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Experience of Continuous Glucose Monitoring Use Among Diabetic Patients and Healthcare Providers in South Korea

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Abstract

Purpose: Despite the growing adoption of continuous glucose monitoring (CGM) systems for diabetes management, limited research exists on the perceived benefits and challenges of CGM from both patient and physician perspectives. This study aimed to explore experiences and opinions regarding CGM use among diabetic patients, physicians, and diabetes educators in Korea.

Methods: An anonymous online survey was conducted from January to December 2021 across four university hospitals in Korea. The survey targeted diabetic patients, physicians, and diabetes

education nurses, collecting data on CGM usage, perceived benefits, and barriers to use.

Results: A total of 1,010 diabetic patients completed the survey (mean age 51.4 years; 52.4% female; 337 with type 1 diabetes, 642 with type 2 diabetes). Among them, 92.7% reported that CGM use helped in managing their diabetes. Commonly cited advantages included glucose monitoring without finger pricks (56.6%), maintaining target glucose levels (40.1%), and better postprandial glucose stability (25.1%). Most patients (81.9%) continued using CGM, while 18.1% discontinued due to high cost (63.4%), maintenance burden of sensor attachment (31.1%), and physical discomfort (29.5%). Among physicians, 51.9% prescribed CGM to type 1 diabetes patients—60% preferred Libre 1. Only 14.5% of type 2 diabetes patients were prescribed CGM, with Libre 1 also being the most used (91%). Main reasons for CGM refusal were cost, discomfort, and body attachment issues.

Conclusion: Most patients and healthcare providers viewed CGM as beneficial for glycemic control. Addressing cost and comfort-related concerns could improve CGM uptake and sustained use.

Keywords: Continuous glucose monitoring; Blood glucose self-monitoring; Diabetes mellitus

Introduction

Diabetes is the leading cause of premature death, accounting for 11.8% of all deaths worldwide among people aged <60 years [1]. Approximately 10.5% of the global adult population aged 20–79 years (nearly 537 million people) has been diagnosed with diabetes. This percentage is expected to increase to 12.2% (approximately 783.2 million) by 2045. According to the 2022 Diabetes Fact Sheet [2], the prevalence of diabetes in adults older than 30 years in Korea is 14.5%, indicating that one in six adults has diabetes. Furthermore, 2.8% of all deaths in 2021 were attributed to diabetes [3]. According to the level of diabetes management, only 25% achieve the target blood glucose levels, with glycated hemoglobin levels of 6.5% or less [2]. Therefore, achieving the blood glucose targets remains a challenge. The ultimate goal of diabetes management is to delay acute and chronic complications through effective glycemic control, thereby reducing mortality and improving the quality of life. To achieve this goal, the implementation of self-management strategies such as exercise, dietary management, and modifications of cardiovascular risk factors such as hyperglycemia, hypertension, dyslipidemia, obesity, and smoking is crucial [4]. One of the most important approaches to self-manage blood glucose levels is to monitor them through Self-Monitoring of Blood Glucose (SMBG). Despite its significance, many patients do not frequently employ SMBG due to the pain, discomfort, and stigma associated with the necessity of collecting blood samples [5]. Recently, Continuous Glucose Monitoring (CGM) has been used to alleviate this discomfort and offer continuous blood glucose monitoring. A CGM is a device that automatically measures blood glucose in the interstitial fluid under the skin every 5 minutes, detects blood glucose 288 times a day, and transmits the data to the receiver. CGM represents an effective strategy to detect irregularities in a patient's blood glucose pattern, tailor treatment approaches, and promote lifestyle modifications [6]. Numerous studies have consistently demonstrated that CGM is more effective than SMBG alone in patients with type 1 and type 2 diabetes receiving insulin therapy [7-10]. In the 2024 American Diabetes Association guidelines, real-time CGM (rtCGM) or intermittently

scanned CGM (isCGM) should be offered to adults with diabetes on Multiple Daily Injections (MDI) or Continuous Subcutaneous Insulin Infusion (CSII) who are capable of using the devices safely. They recommend that the appropriate devices should be selected based on individual circumstances, preferences, and needs, and that training on proper CGMS use should be provided [11].

In Korea, although rtCGM has been introduced since 2000, it has not been widely used due to cost problems, but since 2018, the cost burden has been reduced as insurance has been covered in type 1 diabetes patients, and as a relatively simple isCGM which does not require calibration and does not have a transmitter has been introduced since September 2020, CGM use is increasing not only in patients with type 1 diabetes but also in patients with type 2 diabetes [12]. CGM significantly improves glycemic control by reducing A1C levels in patients with diabetes. They effectively reduce the incidence of hypoglycemia through real-time glucose monitoring and alerts. CGM enhances the quality of life by enabling better diabetes self-management and providing continuous data for informed decision-making. Furthermore, CGM allows patients to spend more time within their target glucose range, improving overall diabetes management [13-15]. Despite their numerous advantages, CGM is not often used continuously for more than a year in Korea. From the patient's perspective, the cost of CGM and the potential side effects that may arise from their use can be significant concerns. This is thought to be related to the increasing incidence of adverse events [16,17], as the sensors are inserted invasively and remain in place for as long as 14 days for intermittent use. Skin irritation and rashes have been reported in the pediatric study population of the DirecNet research group [18]. A recent study of 83 pediatric patients who used CGM found that 80% experienced skin problems, including itching (70%), eczema (46%), and wounds (33%) [19]. The incidence of these side effects is expected to increase with the extended usage of CGM, and they need to be addressed appropriately. Healthcare providers (HCPs) may find it challenging when patients experience side effects, as it can necessitate considerable time and effort to provide necessary education. Many primary care clinicians hesitate to initiate CGM due to concerns regarding the time or effort needed to educate patients, doubts about patient acceptance, or ability to manage the device. Additionally, adverse events of CGM act as barriers to use for both users and medical staff. In fact, while some quantitative studies have already been conducted on the usefulness of CGM, studies on the barriers to use perceived by patients and medical staff are limited. Also, there have been no large-scale studies about the advantages and disadvantages of CGM. Therefore, the purpose of this study was to investigate the advantages and disadvantages of using CGM for patients and HCPs through a large-scale online survey.

