REVIEW ARTICLE KERALA MEDICAL JOURNAL

20 Years of Continuous Glucose Monitoring in India: Options and Indications

Jothydev Kesavadev[a], Sreelakshmi R[a], Gopika Krishnan[a], Anjana Basanth[a]

a. Jothydev's Diabetes and Research Centre, Trivandrum, Kerala, India.*

Published on 21st October 2024

ABSTRACT

The increasing prevalence of diabetes worldwide is a major concern, especially in developing countries where achieving optimal glycemic control is challenging. Continuous Glucose Monitoring (CGM) systems have revolutionized diabetes management by providing detailed and real-time insights into glucose fluctuations. Over the past 20 years, CGM technology has significantly evolved with improved accuracy, user-friendliness, and clinical utility. This review discusses the progressive development of CGM systems in India, types of CGM systems including professional, real-time, intermittently scanned, and integrated CGMs, and their specific indications. The review also highlights novel innovations in CGM and explores the importance of metrics such as Time in Range (TIR) and Time in Tight Range (TITR) in glycemic management. By enhancing patient and healthcare provider decision-making, CGM systems have become an inevitable part of diabetes care, offering a more comprehensive and effective approach to managing the condition.

Keywords: Diabetes, CGM, Technology, RT-CGM, P-CGM, Glucose Monitoring, Time in Range, Time in Tight Range

*See End Note for complete author details

INTRODUCTION

Continuous Glucose Monitoring (CGM) is an innovative technology used in diabetes management that provides detailed information about the direction, magnitude, duration, frequency, and causes of fluctuations in glucose levels throughout the day.[1] It is exciting that the global estimate of CGM users is now greater than seven million.[2] Continuous glucose monitoring allows people with diabetes to determine whether their glycemic targets are being safely met and analyze the response to a therapy on an individual basis. Incorporating these findings into diabetes care might be helpful in facilitating optimal treatment decision-making, avoiding hypoglycemia.[3]

BASIC DESIGN OF A CGM

A CGM system typically comprises three parts: a tiny sensor inserted subcutaneously (disposable sensors) or placed inside the body (implantable sensor), a transmitter that sends the information wirelessly to a software program stored on a smartphone, insulin pump, or a separate device called a receiver.[3] Currently available CGMs measure glucose level in the interstitial fluid (ISF) through a tiny sensor inserted subcutaneously under the skin, usually on the abdomen or arm. The sensor measures glucose level every few minutes and transmits the information wirelessly to a monitoring device.[4] The accuracy of CGM is generally assessed using a metric called Mean Absolute Relative Difference (MARD). MARD is a statistical measure used to evaluate the accuracy of glucose readings from CGM devices by comparing them to reference glucose measurements. Lower MARD values indicate higher accuracy of the CGM system.[5] Implementing CGM as a vital element in diabetes management aids both patients and healthcare professionals (HCPs) in making timely decisions, and in improving the quality of life (QoL).

EVOLUTION OF CGM

The development of implantable glucose sensors and sensor technologies began in the early 1980s,

Cite this article as: Kesavadev J, Sreelakshmi R, Krishnan G, Basanth A. 20 Years of Continuous Glucose Monitoring in India: Options and Indications. Kerala Medical Journal. 2024 Oct 21;17(3):157–65. | DOI: https://doi.org/10.52314/kmj.2024.v17i3.665

Corresponding Author:
Dr. Jothydev Kesavadev MD, FRCP (London, Glassgow, Edinburg) FACE, FACP
Chairman, and Director, Jothydev's Diabetes Research Centers, Kerala, India Ph: 9895040055, Email:jothydev@gmail.com

contributing to the development of CGM devices. Initially, CGM was used as a research tool. Until the FDA approved the first MiniMed Continuous Glucose Monitoring System (CGMS), CGMS Gold (Medtronic MiniMed, CA, USA), in 1999, this technology was not commercially accessible.[6] The first professional CGM for glucose monitoring was a blinded system, meaning the patient was unaware of the glucose data acquired for three days. The data was extracted and reviewed at the healthcare provider's office. The system includes a glucose sensor, a monitor, a connecting cable, a Com-Station compatible with Windows 95 that allowed glucose readings to be stored as data, and a test plug to assess the function of the sensor. The device measured the glucose levels of the interstitial fluid every 10 seconds, over 5-minute intervals. CGM readings alone were not suitable for the therapeutic decision-making and required a confirmatory finger-pick test. The main advantage of CGMS Gold was its ability to unveil patterns that are missed by conventional blood glucose monitoring.

