase**.
- Absolute risk of hospitalization increased insignificantly by 0.5% with CGM; after PSW this was a significant **1.6% increase**.

DISCUSSION

- A modest decrease in A1c was attributed to CGM initiation; however, patients initiating CGM had a higher risk of ED or hospitalization use when compared with test strip initiators.
- The adjusted model assumes all confounders are included, but there are likely hidden confounders that may predispose CGM initiators to higher acute healthcare utilization.

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