Methods

Study design

This multicenter, cross-sectional survey-type study investigated the utilization, discomfort levels, and its countermeasures for CGM in patients with diabetes and HCPs.

Survey

The patient questionnaire comprised 28 questions, designed based on a thorough literature review [20,21] (Figure 1). In contrast, the questionnaire for medical staff consisted of 10 questions to evaluate

doctors' experience in prescribing and using CGM. An additional 10 questions were developed for educational nurses based on data from a literature review [21].

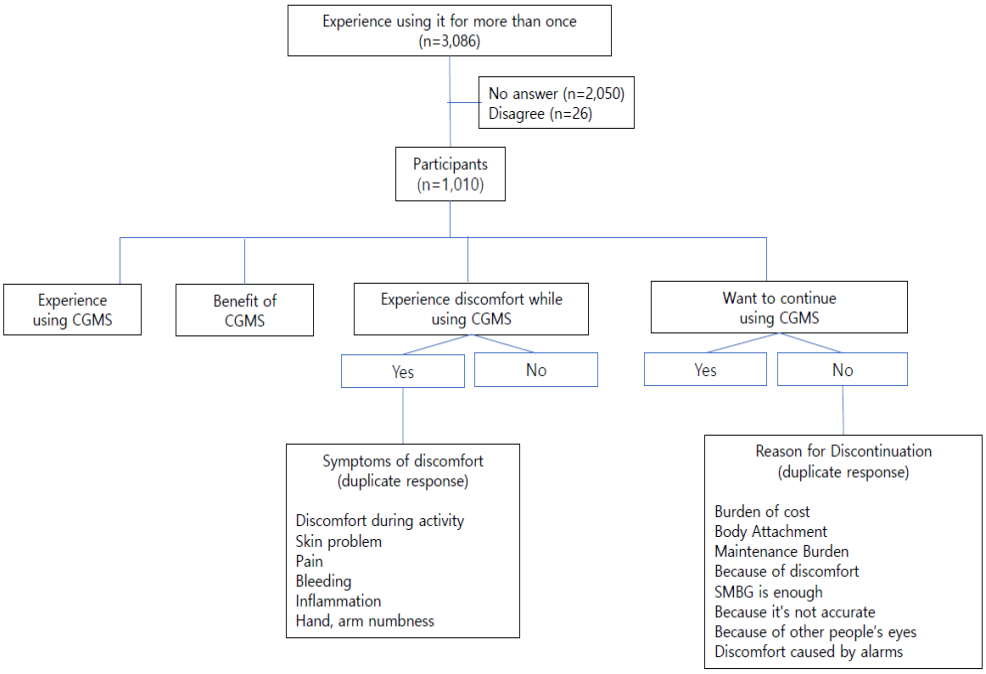

Figure 1: Inclusion & Exclusion criteria of this study.

Participants

From January 2021 to December 2021, we conducted an online structured questionnaire involving diabetic patients who were using CGM at four university hospitals in Seoul, Korea. Participants were required to understand the questionnaire and voluntarily agree to participate in order to collect relevant data. Before the survey was conducted, 1,036 patients were provided with an online explanation of the purpose of the study. After obtaining consent, the structured questionnaire was distributed online, and responses were subsequently collected. Of the initial group, 26 individuals declined to participate, resulting in 1,010 completed surveys. The physician survey utilized a structured online questionnaire targeting both physicians prescribing CGM and diabetes education nurses responsible for CGM education. Informed consent was obtained prior to the survey, and the survey was completed by 29 endocrinology specialists and 9 nurses specializing in diabetes education with over 10 years of experience.

Ethical considerations

This study received approval from the Institutional Review Boards of Kangdong Kyung Hee University Hospital (KHNMC 2022-04-035), Seoul Samsung Medical Center (2022-05-093), Seoul St. Mary's Hospital (2022-1507-0002), and Yeouido St. Mary's Hospital (2022-1202-0003). All participants were provided with detailed information about the study's objectives, methods, expected outcomes, and procedures through an online consent form. They were explicitly informed that their data would be used solely for academic research purposes. To ensure confidentiality and comply with the Personal

Information Protection Act, all personal information was anonymized to prevent identification. Participants were also informed of their right to withdraw from the online survey at any time without consequences. After confirming their understanding and agreeing to participate voluntarily, participants proceeded with the online survey.

Data analysis

The collected data were analyzed using SPSS version 19.0 (IBM Corp., Armonk, NY, USA). Each item was subjected to a frequency analysis, with the results expressed as numerical counts and percentages, as well as means and standard deviations.

