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(RESEARCH ARTICLE)

Continuous Glucose Monitoring in Internal Medicine Residency Clinic: Prospective Open-label trial – Two- and four-months changes in HbA1c, Average blood glucose, and time in range data after switching from Self-monitoring blood glucose

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Abstract

This prospective study aimed to evaluate how continuous glucose monitoring (CGM) use affects Glycemic Management Indicator (GMI) levels, which reflect HbA1c (estimated HbA1c), average blood glucose, and time in range (TIR) in patients who require multiple insulin injections—primarily those with Type 2 diabetes—and a patient with Type 1 diabetes mellitus. The goal of the project was to assess the role of Internal Medicine Residents in CGM management following education and subsequent supervision by an endocrinologist in the Internal Medicine residency clinic. If successful, our goal is to expand to other Internal Medicine residency programs across the USA and to integrate it into the Internal Medicine residency curriculum as an ACGME requirement.

Patients were recruited from the Internal Medicine Residency Clinic. Eligibility criteria included an initial HbA1c level between 7% and 14%, self-monitoring of blood glucose (SMBG) four times daily, and qualification for CGM use.

Additionally, the study includes patients with Diabetes Mellitus who use three to four daily insulin injections, with or without other diabetic medications. Patients share their CGM data with the Internal Medicine Clinic. All residents work under the supervision of a board-certified endocrinologist, who oversees the project and is also part of the clinic. The CGM team adjusts the patient's treatment every 2 weeks. The study is planned to last 24 months. Currently, we have 4 months of data from 24 patients, providing insight into patient outcomes to date. The data show that after switching from SMBG to CGM, the GMI decreased from 9.92% to 7.74% at 2 and 4 months. The average blood glucose decreased from 275 mg/dl to 176 mg/dl, and the TIR increased from 30% to 57%. The major improvement in glycemic control occurred primarily during the first 2 months after the switch from SMBG to CGM.

Keywords: Continuous Glucose Monitoring (CGM); GMI; Hba1c; Diabetes Mellitus Type 2; Internal Medicine Residency Clinic; Board-Certified Endocrinologist; Blood Glucose

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1. Introduction

Diabetes Mellitus (DM) is one of the most common chronic conditions managed in clinical settings. It affects nearly every organ in the body and can lead to serious long-term complications if not adequately controlled. Therefore, patients must keep their glucose levels within target ranges to prevent disease progression. A key component of this is glucose monitoring. Traditional methods include self-monitoring with a glucometer and periodic HbA1c testing using blood samples. HbA1c reflects the average blood glucose over the past 2-3 months. The target for adults with diabetes is less than 7%. Because SMBG is performed only four times per day, it provides only occasional snapshots of blood glucose levels and may miss important fluctuations, such as episodes of hypoglycemia or hyperglycemia. Notably, SMBG does not capture daily fluctuations attributable to insulin doses or physical activity. Continuous Glucose Monitors (CGM) address these limitations by providing continuous, real-time data on glucose trends [1]. With CGM, we also obtain a value called the "Glucose Management Indicator" (GMI), which provides a reliable estimate of three-month metrics based on 10-14 days of data and effectively serves as an estimate of HbA1c [2]. Additional insights from CGM help patients and healthcare providers make more precise decisions regarding insulin, medication adjustments, and lifestyle changes to improve quality of life and glycemic control in Diabetes Mellitus [3]. Additionally, CGM can motivate patients by visually demonstrating changes in response to interventions [4-6]. Our previous studies were retrospective and observational, and we examined improvements in glucose control over a long period, such as 3 years [7].

This study was prospective, open-label, and aimed to demonstrate that the majority of the improvement in glucose control occurs within the first 2-4 months after initiation of CGM.