When CGM was first commercially available, its measurement error was more than ± 20%. Technological advancements have reduced measurement errors (±10%) and improved accuracy. Furthermore, improvements in the size, weight, complexity, and cost of CGM sensors/devices contributed to better performance of these devices in terms of duration of use, specificity, user-friendliness, user interface and displays, and data analysis and management. Based on their intended use, four types of CGM systems have been developed: Professional/Blinded CGM (P-CGM), Intermittently scanned CGM (isCGM), Real-time CGM (rt-CGM), and Integrated CGM (iCGM).[7]

In India, the evolution of CGM started with the availability of CGMS Gold in 2005.[6,8] iPro2 (Medtronic), the professional CGM introduced in India in 2016, was popular for nearly a decade.[9] The iPro2 collects and stores data from a glucose sensor that can be uploaded into CareLinkiPro® Therapy Management Software for Diabetes (CareLinkiPro, MMT-7340), to generate reports and store data. The device can store data up to 144h (6 days). In 2015, Abbott received FDA approval in India for FreeStyle® Libre Pro Flash Glucose Monitoring System. India was the first country to launch this professional CGM that does not require user calibration with finger-prick blood glucose.[10] The FreeStyle Libre Pro Flash Glucose Monitoring System comprises a handheld reader, a disposable sensor, and FreeStyle Libre Pro software. The device is indicated only for HCPs for use in people aged 18 years and older with diabetes. FreeStyle Libre Pro System provides HCPs with an Ambulatory Glucose Profile (AGP), a report produced from comprehensive glucose data that offers a visual snapshot of a person's typical daily glucose level and reveals hypoglycemic and hyperglycemic trends, facilitating better patient therapy and education. Healthcare providers can link an individual's glucose trends from AGP for more personalized and informed treatment decisions and enhanced communication between HCPs and patients.[11]

In 2020, Abbott launched FreeStyle Libre in India.[12] FreeStyle® Libre has a sensor and reader that provides real-time glucose readings upon scanning the sensor with the reader/smartphone app, offering a complete picture of a person's glucose levels without painful finger sticks. The system has a sensor wear time of 14 days and a warmup period of I hr.

Guardian Connect, the first real time CGM (RT-CGM) in India, utilizes Guardian Sensor 3, the Guardian Connect transmitter, and the Guardian Connect app to transmit data via Bluetooth every 5 minutes to the user's smart phone or device via the Guardian Connect App via CareLink personal and professional software. Approved by FDA in 2018, the Guardian Connect system is indicated for the periodic monitoring of glucose levels in the interstitial fluid in patients aged 14 to 75 years. Guardian Sensor 3 is indicated for 7 days of continuous use and is approved for use as an adjunctive device to complement information obtained from standard blood glucose monitoring devices and requires 2 daily finger stick calibrations. It is a stand-alone system which displays past glucose data from the previous 3, 6, 12, or 24 hours. The system has personalized alerts and alarm features, including adjustable volume settings at night and throughout the day, and snooze feature to silence CGM alerts for a period. The Guardian Connect transmitter powers the sensor, collects and calculates sensor data, and transmits the data via Bluetooth version 4.0 to the Guardian Connect app installed on a compatible mobile device. The transmitter is only compatible with the Guardian Sensor 3. The app displays the data, provides a user interface for sensor calibration, enters data such as exercise and meals, and uploads information to the CareLink Personal website.[13]

Guardian 4 Sensor

The Guardian 4 sensor is part of the CGM system and is compatible with the MiniMed™ 780G system that uses the Guardian 4 transmitter. Guardian 4 sensor is used in conjunction with the Guardian App.

Many CGM systems are widely used in countries other than India. Some recently introduced CGM systems include Dexcom G7, FreeStyle Libre 3 etc. Dexcom G7 is CGM with a MARD of 8.2% in adults measures interstitial glucose levels and sends the data to compatible devices including smart phones and the G7 receiver every 5 minutes. The all-in-one sensor/transmitter, which has a 10-day lifespan, can be worn on the upper buttocks and back of arm in children 2–6 years old and on the back of the arm in people aged 7 years and older. The data can be tracked by the users using the G7 app, support personnel on the Follow app, and by health care professionals on the Clarity app. FreeStyle Libre 3 is the latest generation of iCGM from Abbott which has the smallest, thinnest and most discreet glucose sensor. The FreeStyle Libre 3 reader is a small handheld device that displays real-time glucose readings directly from a small sensor worn on the back of a person's upper arm on an easy-to-see screen.