Results

Patient's baseline characteristics

The survey included 1,010 patients, of whom 481 (47.6%) were male and 529 (52.4%) were female. The average age of the participants was 51 years, with 41.5% under 50 years old, 37.7% aged 50 to less than 65 years, and 20.8% aged 65 years and older. The average duration of diabetes was 13 years, with 29.2% having had diabetes for more than 5 but less than 10 years. Type 2 diabetes accounted for 63.6% of the cases, while type 1 diabetes accounted for 33.4%. Among those with type 2 diabetes, 42.4% were using insulin at least once, and 46.9% were taking oral hypoglycemic agents. Regarding education on CGM usage, 90.2% of type 1 diabetes patients and 94.2% of type 2 diabetes patients reported having received training. Additionally, 75.1% of type 1 diabetes patients and 85.5% of type 2 diabetes patients had received prior education on potential discomforts associated with CGM usage **(Table 1).**

Table 1: Patients' baseline characteristics (N=1,010).

Variables	Categories	Total (N=1,010)	T1DM (N=337)	T2DM (N=642)	Others (N=31)
		N (%)	N (%)	N (%)	N (%)
Sex	Male	481 (47.6)	138 (40.9)	338 (52.6)	5 (16.1)
	Female	529 (52.4)	199 (59.1)	304 (47.4)	26 (83.9)
Age (years)	<50	419 (41.5)	200 (59.3)	200 (31.2)	19 (61.3)
	50≤ <65	381 (37.7)	86 (25.5)	287 (44.7)	8 (25.8)
	≥65	210 (20.8)	51 (15.1)	155 (24.1)	4 (12.9)
	Mean±SD	51.4±14.6	45.6±15.8	54.7±12.9	45.6±12.2
Duration of diabetes (years)	≤1	76 (7.6)	14 (4.2)	55 (8.6)	7 (29.2)
	2–4	114 (11.4)	38 (11.3)	69 (10.7)	7 (29.2)
	5–9	292 (29.2)	97 (29.0)	188 (29.3)	7 (29.2)
	10–19	241 (24.1)	89 (26.6)	152 (23.70	0
	≥20	278 (27.8)	97 (29.0)	178 (27.7)	3 (12.5)
	Mean±SD	12.9±10.8	13.6±10.3	12.8±11.0	5.0±7.7
Type of diabetes		1010 (100)	337 (33.4)	642 (63.6)	31 (3.1)
treatment method	Diet	89 (8.8)	0	69 (10.7)	20 (64.5)
	Oral agent	305 (30.2)	3 (0.9)	301 (46.9)	1 (3.2)
	Oral agent \+Insulin	204 (20.4)	11 (3.3)	192 (29.9)	1 (3.2)
	Insulin	410 (40.6)	323 (95.8)	80 (12.5)	7 (22.6)
	etc.	2 (0.2)	0	0	2 (6.5)
Training experience on how to use CGM	Yes	938 (92.9)	304 (90.2)	605 (94.2)	29 (93.5)
	No	72 (7.1)	33 (9.8)	37 (5.7)	2 (6.5)
Educational experience related to CGM discomfort	Yes	827 (81.9)	253 (75.1)	549 (85.5)	25 (80.6)
	No	183 (18.1)	84 (24.9)	93 (14.5)	6 (19.4))

T1DM: type 1 diabetes mellitus, T2DM: type 2 diabetes mellitus

Patient experience

Based on the results of the survey pertaining to the specific products used by diabetes type, patients with type 1 diabetes had previously used Libre 1 (67.4%), Dexcom 6 (46.9%), and Guardian 3 (4.7%); currently used Libre 1 (45.7%), Dexcom 6 (40.4%), and Guardian 3 (1.8%); or had not used CGMS at all (12.2%). Among patients with type 2 diabetes, 97.7%, 2.3%, and 0.9% had previously used Libre 1, Dexcom 6, and Guardian 3, respectively; 43.9%, 1.6%, and 0.2% currently used Libre 1, Dexcom 6, and Guardian 3, respectively; and 54.5% did not use a CGMS at the time of the survey. For those with type 1 diabetes, 82.2% utilized a CGMS ≥4 times during the survey; for type 2 diabetes, 47.7%, 27.1%, and 17.4% used a CGMS 1 time, ≥4 times, and 2 times during the survey **(Table 2)**.

Table 2: Patients' experiences with CGM use (N=1,010).