2. Study Design and Methods

2.1. Procedure

This prospective study evaluated the impact of CGM on patients with uncontrolled DM receiving care at an Internal Medicine Residency Clinic. Eligible participants included adults aged 18 or older with Type 2 DM and one patient with Type 1 DM, all with a baseline HbA1c above 7% while using SMBG and on a regimen of three to four daily insulin injections, with or without additional oral diabetic medications and/or injectable GLP-1 receptor agonists. All patients were previously self-monitoring their blood glucose at least four times daily. Participation in CGM use was voluntary, based on patient preference and insurance coverage, and offered as part of routine clinical practice. Each patient was monitored throughout the study, with four months of current data available. CGM data are remotely accessible to the CGM team and actively overseen. Resident physicians contacted patients by phone biweekly and conducted in-clinic visits every 2 months in collaboration with the CGM team, all under the supervision of a board-certified endocrinologist. To promote patient engagement and safe management, participants received written instructions for insulin adjustments based on CGM trends, counseling on diet and exercise, and educational materials on the carbohydrate and caloric content of their foods. Understanding of the CGM procedure was confirmed through a "teach-back" method conducted by CGM team members. Table 2 details the study design and procedures over the course of the months.

Table 1 Study design and procedures over the course of the months

Timeline & Tasks	
Initial Visit	Consent Form CGM-SAT Survey Recent HbA1c
Every 2 Weeks (telephone call)	CGM data trend Medication Management Diet/Lifestyle Changes Insulin Use Compliance CGM Use Compliance Non-Insulin Medication Compliance IM Clinic Visit Compliance CGM Insurance Coverage
Every 2 Months (in-clinic)	CGM data trend

	Medication Management
Every 6 Months	Repeat CGM-SAT Survey

Patients were withdrawn from the trial if they did not follow the study procedures, had severe allergic reactions to the CGM tape, or experienced severe, unexpected hypoglycemia, diabetic ketoacidosis (DKA), or Hyperglycemic Hyperosmolar State (HHS) while using CGM. Patients were advised they may leave the study at any time if they choose.

2.2. Inclusion and Exclusion Criteria

The inclusion and exclusion criteria for study participants are outlined in Table 2.

Table 2 Inclusion and exclusion criteria of the participants

Enrolment Inclusion Criteria	**Exclusion Criteria**
Patients aged 18 years or older who speak proficient English	Patients unable to understand instructions for insulin titration based on CGM data
Patients diagnosed w/ Type 1 or Type 2 Diabetes Mellitus	Patients wearing the CGM device less than 70% of the time
Patients with an HbA1c > 7% who are receiving primary care at the internal medicine residency clinic	Patients with impaired decision-making capacity
Patients receiving CGM: Dexcom G6 or G7, Freestyle Libre 3 as part of their standard care	Patients missing more than 2 scheduled visits
Patients on 3-4 daily insulin injections with or without oral or injectable antidiabetic medications	Pregnant or incarcerated patients
Patients able to adjust insulin based on CGM data	Patients unresponsive to clinic contact
Available to talk to residents every 2 weeks via telephone about adjusting insulin doses based on CGM readings	Patients whose insurance does not cover the CGM device

2.3. Variables

To better understand how CGM impacts patients, while being treated by internal medicine residents, the investigators collected the following variables found in Table 3.

Table 3 Variables and Operationalization

Variable	**Operationalization**
GMI	The percent of GMI improvement over 2 and 4 months
Average blood glucose	The average blood glucose (mg/dl) taken over 120 days…
Time in range	The percent of time in range after 2 and 4 months of CGM usage
Low blood glucose (%; 54-69 mg/dl)	
Very low blood glucose (%; <54 mg/dl)	
High blood glucose (%; 180-250 mg/dl)	
Very high blood glucose (%; >250 mg/dl)	
CGM Satisfaction	
Diet and Lifestyle Modification	
Compliance: Insulin Regimen	

Compliance: Non-Insulin DM Medications	
Compliance: IM Clinic Visits	

All continuous variables were collected consistently over the 4-month period. These variables were averaged to represent a single mean value at months 1, 2, and 4. Data on categorical variables such as diet and lifestyle modifications, insulin regimen, non-insulin DM medications, and IM clinic visits were collected three times at months 1, 2, and 4. Lastly, CGM satisfaction was collected only once after the first month of CGM use.