NOVEL INNOVATIONS IN CGM SYSTEMS

Dexcom ONE+

The Dexcom ONE+ system consists of a water-resistant sensor to measure blood glucose, a transmitter that sends CGM readings and a Dexcom One smartphone-compatible app. The system allows for real-time monitoring of blood glucose by both the user and up to ten additional people to allow for shared monitoring. Dexcom ONE+ can be worn at three different locations – abdomen, back of upper arms, or upper buttocks (only in children aged 2-17 years). The device also has a 'delay first high' option to avoid repeated high-reading alerts and, thereby, help avoid alert fatigue that demotivates a user and reduces compliance.[14]

Simplera

Simplera Sync (Medtronic) is a disposable, all-in-one continuous glucose monitor. It features an improved user experience at half the size of previous Medtronic sensors with a simple, two-step insertion process. In 2024, the MiniMed™ 780G system with Simplera Sync™ sensor received CE approval. MiniMed™ 780G system with Simplera Sync™ sensor is indicated for people aged 7 years and older and compatible with iOS and Android. The Simplera™ CGM for integrated use with the InPen™ smart insulin pen received CE Mark in September 2023.[15]

CareSens Air Real-Time CGM

The CareSens Air is the first CGM device developed by i-sens, Inc. (Incheon, South Korea) that has been approved by the South Korean Ministry of Food and Drug Safety as an adjunctive use device. It can be used for 15 consecutive days and features a calibration mechanism for reliability. The CGM continuously measures glucose levels in interstitial fluid, providing data on trends in glucose changes to the users' smartphone every 5 minutes. It is ergonomic and easy to use. Real-time glucose fluctuations and various events can be seen at a glance, and data can be shared through the Sens365 app and website.[16]

Dexcom Stelo

The Dexcom Stelo Glucose Biosensor System is the first over-the-counter (OTC) iCGM, approved by the FDA, intended for individuals aged 18 years and older who are non-insulin users, or those without diabetes. This 15-day CGM uses a wearable sensor, paired with an application installed on a user's smartphone or other smart device, to continuously measure, record, analyze and display glucose values. Glucose measurements and trends will be presented to the corresponding apps every 15 minutes.[17]

Eversense E3

Eversense E3 is the world's first and only long-term implantable CGM system with six months of glucose real-time readings and only two sensors per year. The sensor is inserted by an Eversense Inserter in the upper arm and continuously measures glucose for up to 6 months. Worn over the sensor, the transmitter wirelessly sends data to user's mobile device. It is removable and rechargeable and provides unique on-body vibe alerts. The Eversense app receives and displays data in easy to-read charts and graphs. There is no need to carry a separate receiver. Instead, the users can discreetly check the information on an Android™ or iOS® smartphone or Apple Watch®. Remote real-time monitoring capability for up to 5 people is also a smart feature of the CGM.

Eversense 365-day system

The Eversense 365-day system, the upgraded version of the E3 system is another breakthrough innovation from Senseonics. The 365 days accuracy of the next-generation Eversense Sensor was proved in clinical trials including ENHANCE. This is a major technological leap towards offering the differentiated benefits of implantable CGM for one full year with a single sensor.[18]

FreeStyle Libre 2 and FreeStyle Libre 3 Sensors

The US FDA has cleared FreeStyle Libre 2 and FreeStyle

Figure 1. **Types of CGM systems (((a) Guardian Connect (b) Dexcom G6 (c) Dexcom G7 (d) FreeStyle Libre 3 (e) Eversense (rt-CGMs)) (f) FreeStyle Libre Pro (P-CGM) (g) FreeStyle Libre (isCGM)))**

Libre 3 iCGM system sensors for integration with the automated insulin delivery (AID) system. They are also cleared for use by children as young as two years old, for use by women with diabetes who are pregnant. The senor has a wear time of 14 days. FreeStyle Libre 3 sensor also integrates with CamDisb's CamAPS FX mobile app and Ypsomed's mylife YpsoPump.[19] FreeStyle Libre 2 Plus sensor is the modified version of FreeStyle Libre 2 sensor cleared in 2023 by the FDA for use with AID systems. It is the first and only CGM available in the United States with a wear time of 15 days for people with diabetes aged 2 years and older. FreeStyle Libre 2 Plus sensor can be integrated with the t:slim X2 insulin pump.

Table 1 and Table 2 demonstrate the currently available real time and professional CGM systems. **Figure 1** depicts different types of currently available CGMs.

CONTINUOUS GLUCOSE MONITORING AND TIME-IN-RANGE

Time-in-range (TIR)

TIR is defined as the percentage of time an individual spends with their blood glucose levels in the target range. It includes three key CGM measurements: time spent within target glucose range (TIR), time spent below target glucose range (TBR), and time spent above target glucose range (TAR). For instance, if a person's TIR is 50%, it can be explained as of the 24 hrs duration of a day, the person spent 12 hours within the target glycemic range. The target range varies depending upon the individual, but general guidelines suggest the range as 70 to 180 mg/dL. TIR can be measured accurately by using a CGM device. These devices are equipped with software/apps that automatically record the TIR that helps both patients and health care professionals to derive a clearer picture of their glycemic profile on a timely basis.[20,21]