Variables	Categories	Total (N=1,010) N (%)	T1DM (N=337) N (%)	T2DM (N=642) N (%)	Others (N=31) N (%)
Experience in use (duplicate response)	Libre 1	885 (87.6)	227 (67.4)	627 (97.7)	31 (100)
	Dexcom 6	175 (17.3)	158 (46.9)	15 (2.3)	2 (6.5)
	Gardian 3	22 (2.2)	16 (4.7)	6 (0.9)	0
Currently in use	No	414 (41.0)	41 (12.2)	350 (54.5)	23 (74.2)
	Libre 1	443 (43.9)	154 (45.7)	281 (43.8)	8 (25.8)
	Dexcom 6	146 (14.5)	136 (40.4)	10 (1.6)	0
	Gardian 3	7 (0.7)	6 (1.8)	1 (0.2)	0
Number of use experiences	1 time	339 (33.6)	16 (4.7)	306 (47.7)	17 (54.8)
	2 time	138 (13.7)	22 (6.5)	112 (17.4)	4 (12.9)
	3 time	75 (7.4)	22 (6.5)	50 (7.8)	3 (9.7)
	4 time >	458 (45.3)	277 (82.2)	174 (27.1)	7 (22.6)
Advantages of using (duplicate response)	Assisting with the maintenance of target blood glucose levels	405 (40.1)	139 (41.2)	247 (38.5)	19 (61.3)
	Reduces the fear of hypoglycemia	159 (15.7)	71 (21.1)	82 (12.8)	6 (19.3)
	achieving postprandial glycemic stability	254 (25.1)	78 (23.1)	171 (26.6)	5 (16.1)
	Dietary management	186 (18.4)	50 (14.8)	130 (20.2)	6 (19.4)
	Insulin dose adjustment	137 (13.6)	45 (13.4)	92 (14.3)	0
	Monitoring of blood glucose levels without blood sampling	572 (56.6)	195 (57.9)	361 (56.2)	16 (51.6)
	Reduction of blood glucose test time, convenience	133 (13.2)	45 (13.4)	85 (13.2)	3 (9.7)
	Etc.	16 (1.6)	5 (1.5)	10 (1.6)	1 (3.2)
Usefulness of blood glucose management	It really is	567 (56.1)	187 (55.5)	364 (56.7)	16 (51.6)
	Yes	370 (36.6)	128 (38.0)	228 (35.5)	14 (45.2)
	Is average	65 (6.4)	19 (5.6)	45 (7.0)	1 (3.2)
	Not like that	5 (0.5)	2 (0.6)	3 (0.5)	0
	Very not so	3 (0.3)	1 (0.3)	2 (0.3)	0
Convenience in blood glucose management	It really is	549 (54.4)	187 (55.5)	346 (53.9)	16 (51.6)
	Yes	387 (38.3)	126 (37.4)	247 (38.5)	14 (45.2)
	Is average	63 (6.2)	20 (5.9)	42 (6.5)	1 (3.2)
	Not like that	9 (0.9)	4 (1.2)	5 (0.8)	0
	Very not so	2 (0.2)	0 (0.0)	2 (0.3)	0

CGM: continuous glucose monitoring, T1DM: type 1 diabetes mellitus, T2DM: type 2 diabetes mellitus

Patient advantages

When asked if CGM use helped manage their diabetes, 92.7% of the patients provided affirmative responses, including "It really is" and "Yes." When asked if a CGM was convenient for managing their diabetes, 92.7% of the patients provided positive responses, including "It really is" and "Yes" **(Table 2).** When asked about the benefits of using a CGM, patients with type 1 diabetes cited the following benefits: "monitoring of blood glucose levels without blood sampling" (57.9%), "assisting with the maintenance of target blood glucose levels" (41.2%), "achieving postprandial glycemic stability" (23.1%), and "reduces the fear of hypoglycemia" (21.1%). Those with type 2 diabetes cited the following benefits of CGM use: "monitoring of blood glucose levels without blood sampling" (56.2%), "assisting with the maintenance of target blood glucose levels" (38.5%), "achieving postprandial glycemic stability" (26.6%), and "dietary management" (20.2%) **(Table 2).**

Patient disadvantages

Among the patients who used CGM, 602 (59.6%) reported experiencing discomfort during usage, while 408 (40.4%) reported the absence of discomfort. This suggests that a significant proportion of users experienced some degree of discomfort. Among them, 82.8% of the patients with type 1 diabetes and 48.1% with type 2 diabetes reported discomforts. All patients reported "discomfort during activity"

(53.8%), "skin problems" (45.0%), "pain" (43.0%), "bleeding" (24.4%), "inflammation "(8.6%), and "hand, arm numbness" (7.6%). Among patients diagnosed with type 1 diabetes, the foremost factors contributing to discomfort were identified as "skin problems" (59.5%), "pain" (53.8%), "discomfort during activity" (49.1%), and "bleeding" (41.6%). In those with type 2 diabetes, the primary causes were "discomfort during activity" (58.3%), "pain" (32.7%), and "skin problems" (31.4%). Of the total respondents, 41.4% had experienced a fall before the end date. The prevailing causes attributed to these falls were as follows: "when dressing and undressing" (33.3%), "I don't know when it fell" (29.2%), "in the shower" (26.6%), and "I sweat a lot" (23.2%). The strategies were employed to address their discomfort: "not treated" (47.1%), "self-treatment (ointment, etc.)" (39.5%), "product customer center inquiry" (7.8%), "consultation with the medical staff in charge" (7.4%), and "individual treatment (dermatology, etc.)" (3.1%). When asked about their preference to continue utilizing their CGM, 81.9% of the respondents expressed their intention to do so, of whom 83.4% had type 1 diabetes and 81.0% had type 2 diabetes. The factors contributing to the discontinuation of CGM usage were as follows: "burden of cost" (58.9%), "because of discomfort" (39.3%), and "body attachment maintenance burden" (28.6%) in those with type 1 diabetes and "burden of cost" (64.5%), "body attachment maintenance burden" (32.8%), and "because of discomfort" (24.6%) in those with type 2 **(Table 3)**.

Table 3: Patients' discomfort with the use of CGM.