2.4. Statistical Analysis

To assess GMI, average BG, low BG, high BG, and very high BG, a one-way repeated measures ANOVA was performed. This allowed investigators to observe mean differences between months 1, 2, and 4 for each of the continuous variables. To assess diet and lifestyle modification, compliance with the insulin regimen, compliance with non-insulin DM medications, and compliance with IM clinic visits, the Friedman test was chosen. This allowed investigators to observe mean rank differences between months 1, 2, and 4 for each of the categorical variables.

3. Results

As shown in Table 4, 96% of patients had Type 2 DM, and 4% had Type 1 DM. Seventy-five percent were male, and twenty-five percent were female. The mean for each continuous variable at each time point is shown in Table 5. Similarly, the frequency for each categorical variable at each time point is shown in Table 6.

Table 4 Descriptions of the patients with DM included in our retrospective study

	Percentage of Patients
Type 1	4%
Type 2	96%
Male	75%
Female	25%

Table 5 Result Variables, Mean and Standard Deviation

Variable	**Mean**	**SD**
GMI_T1	9.45%	2%
GMI_T2	7.78%	1%
GMI_T4	7.65%	1%
AvgBG_T1	255.660	87.580
AvgBG_T2	184.545	48.645
AvgBG_T4	184.348	52.204
TIR_T1	35.8%	26%
TIR_T2	57.4%	28%
TIR_T4	56.8%	27%
Low_T1	0.3%	2%
Low_T2	0.3%	1%
Low_T4	0.5%	1%

VLow_T1	0.0%	0%
VLow_T2	0.1%	0%
VLow_T4	0.0%	0%
High_T1	41.0%	21%
High_T2	27.1%	15%
High_T4	24.6%	13%
VHigh_T1	23.0%	20%
VHigh_T2	16.6%	20%
VHigh_T4	18.2%	23%

Note: GMI = Glycemic Management Indicator; AvgBG = Average Blood Glucose; TIR = Time in Range; Low = Low Blood Glucose; VLow = Very Low Blood Glucose; High = High Blood Glucose; VHigh = Very High Blood Glucose; "T" = time in months.

Table 6 Compliance of participants

Variable	Compliant	Non-Compliant
DLMod_T1	98%	2%
DLMod_T2	92%	8%
DLMod_T4	97%	3%
C_Ins_T1	98%	2%
C_Ins_T2	95%	5%
C_Ins_T4	100%	0%
C_NIM_T1	98%	2%
C_NIM_T2	95%	5%
C_NIM_T4	100%	0%
C_CV_T1	100%	0%
C_CV_T2	90%	10%
C_CV_T4	92%	8%
	Satisfied	Not Satisfied
CGM_S_T1	100%	0%

Note: DLMod = Diet and Lifestyle Modification; C_Ins = Insulin Compliance; C_NIM = Non-Insulin DM Medications Compliance; C_CV = Clinic Visit Compliance; "T" = time in months.

3.1. Power Analysis

Using G*Power (version 3.1.9.7), a power analysis was conducted to determine the minimum sample size required for a repeated-measures ANOVA with three measurement occasions. For the analysis, effect size was set to 0.25, alpha to 0.05, power (1 – β) to 0.95, correlation among the measures to 0.5, and sphericity to 1. The results indicated that a sample size of 43 was needed to sufficiently power the analysis.