IC-TIR recommendations for Time-in-range

The IC-TIR (International Consensus on Time-in-Range) expert panel recommends a target range of 70-180 mg/dL [3.9-10.0 mmol/L] for individuals with type 1 diabetes and type 2 diabetes, and 63-140 mg/dL [3.5-7.8 mmol/L] during pregnancy, along with a set of targets for the time per day [% of CGM readings or minutes/hrs]. TIR simplifies the significance of these values such that a patient with diabetes should aim to spend at least 17 hours a day or more than 70% of their time in the blood glucose range of 70-180 mg/dL. However, the target range was lowered for pregnant women to 63-140 mg/dL as the blood glucose levels are lower in pregnancy. The recommendations also outline fixing targets for people with diabetes who are older and/or considered high-risk and the time-in-range bar was set at 50% for these categories. The guidelines also suggest that for patients with diabetes, the time spent below 70 mg/dL (TBR) should be less than 1 hour a day or under 4% of the time and time spent at or above 180 mg/dL (TAR) should be less than 6 hours a day or 25% of the time. For people with serious hypoglycemia, the time spent below 54 mg/dL should be less than 15 minutes a day or 1% of the time and the time spent above 250 mg/dL should be less than 1 hour and 15 minutes a day or 5% of the time.[22]

TIR – South Asia Recommendations

There are a number of roadblocks for the employment of CGM devices in South Asia such as illiterate patients, incompetency with the use of CGM devices, non-reimbursable market, overcorrection or under correction of potential hyperglycemia/hypoglycemia

Table 1. Currently available RT-CGMs

System Type	Device	Age	Wear time duration of sensor	Calibration required	Alarms for highs/ lows	Data accession Software/ devices	Arrows	iCGM designation
Real-time CGM	Freestyle Libre 3	4+ years	14 days	No	Yes	FreeStyle Libre Link, LibreView	Glucose is rising quickly (>2 mg/dL/ minute) ↑ Glucose is rising (1–2 mg/dL/ minute) ↗ Glucose is changing slowly (>1 mg/dL/minute) → Glucose is falling (1–2 mg/dL/ minute) ↘ Glucose is falling quickly (>2 mg/dL/minute) ↓	Yes
	Dexcom G6	2+ years	10 days	No	Yes	Dexcom CLARITY software for data analysis. Data visualization in Android and iPhone apps, smartwatches, Tandem t: slim X2 pump	Glucose is rapidly rising (>3 mg/dL/ minute) ↑↑ Glucose is rising (2–3 mg/dL/ minute) ↑ Glucose is slowly rising (1–2 mg/dL / minute) ↗ Glucose is steady (not increasing or decreasing >1 mg/dL/ minute) → Glucose is slowly falling (1–2 mg/dL /minute) ↘ Glucose is falling (2–3 mg/dL/minute) ↓ Glucose is rapidly falling (>3 mg/dL/minute) ↓↓	Yes
	Dexcom G7	2+ years	10 days	No	Yes	Dexcom Clarity Dexcom Follow app for friends & family	Glucose is rising (30.6-45 mg/dL in 15 minutes)↑ Glucose is falling (30.6-45 mg/dL in 15 minutes) ↓ Steady (<14.4 mg/dL in 15 minutes) → Glucose is slowly rising (14.4-30.6 mg/dL in 15 minutes) ↗ Glucose is slowly falling. (14.4-30.6 mg/dL in 15 minutes) ↘ Glucose is rapidly rising. (> 45 mg/dL in 15 minutes) ↑↑ Glucose is rapidly falling. (>45 mg/dL in 15 minutes) ↓↓	Yes
	Dexcom ONE+	>2 years	10 days	No	Yes	Dexcom ONE+ mobile app	Steady (Changing less than 30 mg/dL in 30 minutes) → Slowly rising (Changing 30–60 mg/dL in 30 minutes) ↗ Slowly falling (Changing 30–60 mg/dL in 30 minutes ↘ Rising (Changing 60–90 mg/dL in 30 minutes) ↑ Falling (Changing 60–90 mg/dL in 30 minutes) ↓ Rapidly rising (Changing more than 90 mg/dL in 30 minutes) ↑↑ Rapidly falling (Changing more than 90 mg/dL in 30 minutes) ↓↓	No
	Guardian Connect	14+ years	7 days	Twice per day	Yes	Guardian Connect Android and iPhone apps.	Glucose is rising at a rate of ≥3 mg/dL/minute↑↑↑ Glucose is rising at a rate of ≥2 but <3 mg/dL/minute↑↑ Glucose is rising at a rate of ≥1 but <2 mg/dL/minute↑ Glucose is falling at a rate of ≥1 but <2 mg/dL/ minute↓ Glucose is falling at a rate of ≥2 but <3 mg/dL/ minute↓↓ Glucose is falling at a rate of ≥3 mg/dL/minute↓↓↓	No
	Eversense	18+ years	90 days	Twice per day	Yes	Android and iPhone apps	Gradually falling or rising glucose level at a rate between 0.0 mg/dL-1.0 mg/dL/ minute → Moderately rising glucose level at a rate between 1.0 mg/dL-2.0 mg/dL/minute ↗ Moderately falling glucose levels at a rate between 1.0 mg/dL-2.0 mg/dL/minute↘ Very rapidly rising glucose levels at a rate more than 2.0 mg/dL/ minute ↑ Very rapidly falling glucose levels at a rate more than 2.0 mg/dL/ minute↓	No
	Eversense E3	18+ years	180 days	Yes	Yes	Eversense® CGM app. Monitor glucose levels on Android™, iOS™ smartphone or Apple Watch.	Gradually rising or falling glucose levels (falling or rising at a rate between 0.0 mg/dL and 1.0 mg/dL per minute) → Moderately rising glucose levels, (rising at a rate between 1.0 mg/dL and 2.0 mg/dL per minute) ↗ Moderately falling glucose levels, falling at a rate between 1.0 mg/dL and 2.0 mg/dL per minute) ↘ Very rapidly rising glucose levels (rising at a rate more than 2.0 mg/dL per minute) ↑ Very rapidly falling glucose levels (falling at a rate more than 2.0 mg/dL per minute) ↓	
	Simplera	7+ years	7 days	No	Yes	iOS, Android	-	No