Variables	Categories	Total	T1DM	T2DM	Others
		N (%)	N (%)	N (%)	N (%)
Experience of discomfort (N=1,010)	Yes	602 (59.6)	279 (82.8)	309 (48.1)	14 (45.2)
	No	408 (40.4)	58 (17.2)	333 (51.9)	17 (54.8)
Symptoms of discomfort (N=602) (duplicate response)	Discomfort during activity	324 (53.8)	137 (49.1)	180 (58.3)	7 (50.0)
	Skin problem	271 (45.0)	166 (59.5)	97 (31.4)	8 (57.1)
	Pain	259 (43.0)	150 (53.8)	101 (32.7)	8 (57.1)
	Bleeding	147 (24.4)	116 (41.6)	30 (9.7)	1 (7.1)
	Inflammation	52 (8.6)	32 (11.5)	20 (6.5)	0
	hand, arm numbness	46 (7.6)	19 (6.8)	25 (8.1)	2 (14.3)
	Etc.	77 (12.8)	36 (12.9)	39 (12.6)	2 (14.3)
Coped with discomfort (N=602) (duplicate response)	Not treated	285 (47.1)	120 (56.6)	160 (42.8)	5 (26.3)
	Self-treatment (ointment, etc.)	239 (39.5)	73 (34.4)	153 (40.9)	13 (68.4)
	Product customer center inquiry	47 (7.8)	20 (9.4)	26 (7.0)	1 (5.3)
	Consultation with the medical staff in charge	45 (7.4)	9 (4.2)	34 (9.1)	2 (10.5)
	Individual treatment (dermatology, etc.)	19 (3.1)	4 (1.9)	15 (4.0)	0
	Etc.	50 (8.3)	17 (8.0)	32 (8.6)	1 (5.3)
Discontinued before ending (N=1,010)	Yes	418 (41.4)	207 (61.4)	201 (31.3)	10 (32.3)
	No	592 (58.6)	130 (38.6)	441 (68.7)	21 (67.7)
Discontinued before ending (N=418) (duplicate response)	When dressing and undressing	139 (33.3)	79 (38.2)	56 (27.9)	4 (40.0)
	I don't know when it fell	122 (29.2)	58 (28.0)	60 (29.9)	4 (40.0)
	In the shower	111 (26.6)	68 (32.9)	41 (20.4)	2 (20.0)
	I sweat a lot	97 (23.2)	54 (26.1)	42 (20.9)	1 (10.0)
	During exercise	60 (14.4)	38 (18.4)	21 (10.4)	1 (10.0)
	Etc.	78 (18.7)	42 (20.3)	34 (16.9)	2 (20.0)
Continued to use (N=1,010)	Continue to use	827 (81.9)	281 (83.4)	520 (81.0)	26 (83.9)
	Discontinue to use	183 (18.1)	56 (16.6)	122 (19.0)	5 (16.1)
Reason for discontinuation (N=183) (duplicate response)	Burden of cost	116 (63.4)	33 (58.9)	79 (64.8)	4 (80.0)
	Body attachment maintenance burden	57 (31.1)	16 (28.6)	40 (32.8)	1 (20.0)
	Presence of discomfort	54 (29.5)	22 (39.3)	30 (24.6)	2 (40.0)
	SMBG is enough	32 (17.5)	10 (17.9)	22 (18.0)	0
	Because it's not accurate	27 (14.8)	6 (10.7)	21 (17.2)	0
	Because of other people's eyes	12 (6.6)	4 (7.1)	8 (6.6)	0
	Discomfort caused by alarms	5 (2.7)	0 (0.0)	4 (3.3)	1 (20.0)
	Etc.	11 (6.0)	5 (8.9)	6 (4.9)	0

CGM: continuous glucose monitoring, T1DM: type 1 diabetes mellitus, T2DM: type 2 diabetes mellitus

Physician experience

When asked about the proportion of patients with type 1 diabetes who were prescribed with CGM, 51.9% of the physicians provided the following patient allocation: Libre 1, Dexcom 6, and Gardian 3 in 60.0%, 30.3%, and 4.5% of the patients, respectively. CGM had been prescribed by physicians to 14.5% of the patients with type 2 diabetes; approximately 91.0% of the physicians prescribed Libre 1, 2.4% prescribed Dexcom 6, and 0.7% prescribed Gardian 3. When prescribing CGM to patients with type 2 diabetes, 81.5% prescribed it for "patients with severe hyperglycemia," 51.9% for "patients with frequent hypoglycemia," 29.6% for "first time insulin users," and 25.9% for patients in whom "diabetes first diagnosis, medication adjustment, and lifestyle therapy needed" upon initial diagnosis **(Table 4).** The reasons for prescribing CGM were as follows: "helps regulate insulin dose" (60.7%), "helps maintain target blood glucose" (53.6%), and "reduces the fear of hypoglycemia" (50.0%). The barriers to the utilization of CGM in their practices were as follows: "expensive" (89.3%), "no time to explain CGM at first prescription" (67.9%), and "difficulty accessing the website to check the ambulatory glucose profile (AGP) report" (57.1%) **(Table 5).** According to the surveyed physicians, the reasons why patients with type 1 diabetes refused to use CGM were as follows: "The burden of maintaining body attachment" (82.8%), "because of discomfort (skin side effects, bleeding, etc.)" (55.2%), and "burden of cost" (51.7%). Among those with type 2 diabetes, the most common reasons for refusal were "burden of cost" (93.1%), "the burden of maintaining body attachment" (65.5%), and "because of discomfort (skin side effects, bleeding, etc.)" (55.2%) **(Table 4).** With respect to the approaches employed by the prescribing doctor to the patient's discomfort, 53.6% opted to have the "CGM discontinued," 39.3% preferred to "observe symptoms while maintaining CGM," 25.0% chose "ointment prescription," and 10.7% answered either "dermatology, etc. requests for treatment" or "product customer center inquiry description." With regard to their perspectives on the adoption of new technologies for glycemic stability, 96.6% chose either the "positive" or "very positive" response, while 3.4% chose the "common" response **(Table 5).**

Table 4: Doctors' experience with CGMS use (N=29).