3.2. GMI

A one-way repeated-measures ANOVA was conducted to assess whether there were statistically significant differences in GMI across three time points (months 1, 2, and 4) among patients seen at a resident-led clinic. There were no outliers, and the data at all three time points were normally distributed, as assessed by boxplot and Shapiro-Wilk test ($p > .05$), respectively. The assumption of sphericity was violated, as assessed by Mauchly's test of sphericity, $\chi^2(2) = 33.419$, $p < .001$. Therefore, a Greenhouse-Geisser correction was applied ($\varepsilon = 0.571$). Patients seen and treated at a clinic led by residents showed a statistically significant change in GMI over time, $F(1.142, 28.546) = 27.926$, $p < .001$, partial $\eta^2 =$

0.528, with GMI decreasing from month 1 (*M* = .0996, *SD* = 0.01979) to month 2 (*M* = .0772, *SD* = .01029) but remaining unchanged from month 2 to month 4 (*M* = .0773, *SD* = 0.01143;). Post hoc analysis with a Bonferroni adjustment revealed that GMI decreased statistically significantly from month 1 to month 2 (*Mdiff* = 0.022, 95% CI [.012, .033], *p* < .001) but not from month 2 to month 4 (*Mdiff* = .0001, *p* = 1.00).

A one-way repeated measures ANOVA was conducted to determine whether there were statistically significant differences in blood glucose (BG) measured at three time points (i.e., months 1, 2, and 4) for patients seen at a resident-led clinic. There were no outliers, and the data at all three time points were normally distributed, as assessed by boxplot and Shapiro-Wilk test (p > .05), respectively. The assumption of sphericity was violated, as assessed by Mauchly's test of sphericity, χ2(2) = 40.884, p < .001. Therefore, a Greenhouse-Geisser correction was applied (ε = 0.538). Patients seen and treated at a clinic led by residents showed a statistically significant change in BG over time, F(1.077, 23.691) = 27.247, p < .001, partial η2 = 0.553, with BG decreasing from month 1 (M = 278.174, SD = 83.62) to month 2 (M = 179.652, SD = 44.24) but remaining unchanged from month 2 to month 4 (M = 184.35, SD = 52.20).Post hoc analysis with a Bonferroni adjustment revealed that BG decreased statistically significantly from month 1 to month 2 (Mdiff = 98.522, 95% CI [51.44, 145.61], p < .001) but not from month 2 to month 4(Mdiff = 4.70, p = .793)(Fig 1).