Table 2. Currently available Professional CGMs

System Type	Device	Wear time duration of sensor	Calibration required	Frequency of glucose readings	MARD	Data accession Software/devices	Arrows
Professional CGM	Libre Pro	14 days	No	Every 15 minutes	12.3%.	Data can be downloaded using Care-Link™ iPro software	No

Table 3. Proposed modifications to the established TIR targets for South Asian Population

S.No.	Target limits	Proposed modifications in CGM target limits
1	Change of lower limit in older and high-risk population.	Recommendation 1.1: TIR buffer can be of 90-180 mg/dL. The lower limit of TIR can be fixed as 90 mg/dL instead of 70 mg/dL. Recommendation 1.2: TIR above 50%, and considering limited life expectancy or limited functional age, gradually aim above >55%, >60% and >65% as appropriate with an optimal target of >60%.
2	Change of TAR upper limit	Recommendation 2: TAR is categorized into three levels: Level 1:180-249 mg/dL, Level 2: >250-349 mg/dL, and Level 3: >350 mg/dL
3	Revisal of percentage of time spent in TAR upper limit for pregnant women (GDM, T2DM with pregnancy)	Recommendation 3.1: Clear recommendation for GDM is needed for South Asians. For this more research is required. Recommendation 3.2: Flexibility in the percentage spent in TAR limit: <15% TAR for >140mg/dL
4	Recommendations on the frequency to repeat CGM in routine clinical practice	Recommendation 4: Considering the limitations and advantages of CGM, we are recommending a minimum frequency for the assessment of TIR in T2D. For those patients achieving a desirable TIR with minimal time below range, the frequency of repeating the test is minimal and vice versa. The treating physician can make individualised personalised clinical decisions.

(Adapted from Kesavadev J, Misra A, Saboo B, Agarwal S, Sosale A, Joshi SR, Hussain A, Somasundaram N, Basit A, Choudhary P, Soegondo S. Time-in-range and frequency of continuous glucose monitoring: Recommendations for South Asia. Diabetes Metab Syndr. 2022 Jan;16(1):102345)

etc., Considering the importance of the factors such as inadequate diabetes education, problem in accessing emergency medical facilities in case of hypoglycemia, and lack of awareness and training of health care professionals in South Asia that inhibits the wider access and use of CGM, it is essential that the established metrics by the IC-TIR panel should be looked upon critically in the safe interest of people with diabetes.[23] **Table 3** describes the suggested recommendations for TIR targets for South Asian patients with T2D.

Time in Tight Range (TITR)

Time in Tight Range is an emerging metric, defined as the percentage of time a person spends in the glucose range of 70-140 mg/dL. (or) Time in tight range describes the time an individual spends in normoglycemia. TITR lowers the upper threshold of Time in Range from 180 mg/dL to 140 mg/dL. The specified goal is to maintain a TITR> 50%. It can be implemented in clinical practice for timely therapy intensification and optimization. Even though achieving time in tight range is more challenging than achieving time in range, diabetes technologies such as automated insulin delivery (AID) and continuous glucose monitoring aid people with diabetes in accomplishing the goal.[24]

Recommendations on the Frequency to Repeat CGM in Clinical Practice

The IC-TIR does not have recommendations on the frequency of CGM use. In a nonreimbursable market such as in South Asia, people with diabetes need to spend out of their pocket and hence lack long-term sustained CGM use. In type 1 diabetes and gestational diabetes, it is always recommended to have continuous use of CGM if the resources are adequate. In the case of people with type 2 diabetes in South Asia, sustainability of CGM use is not feasible.