	Variables	Categories	% or N (%)
T1DM	Ratio of use among patients in total patients (%)		51.9
	Prescription rate by CGM type	Libre 1	60
		Dexcom 6	30.3
		Gardian 3	4.5
	Doctors' reasons for discontinuing CGM in T1DM patients (duplicate response)	The burden of maintaining body attachment	24 (82.8)
		Because of discomfort (skin side effects, bleeding, etc.)	16 (55.2)
		Burden of cost	15 (51.7)
		Because of strangers	7 (24.1)
		SMBG is enough	5 (17.2)
		Because the numbers are not accurate	2 (6.9)
		Discomfort caused by alarms	1 (3.4)
T2DM	Ratio of use among patients in total patients		14.5
	Prescription rate by CGM type	Libre 1	91
		Dexcom 6	2.4
		Gardian 3	0.7
	The reasons for prescribing CGM in patients with T2DM (duplicate response)	Patients with severe hyperglycemia	22 (81.5)
		Patients with frequent hypoglycemia	14 (51.9)
		first time insulin users	8 (29.6)
		Diabetes first diagnosis, medication adjustment, and lifestyle therapy needed	7 (25.9)
	Doctors' Reasons for T2DM Patients' CGM Rejection (duplicate response	Burden of cost	27 (93.1)
		The burden of maintaining body attachment	19 (65.5)
		Because of discomfort (skin side effects, bleeding, etc.)	16 (55.2)
		SMBG is enough	5 (17.2)
		Because of strangers	4 (13.8)
		Because the numbers are not accurate	3 (10.3)
		Discomfort caused by alarms	0

CGM: continuous glucose monitoring, T1DM: type 1 diabetes mellitus, T2DM: type 2 diabetes mellitus

Table 5: Doctors' experience with CGMS use (cont'd) (N=29).

Variables	Categories	N (%)
Reason for prescription (duplicate response)	Helps regulate insulin dose	17 (60.7)
	Helps maintain target blood glucose	15 (53.6)
	Reduces the fear of hypoglycemia	14 (50.0)
	Helps Postprandial glycemic stability	11 (39.3)
	Diet help	9 (32.1)
	Helps to check blood sugar levels without drawing blood	9 (32.1)
	Reduce blood sugar test time and convenience	1 (3.6)
Obstacles when prescribing CGM (duplicate response)	Expensive	25 (89.3)
	No time to explain CGM at first prescription	19 (67.9)
	Difficulty accessing the website to check the AGP report	16 (57.1)
	Inaccurate compared with SMBG	4 (14.3)
	Concern regarding the occurrence of side effects (bleeding, pain, skin side effects, etc.)	3 (10.7)
	SMBG alone is sufficient for treatment	2 (7.1)
	Less effective than explanations such as AGP report	1 (3.6)
Addressing patients' complaints of discomfort associated with CGM use (duplicate response)	CGM discontinued	15 (53.6)
	Observe symptoms while maintaining CGM	11 (39.3)
	Ointment prescription	7 (25.0)
	Dermatology, etc. request for treatment	3 (10.7)
	Product customer center inquiry description	3 (10.7)
Thoughts on the introduction of new technologies related to blood sugar control	Very positive	22 (75.9)
	Positive	6 (20.7)
	Commonly	1 (3.4)
	Negative	0
	Very negative	0

CGM: continuous glucose monitoring, T1DM: type 1 diabetes mellitus, T2DM: type 2 diabetes mellitus, AGP: ambulatory glucose profile, SMBG: self-monitoring of blood glucose

Educational nurse experience

The nurses who participated in the survey were diabetes education nurses in charge of CGM education and counseling in four hospitals, and nine nurses completed the survey. The average number of CGM-related consultations per day was 17, with an average duration of 32 min for initial education and 22 min for follow-up (F/U) consultation. When asked about the utility of CGM for diabetes education in their patients, all respondents unequivocally replied with either "it really is" or "yes." All (100%) respondents who had received diabetes education thought that the CGM was necessary for both "type 1 diabetes patients" and "MDI patients in type 2 diabetes," 66.7% for "first diagnosis of type 2 diabetes patients" and "person with gestational diabetes," and 22.2% for "patients using an oral hypoglycemic agent" and "person with pre-diabetes." Approximately 72.2% of the diabetes education nurses recommended the use of CGM to patients who were thought to benefit from such a device. Meanwhile, the reasons for not recommending it were as follows: "expense" (88.9%); "cannot be used by patients (smartphone not holding, etc.)" (66.7%);

and "lack of explanation time, etc." (55.6%). The most burdensome aspect of CGS-related work was "frequent inquiries and complaints about user errors" (77.8%), "initial training (application installation, instruction on how to use, etc.) takes a long time" (66.7%), and "result data consultation and Electric Medical Record upload work" (22.2%) **(Table 6).**

Table 6: Education nurses' CGM experience (N=9).