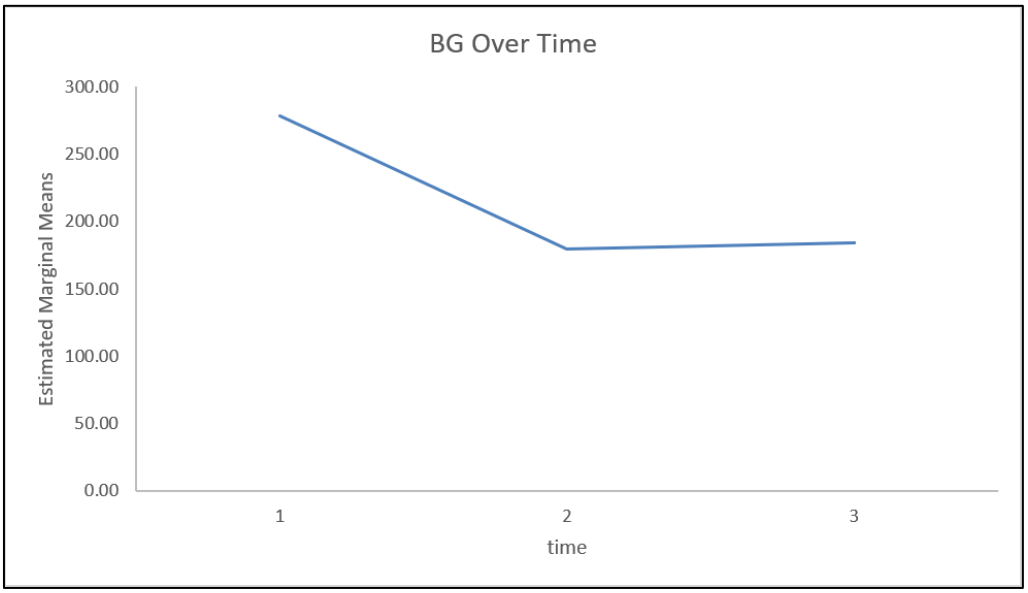

Figure 1 Depiction of Average BG Over Time

3.3. Time in Range

A one-way repeated measures ANOVA was conducted to determine whether there were statistically significant differences in time in range (TIR) measured at three time points (i.e., months 1, 2, and 4) for patients seen at a resident-led clinic. There were no outliers, and the data at all three time points were normally distributed, as assessed by boxplot and Shapiro-Wilk test (*p* > .05), respectively. The assumption of sphericity was violated, as assessed by Mauchly's test of sphericity, $\chi^2(2) = 26.834$, *p* < .001. Therefore, a Greenhouse-Geisser correction was applied (ε = 0.581). Patients seen and treated at a clinic led by residents showed a statistically significant change in TIR over time, *F*(1.162, 25.561) = 16.494, *p* < .001, partial $\eta^2 = 0.428$, with TIR increasing from month 1 (*M* = 31.26%, *SD* = 22.6%) to month 2 (*M* = 58.52%, *SD* = 26.59%) but remaining unchanged from month 2 to month 4 (*M* = 57.70%, *SD* = 27.32%; Figure 2). Post hoc analysis with a Bonferroni adjustment revealed that BG increased statistically significantly from month 1 to month 2 (*Mdiff* = 27.3%, 95% CI [10.3%, 44.2%], *p* < .001) but not from month 2 to month 4 (*Mdiff* = 0.8%, *p* = 1.00).