Considering the limitations and advantages of CGM, the expert panel recommends a minimum frequency for the assessment of TIR in T2D. For those patients achieving a desirable TIR with minimal time below range, the frequency of repeating the test is kept minimal and vice versa.The treating physician can make individualised clinical decisions.[23] **Figure 2** shows the recommended frequency for repeating CGM/TIR assessment in patients with type 2 diabetes in South Asia based on previous AGP report of the patient (non-pregnant).

SIGNIFICANCE OF CHOOSING THE RIGHT CGM

People with type 1 diabetes have to frequently monitor their blood glucose levels for optimal glycemic management. Real-Time CGM will be the wiser choice for people with type 1 diabetes compared to other CGM systems. Current RT-CGM systems automatically transmit a continuous stream of glucose data to the user in real time, provide alerts and active alarms,

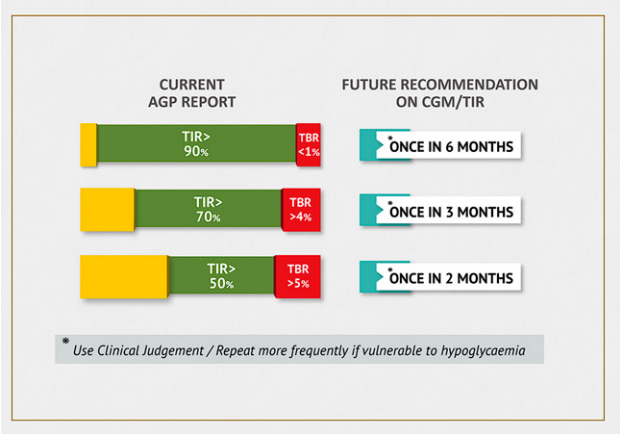

Figure 2. **Recommended frequency for repeating CGM/TIR assessment in patients with type 2 diabetes in South Asia based on previous AGP report of the patient (non-pregnant)**
(Adapted from Kesavadev J, Misra A, Saboo B, Agarwal S, Sosale A, Joshi SR, Hussain A, Somasundaram N, Basit A, Choudhary P, Soegondo S. Time-in-range and frequency of continuous glucose monitoring: Recommendations for South Asia. Diabetes Metab Syndr. 2022 Jan;16(1):102345)

and transmit glucose data (trend and numerical) to a receiver, smart watch, or smartphone. According to the American Diabetes Association, RT-CGM or is-CGM should be offered to youth and adults with type 1 and type 2 diabetes on intensive insulin therapy or continuous subcutaneous insulin infusion who are able to use the devices safely.[25]

Mounting evidence supports the multitude of benefits people with T1D my harness with the use of RT-CGM systems. For instance, a study by Hásková et al., compared the efficacy of RT-CGM (Guardian Connect Mobile) or isCGM (FreeStyle Libre) in maintaining optimal glycemic control in type 1 diabetes revealed that RT-CGM was superior to isCGM in reducing hypoglycemia and improving time in range in adults with T1D.[26] Rubelj et al., in their study confirmed that CGM is effective in achieving better control of type 1 diabetes by significantly improving HbA1c levels in a popula-

Table 4. Recommendations for CGM use by international organizations

RSSDI	ADA	AACE
CGM should be considered in conjunction with SMBG and HbA1C for glycemic status assessment in those T2DM individuals treated with intensive insulin therapy and who are not achieving glucose targets.	Real-time CGM (rtCGM) or intermittently scanned CGM (isCGM) should be offered for diabetes management in adults with diabetes on multiple daily injections (MDI) or continuous subcutaneous insulin infusion (CSII) who are capable of using the devices safely (either by themselves or with a caregiver). rtCGM or isCGM should be offered for diabetes management in adults with diabetes on basal insulin who are capable of using the devices safely (either by themselves or with a caregiver).	rtCGM should be recommended over isCGM to persons with diabetes with problematic hypoglycemia (frequent/severe hypoglycemia, nocturnal hypoglycemia, hypoglycemia unawareness) who require predictive alarms/alerts. However, the lifestyle of persons with diabetes and other factors should also be considered.
In well-controlled T2DM, professional CGM once in 6 months could be sufficient irrespective of the treatment regimen.	rtCGM or isCGM should be offered for diabetes management in youth with type 1 diabetes on MDI or CSII who are capable of using the devices safely (either by themselves or with a caregiver). rtCGM or isCGM should be offered for diabetes management in youth with type 2 diabetes on MDI or CSII who are capable of using the devices safely (either by themselves or with a caregiver).	When used as an adjunct to preprandial and postprandial BGM, CGM can help to achieve A1C targets in diabetes and pregnancy.
CGM may be considered in women with GDM or pregnant women with T2DM and as a supplemental tool to SMBG in individuals with hypoglycemia unawareness and/or frequent hypoglycemic episodes.	In people with diabetes on MDI or CSII, rtCGM devices should be used as close to daily as possible for maximal benefit. isCGM devices should be scanned frequently, at a minimum once every 8 hours to avoid gaps in data.	isCGM should be considered for persons with diabetes who meet 1 or more of the following criteria: Newly diagnosed with T2D, Treated with non-hypoglycemic therapies, Motivated to scan device several times per day, At low risk for hypoglycemia, although desire more data than SMBG provides
	People with diabetes should have uninterrupted access to their supplies to minimize gaps in CGM.	
	Periodic use of rtCGM or isCGM or use of professional CGM can be helpful for diabetes management in circumstances where consistent use of CGM is not desired or available	
	Skin reactions, either due to irritation or allergy, should be assessed and addressed to aid in successful use of devices.	
	People who wear CGM devices should be educated on potential interfering substances and other factors that may affect accuracy.	