Variables	Categories	N (%) or mean±SD
Number of consultations per day related to CGM (includes first visit and F/U) (time)		16.9 ± 12.5
Average duration of initial training (min)		31.7±7.5
Average duration of F/U consultation (min)		21.7±9.7
Among patients who are considered to need CGM How many % are your recommending (%)		72.2 ± 24.4
The degree to which CGM helps in diabetes education	It really is	8 (88.9)
	Yes	1 (11.1)
	Is average	0
	Not like that	0
	Very not so	0
Types of patients requiring CGM (duplicate response)	Patients with T1DM	9 (100)
	T2DM MDI patients	9 (100)
	T2DM first diagnosis	6 (66.7)
	GDM patients	6 (66.7)
	Patients using OHA	2 (22.2)
	Pre-diabetic patients	2 (22.2)
Reasons for not recommending CGM (duplicate response)	Expense	8 (88.9)
	Cannot be used by patients (smartphone not holding, etc.)	6 (66.7)
	Lack of explanation time, etc.	5 (55.6)
	Patient rejection due to discomfort	3 (33.3)
	Consider your physician's preferences	1 (11.1)
The part with the largest workload related to CGM (duplicate response)	Frequent inquiries and complaints about user errors	7 (77.8)
	Initial training (application installation, instruction on how to use, etc.) takes a long time	6 (66.7)
	Result data consultation and EMR upload work	2 (22.2)

CGM: continuous glucose monitoring, T1DM: type 1 diabetes mellitus, T2DM: type 2 diabetes mellitus, GDM: gestational diabetes mellitus, OHA: oral hypoglycemic agent, EMR: electric medical record

Discussion

CGM represents a paradigm shift in glucose management and has become the standard of care for diabetic patients utilizing insulin for blood glucose control. Prior research has predominantly concentrated on the accuracy and reliability of CGM systems, whereas investigations into the experiential aspects of routine usage have been comparatively scarce. This study conducts a comprehensive large-scale survey to elucidate the everyday usage experiences of patients and healthcare providers employing CGM in Korea. A previous study that explored the association between CGM use and blood glucose levels revealed that adult patients with type 1 diabetes who used a CGM were 1.9 times more likely to achieve the target blood glucose levels, as indicated by a glycated hemoglobin level of <7%,

compared with those who did not use a CGM. This observation underscores the heightened likelihood of patients achieving their glycemic targets when utilizing CGM [22]. CGM use confers notable advantages in enhancing glycemic control among patients with type 2 diabetes, especially those in the CGM group, leading to improved treatment regimens compared with those in the control group [23]. This outcome is consistent with the benefits of the CGM reported in this study, which include the facilitation of target blood glucose level maintenance and the mitigation of postprandial hyperglycemia or hypoglycemia. In addition to multiple studies corroborating the efficacy of CGM (7.8), insurance coverage for patients with type 1 diabetes was initiated in South Korea in 2018. An analysis of the Korea Insurance Corporation database from 2019 to 2022 revealed that only 19% of type 1 diabetes patients had ever been prescribed a CGM, indicating a relatively low adoption rate. Additionally, only 10.7% of these patients continued using the CGM consistently [24]. Moreover, the medical staff at Korean university hospitals who participated in the survey confirmed that they only prescribed CGM to half of their patients with type 1 diabetes. When delineating the factors influencing the discontinuation of CGM, more than half of the patients with type 1 diabetes cited “burden of cost” (58.9%), “because of discomfort” (39.3%), and “body attachment maintenance burden” (28.6%). By contrast, doctors, when posed with a similar question, identified “body attachment maintenance burden” (33.8%) as the most important reason, followed by “because of discomfort” (23.5%) and “burden of cost” (20.6%). This disparity in perspectives between patients and doctors underscores the notable differences in their viewpoints. This can be attributed to the fact that the insurance coverage for CGM started in 2018. Although medical professionals may perceive the cost of CGM as relatively low for patients with type 1 diabetes, many patients continue to harbor concerns regarding the perceived financial burden associated with the ongoing utilization of these systems. In the Korean healthcare environment, medical professionals may decline to prescribe CGM for reasons beyond financial considerations. Most existing studies on barriers to CGM use were qualitative studies or were conducted targeting patients with type 1 diabetes. Through qualitative research, barriers such as cost, pain, skin problems, concerns about accuracy, discomfort during activity, and accidental removal were identified [25-28], and research studies also found that cost-related and attachment-related discomfort had the highest rates [29-31].These factors are similar to the reasons reported in this study; in a previous survey evaluating the barriers to the use of diabetic devices in patients with type 1 diabetes introduced in Diabetes Care in 2017, the number one reported barrier was cost (35%), followed by alarm (32%), body attachment maintenance burden (30%), and because it is not accurate (30%) [20]. This study reported that the reasons for discontinuation were “discomfort caused by the alarms” in only 8% and “because it is not accurate” in 14.8%. This is thought to be the result of the high proportion of patients using Libre 1, an intermittent CGM that does not yet have an alarm function in Korea. Furthermore, the enhancements in the Mean Absolute Relative Difference (MARD) values of all available CGM, as these systems underwent refinement, could have played a role in mitigating concerns related to accuracy [32]. The cost and burden of body attachment, which are the biggest barriers to their use in Korea, are expected to