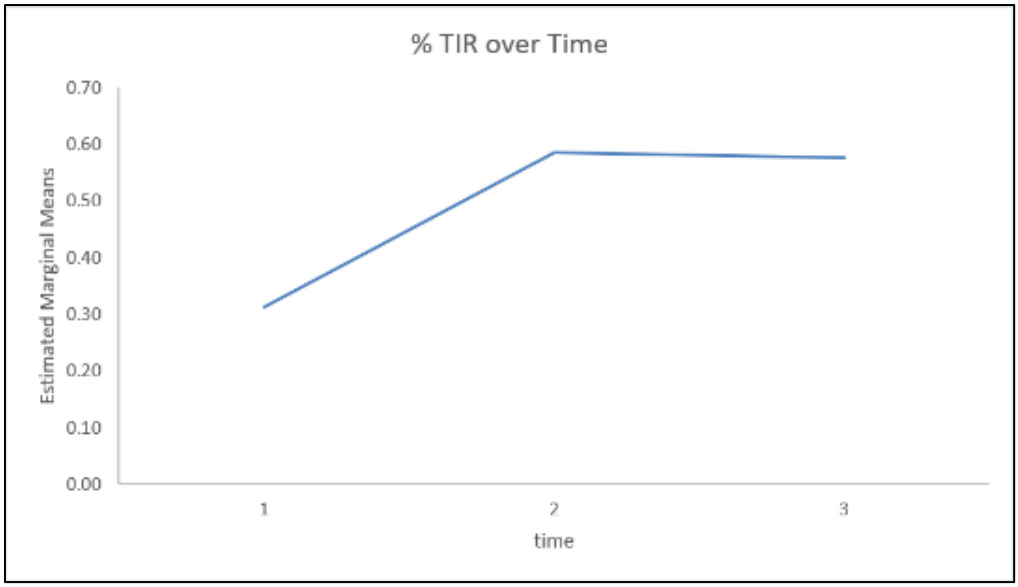

Figure 2 Depiction of TIR Over Time

3.4. High Blood Glucose

A one-way repeated measures ANOVA was conducted to determine whether there were statistically significant differences in high blood glucose (BG) measured at three time points (i.e., months 1, 2, and 4) for patients seen at a resident-led clinic. There were no outliers, and the data at all three time points were normally distributed, as assessed by boxplot and Shapiro-Wilk test ($p > .05$), respectively. The assumption of sphericity was violated, as assessed by Mauchly's test of sphericity, $\chi^2(2) = 8.681$, $p = .013$. Therefore, a Greenhouse-Geisser correction was applied ($\varepsilon = 0.754$). Patients seen and treated at a clinic led by residents showed a statistically significant change in high BG over time, $F(1.508, 34.689) = 10.857$, $p < .001$, partial $\eta^2 = 0.321$, with high BG decreasing from month 1 ($M = 0.4525$, $SD = 0.2055$) to month 2 ($M = 0.2779$, $SD = 0.1669$) but remaining unchanged from month 2 to month 3 ($M = 0.2463$, $SD = 0.1316$; Figure 3). Post hoc analysis with a Bonferroni adjustment revealed that high BG decreased statistically significantly from month 1 to month 2 ($Mdiff = 0.175$, 95% CI [0.029, 0.320], $p = .015$), but not from month 2 to month 4 ($Mdiff = 0.032$, $p = .993$).

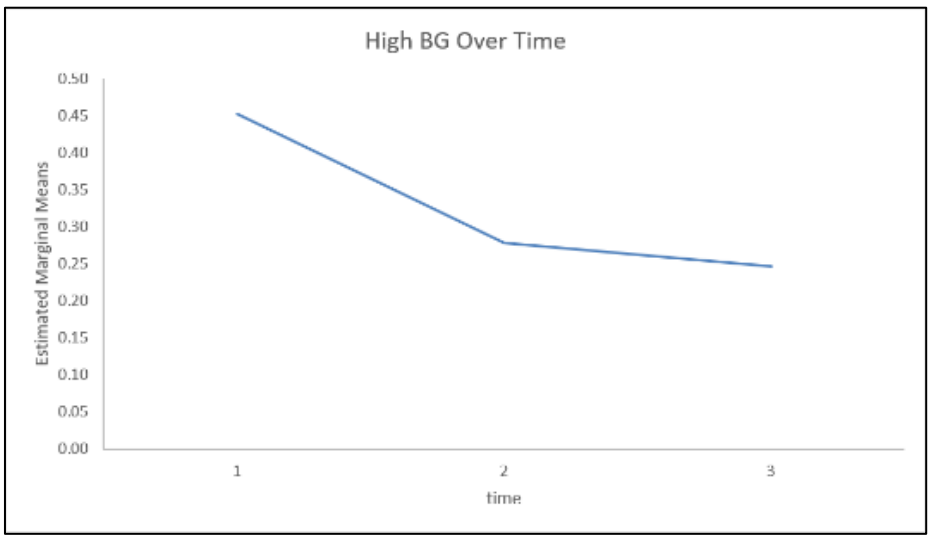

Figure 3 Depiction of High BG Over Time

3.5. Very High Blood Glucose

A one-way repeated measures ANOVA was conducted to determine whether there were statistically significant differences in very high blood glucose (BG) measured over 4 months for patients seen at a resident-led clinic. There

were no outliers, and the data at all three time points were not normally distributed, as assessed by boxplot and Shapiro-Wilk test ($p < .05$), respectively. Moreover, the assumption of sphericity was violated, as assessed by Mauchly's test of sphericity, $\chi^2(2) = 8.681$, $p = .013$.

Because the assumptions for conducting a one-way repeated measures ANOVA were violated, a Friedman test was used to assess differences in very high BG levels. Pairwise comparisons were performed using SPSS Statistics (2012) with a Bonferroni correction for multiple comparisons. Very high BG differed significantly across time points, $\chi^2(2) = 6.522$, $p = .038$. Post hoc analysis revealed statistically significant differences in very high BG between month 1 (*Mdn* = 0.190) and month 2 (*Mdn* = 0.100; $p = .030$; Figure 4), but not between month 2 and month 4 (*Mdn* = 0.095; $p = 1.00$).