tion of highly motivated families, diseased children, adolescents and young adults.[27] The DIAMOND trial showed that use of RT-CGM improved HbA1c and reduced the time spent in the hypoglycemia in the T1D cohort.[28] A recent head-to-head comparative study demonstrated that use of Dexcom G5 RT-CGM is potentially beneficial in reducing time spent in hypoglycemia in MDI-treated T1D adults with impaired hypoglycemia awareness compared with isCGM use which supports the use of RT-CGm use in T1D.[29] It is also well-documented that current RT-CGM devices offer alarm functions, with individualized upper and lower limits, and rapidity of change alerts as well. This is particularly crucial for those who experience frequent episodes of severe hypoglycemia, frequently experience nocturnal hypoglycemia, or have poor awareness of hypoglycemia.[30]

People with type 2 diabetes also prefer CGM systems in this digital era. The ADA and AACE recommendations also support the use of CGM in type 2 diabetes. In prediabetes, the use of CGM aids people to make lifestyle modifications by displaying real-time glucose information that associates their behaviors to glycemic outcomes, providing information about how diet and exercise affects their blood glucose. Access to this information provides opportunities for people with prediabetes to be aware of the glycemic impact of previous behaviors and make more informed decisions in their daily lives. In a recent single-arm prospective study by Lee et al., investigated the feasibility and acceptability of CGM use in 32 individuals with prediabetes reported that majority of the participants were satisfied with the use of CGM.[31] Yost et al. assessed patient satisfaction and feasibility in 15 adults with prediabetes who used CGM in combination with a low-carbohydrate diet. The investigators observed a multitude of benefits including significant reductions in HbA1c and a high rate of satisfaction (93%) among participants.[32]

CGM also is found to be beneficial in managing diabetes therapy. A consensus recommendation from an expert panel with respect to the role of CGM in maintaining TIR among patients using OHAs, suggests that the use of CGM with TIR metric included for 2 weeks will help in readjustment or modification of treatment in these patients and waivers the need to wait for the 3-month duration to check the HbA1c status and efficacy of the treatment. Routine use of TIR is recommended for patients on basal insulin.[33]

Table 4 describes recommendations for CGM use by international organizations.[34-36]

CONCLUSION

CGM has revolutionized glucose (in the interstitial fluid) monitoring by providing multifarious benefits that, before its advent, were impossible to realize for people with diabetes. CGM addresses and alleviates many challenges patients and HCPs face in achieving glycemic targets, making it an inevitable part of diabetes management. It is now well-established that CGM is beneficial in substantially reducing hospitalizations, hypoglycemia, and the overall cost of diabetes care. Currently, CGM is more expensive when compared to conventional monitoring with a blood glucose meter, but it is more cost-effective in the long run.

END NOTE

Author Information

1. Dr. Jothydev Kesavadev, Jothydev's Diabetes and Research Centre, Trivandrum, Kerala, India.
2. Dr. Sreelakshmi R, Jothydev's Diabetes and Research Centre, Trivandrum, Kerala, India.
3. Ms. Gopika Krishnan, Jothydev's Diabetes and Research Centre, Trivandrum, Kerala, India.
4. Ms. Anjana Basanth, Jothydev's Diabetes and Research Centre, Trivandrum, Kerala, India.