gradually improve as the market for CGM develops, driven by competition among diverse manufacturers and advancements in the development of smaller and more user-friendly products [33]. In terms of discomfort such as skin-related side effects and bleeding, a recently developed noninvasive CGM, which is worn on the wrist and uses noninvasive radiofrequency to obtain accurate results, has recently undergone a pilot test in five patients with type 2 diabetes and is expected to elicit fewer complaints [34]. However, this device is still in the pilot stage of development and is not anticipated to become commercially accessible for a considerable duration. Therefore, the discomfort of use still requires attention, which is an important barrier to the use of CGM. In our survey, 82.8% of the patients with type 1 diabetes and 48.1% of the patients with type 2 who used a CGM continuously reported experiencing discomforts; the most prevalent cause of discomfort in patients with type 1 diabetes was attributed to "skin problem" (59.5%). Furthermore, "discomfort during activity" (58.3%) was reported primarily during the initial application or intermittent use of the system. Although objective side effects, such as adverse skin reactions and bleeding, can influence the decision to discontinue CGM usage, subjective symptoms experienced by patients exert a substantial influence on the utilization of these systems. To address this, it is imperative to enhance the clarity of the CGM's intended purpose and highlight its benefits during the initial stages of patient education, alongside comprehensive guidance on the prevention of side effects.

When asked about their course of action in response to a patient's complaint of discomfort, over half of the prescribing physicians indicated their inclination to terminate the use of CGM. This finding underscores the significance of patient discomfort as a barrier to the continued prescription of CGM, despite their manifold advantages. Apart from the subjective discomfort reported by patients, a number of side effects associated with the utilization of these devices have been documented: "skin problem" (45.0%), "bleeding" (24.4%), "inflammation" (8.6%), and "hand, arm numbness" (7.6%). These findings emphasize the necessity for the establishment of comprehensive guidelines addressing the prevention and management of these side effects. A total of 96.6% of prescribers expressed a favorable disposition toward the incorporation of new technologies. However, in terms of practical application, two notable impediments emerged: "expense" (88.9%) and "no time to explain CGM at first prescription" (66.7%) proved to be significant obstacles. Educational nurses similarly conveyed the challenges associated with advocating for the utilization of CGM due to the "lack of explanation time, etc." Moreover, more than half of these nurses (55.6%) noted that the frequent complaints from patients regarding device usage and errors placed the most substantial demands on their professional responsibilities. Therefore, the need for counseling time, in the context of rapidly developing modern devices and a progressively aging user demographic, may serve as additional obstacles to the adoption of new technologies among diabetes patients. This study has some limitations. First, this was a survey of patients with diabetes and medical team who were admitted in university hospitals in Korea; therefore, this population may not be representative of all patients with diabetes and medical team in Korea. Second, this was a questionnaire-based survey pertaining to CGM utilization. Blood tests were not performed, which could have potentially provided a

more accurate reflection of the blood glucose levels among the target patients. Lastly, among the survey subjects, 59.6% of the patients experienced discomfort, while 29.5% of the subjects answered that discomfort was the reason for the suspension of use, so further research is needed on why discomfort did not lead to suspension of use and the level of discomfort symptoms.

In conclusion, this study confirmed the benefits of CGM, particularly their utility in blood glucose monitoring and blood glucose management. The discomforts reported due to CGM usage included discomforts during activity, skin problems, pain, and bleeding. Predominantly, cost emerged as the primary factor influencing the discontinuation of CGM use. Despite the uncomfortable symptoms, 81.9% of the respondents expressed a desire to continue using CGM, underscoring the potential for increased adoption if cost-related and skin discomfort issues were addressed. However, a significant proportion of physicians discontinue prescribing CGM when patients complain of discomfort. Moreover, the recurrent queries regarding CGM usage and errors pose an additional burden to patient training. Therefore, these technologies require further improvements. In addition, this study is very meaningful because it is a large-scale study of patients in multiple hospitals on the benefits and barriers of CGM use and is the first to examine both patients and medical professionals.

Conclusion

This study demonstrated that patients with both type 1 and type 2 diabetes have expressed their preferences for CGM in the following order of popularity: “monitoring of blood glucose levels without blood sampling,” “assisting with the maintenance of target blood glucose levels,” “achieving postprandial glycemic stability,” “dietary management,” “reduction in the fear of hypoglycemia,” and “insulin dose adjustment.” However, respondents primarily reported issues such as “discomfort during activity,” “skin problems,” and “pain” when using CGM. The most commonly cited reasons for not using CGM continuously included the “burden of cost,” “body attachment maintenance burden,” “discomfort,” the belief that “SMBG is sufficient,” and concerns regarding accuracy. Despite these uncomfortable symptoms, 81.9% of the respondents expressed a desire to continue using CGM. Therefore, enhancements in cost-effectiveness and reductions in skin discomfort associated with these systems could encourage more individuals to use them. Additionally, despite the benefits of CGM, physicians often discontinue prescribing them when patients report discomfort. Persistent inquiries about CGM errors can also pose a significant burden on training efforts. Hence, substantial improvements are necessary to address these challenges.

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