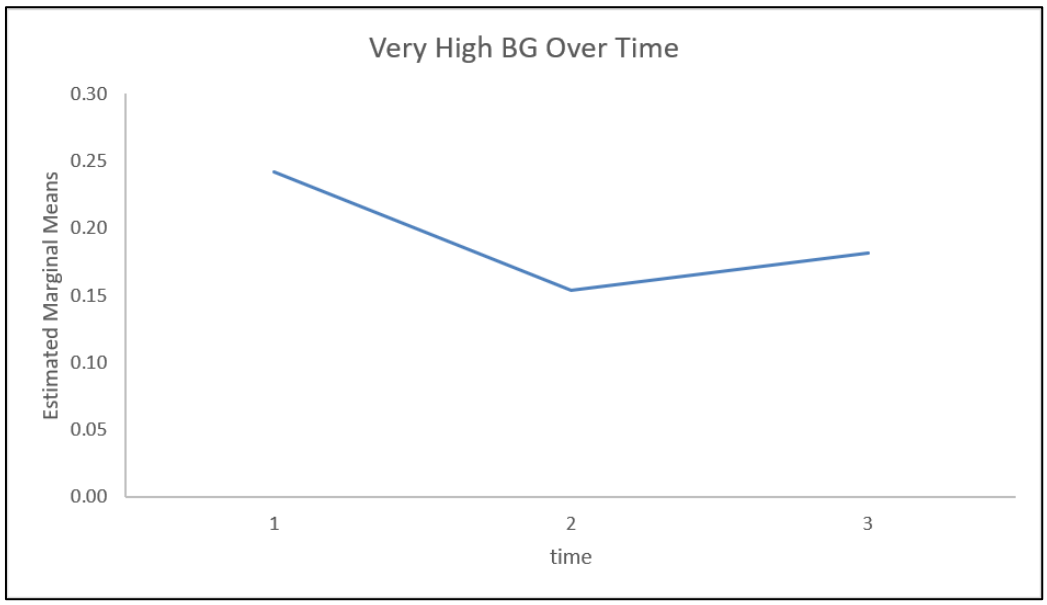

Figure 4 Depiction of Very High BG Over Time

3.6. Low Blood Glucose and Very Low Blood Glucose

As shown in Table 5, close to 0% of patients fell into the Low Blood Glucose or Very Low Blood Glucose categories. Given the small sample size and minimal variance, the investigators opted not to attempt an analysis.

3.7. Categorical Analysis

For all categorical variables, including CGM Satisfaction, Diet and Lifestyle Modification, Insulin Regiment compliance, Non-Insulin DM Medications Compliance, and IM Clinic Visits compliance, there was little variation in frequency. As shown in Table 6, nearly 100% of patients were compliant across all variables, and 100% were satisfied with the CGM system. Consequently, no formal analysis was conducted due to the lack of variation.

4. Discussion

One of the significant achievements in diabetes mellitus over the past 30 years is the adoption of CGM for treatment monitoring [8-9]. The initial studies were conducted in patients with type 1 DM, followed by studies in patients with type 2 DM [10-15].

Compared with Self-monitoring of Blood Glucose (SMBG), these devices provide a comprehensive 24-hour view of glucose levels and enable real-time responses to high or low readings [11]. They are also motivating because they display blood glucose levels instantly. In contrast, SMBG provides only a single measurement, missing the full pattern of glucose fluctuations throughout the day[2-6].

The 2025 ADA Standards of Care recommend that primary care physicians offer continuous glucose monitoring (CGM) to most people with diabetes, including those with type 2 diabetes and those on non-insulin therapies, because it provides real-time data to inform treatment decisions. This is a major update from previous guidelines, underscoring the importance of technology and personalized diabetes care in primary care. Physicians should introduce CGM at

diagnosis and provide education and support. CGM should be used not only in specialized endocrine clinics but also in General Internal Medicine clinics in the USA, as per the ADA recommendation. The document states that, unfortunately, General Internists rarely use CGM, which needs to change.

Our study has a few limitations.

Patient compliance with diet, lifestyle interventions, medication regimens, and other modifications varied. Some had easier access and motivation to follow specific adjustments, while others did not. All patients in the clinic were counseled on medication adherence and CGM use and provided with written information on standard dietary recommendations. Those who were more compliant were expected to have better-controlled GMI and blood sugar levels than those who were less compliant. Varying comorbidities among patients may influence their response to diabetic treatment. Patients were not categorized based on other chronic conditions such as chronic kidney disease, anemia, chronic liver diseases, hyperlipidemia, obesity, mobility disorders, autoimmune diseases, and genetic disorders. Although many patients share similar comorbidities, these can still confound the application of the data to a larger population. Using GMI helps address some of the inherent limitations of measuring HbA1c in conditions such as anemia, chronic kidney disease, and chronic liver disease[15-16].

The study was also conducted at a single clinic, which could limit the extent to which our data apply to a broader population.

The primary strength of this study is demonstrating that glycemic control can be improved not only in primary care or specialized endocrinology clinics but also in an internal medicine residency continuity teaching clinic. Internal medicine and transitional year residents managed the study after receiving initial education and ongoing supervision from an endocrinologist. This is the first prospective trial in the USA involving internal medicine and transitional year residents in the management of the most challenging patients with Diabetes Mellitus on multiple daily insulin injections, using CGM in an Internal Medicine Residency Clinic.

This supports the understanding that the CGM device can be safely used not only in primary care offices and specialized clinics for treating the most complex diabetes mellitus patients but also in general Internal Medicine residency clinics. To implement this, Internal Medicine Residents need to be educated and supervised by an endocrinologist, as in our study, so that, upon completing their residency program, they can use CGM independently to treat diabetes mellitus.

In our prospective trial at 4 months, we observed a significant drop in GMI (estimated HbA1c), with a decrease of 2.22%, reductions in average blood glucose from 275 to 176 mg/dL, and in time in range from 30% to 57%. An interesting observation in our study was a significant drop in HbA1c and average blood glucose, as well as an increase in TIR, and a decrease in high and very high blood glucose levels during the first 2 months after starting CGM. After that, over the next 2 months, the differences in these parameters were not statistically significant. All patients were satisfied with the usage of CGM. They also reported compliance with diet and lifestyle interventions, the Insulin Regimen, and non-Insulin antidiabetic medications, and clinical visits.

We attribute this statistically significant improvement in diabetic control to the first 2 months, and not a statistically significant change between 2 and 4 months after starting CGM, due to initial strict adherence to the diabetes treatment regimen using CGM, with improvement approaching the goals, followed by a period of probable relative complacency with the results achieved.

We believe that our positive prospective trial data can be adopted by other Internal Medicine Residency programs to improve diabetes mellitus patient care and enhance medical resident education across the USA. We also believe that CGM education for the management of diabetes mellitus should be included in the ACGME Internal Medicine Residency Curriculum, based on our current prospective data and prior retrospective data [7]. In this way, Internal Medicine Residents, upon completion of their Program, can work independently with CGM to manage patients with diabetes mellitus.

5. Conclusion

In our first prospective study in an Internal Medicine residency clinic at 4 months, we found that CGM, compared with SMBG, led to significant improvements in GMI, average blood glucose, and TIR. This demonstrates the feasibility of implementing CGM not only in specialist endocrine clinics but also in an Internal Medicine residency clinic, in a project managed by Internal Medicine and transitional year residents under the supervision of an endocrinologist. This pioneering study highlights the potential of CGM to enhance medical residents' education and to be included in the

ACGME's Internal Medicine educational curriculum. Expanding CGM use across US residency programs could elevate the standard of diabetes care nationwide, in line with the ADA's 2025 Standards of Care for Diabetes Mellitus.

Compliance with ethical standards

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Disclosure of conflict of interest

None to be disclosed for any of the authors.

Statement of informed consent

Informed consent was obtained by all participants in the study

Disclaimer

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This study's information is based on results from patients using Dexcom G6, G7, or Freestyle Libre continuous glucose monitoring (CGM) devices, primarily Dexcom G6 or G7. Our study does not assess the effectiveness of other similar CGM devices and does not endorse any particular brand. More research is needed to fully understand the use and effectiveness of CGM devices. The findings of this evaluation should not be used to make medical decisions and should always be considered alongside professional medical advice.

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