Conflict of Interest: None declared

REFERENCES

1. David Rodbard. Continuous Glucose Monitoring: A Review of Successes, Challenges, and Opportunities. Diabetes Technology & Therapeutics. 2016; 18:S2-3-S2-13.
2. Close KL (2022) CGM users worldwide. Close Concerns
3. Continuous Glucose Monitoring - NIDDK [Internet]. [cited 2024 Oct 5].
4. Facchinetti A. Continuous Glucose Monitoring Sensors: Past, Present and Future Algorithmic Challenges. Sensors (Basel). 2016;16(12):2093.
5. Timothy S. Bailey and Shridhara Alva. Landscape of Continuous Glucose Monitoring (CGM) and Integrated CGM: Accuracy Considerations. Diabetes Technology and Therapeutics, 2021; 23(S3): p. S-5-S-11.
6. Jothydev Kesavadev, Lakshmy Ramachandran, Gopika Krishnan. Glucose Monitoring Technologies Complementary or Competitive? Role of Continuous Glucose Monitoring versus Flash Glucose Monitoring versus Self monitoring of Blood Glucose. Journal of Diabetology. 2017; 8(3):61
7. Funtanilla VD, Candidate P, Caliendo T, Hilas O. Continuous Glucose Monitoring: A Review of Available Systems. P T. 2019 ;44(9):550-553.
8. Kesavadev, Jothydev. From Urine Tests to Cloud-Based Data: The Advances in Diabetes Technology. International Journal of Diabetes and Technology.2022; 1(1):p 1-2.
9. Hirsch IB. Introduction: History of Glucose Monitoring. 2018. In:

Role of Continuous Glucose Monitoring in Diabetes Treatment. Arlington (VA): American Diabetes Association; 2018

10. Abbott MediaRoom [Internet]. [cited 2024 Oct 5]. First-of-its-Kind Diabetes Technology Revolutionizes How Glucose Data is Collected and Analyzed for People in India.
11. FreeStyle Libre Pro - FreeStyle Libre | Abbott [Internet]. [cited 2024 Oct 5].
12. FreeStyle® Libre System in India Providing Real-time Continuous Glucose Monitoring for People with Diabetes [Internet]. [cited 2024 Oct 5].
13. Guardian™ Connect Continuous Glucose Monitor | Medtronic [Internet]. 2018 [cited 2024 Oct 5].
14. Dexcom [Internet]. [cited 2024 Oct 5]. Dexcom ONE Glucose Monitor for Type 1 - Type 2 Diabetes.
15. Medtronic Diabetes announces world's first approval for MiniMed™ 780G System with Simplera Sync™ disposable, all-in-one sensor - Jan 8, 2024 [Internet]. [cited 2024 Oct 5].
16. Kim KS, Lee SH, Yoo WS et al. Accuracy and Safety of the 15-Day CareSens Air Continuous Glucose Monitoring System. Diabetes Technology and Therapeutics. 2024 ;26(4):222-228.
17. PROD - US - Stelo HP lead form [Internet]. Accessed on 30 March 2024
18. Senseonics Announces FDA Approval of the Eversense® E3 Continuous Glucose Monitoring System for Use for Up to 6 months; Provides 2022 Business Outlook [Internet]. [cited 2024 Oct 5].
19. Abbott MediaRoom [Internet]. [cited 2024 Oct 18]. U.S. FDA Clears Abbott's FreeStyle Libre® 2 and FreeStyle Libre® 3 Sensors for Integration with Automated Insulin Delivery Systems.
20. Kesavadev J, Shankar A, Ashok AD et al. Our First 825 T2DM Patients on 14-Day Factory-Calibrated Glucose Monitoring System: Clinical Utility and Challenges. Journal of Diabetes Science and Technology, 2018; 12(1): p. 230-231.
21. Kesavadev J, Vigersky R, Shin J et al. Assessing the Therapeutic Utility of Professional Continuous Glucose Monitoring in Type 2 Diabetes Across Various Therapies: A Retrospective Evaluation. Advances in therapy. 2017; 34(8): p. 1918-1927.
22. Battelino T, Danne T, Bergenstal RM, Amiel SA, Beck R, Biester T, et al. Clinical Targets for Continuous Glucose Monitoring Data Interpretation: Recommendations From the International Consensus on Time in Range. Diabetes Care. 2019 Aug;42(8):1593–603.
23. Kesavadev J, Misra A, Saboo B et al. Time-in-range and frequency of continuous glucose monitoring: Recommendations for South Asia. Diabetes and Metabolic Syndrome: Clinical Research and Reviews. 2022;16(1):102345
24. Beck RW, Raghinaru D, Calhoun P et al. A Comparison of Continuous Glucose Monitoring-Measured Time-in-Range 70-180 mg/dL Versus Time-in-Tight-Range 70-140 mg/dL. Diabetes Technology and Therapeutics. 2024;26(3):151-155.
25. Peters AL, Ahmann AJ, Battelino T, Evert A, Hirsch IB, Murad MH, et al. Diabetes Technology-Continuous Subcutaneous Insulin Infusion Therapy and Continuous Glucose Monitoring in Adults: An Endocrine Society Clinical Practice Guideline. J Clin Endocrinol Metab. 2016 Nov;101(11):3922–37.
26. Hásková A, Radovnická L, Petruželková L et al. Real-time CGM Is Superior to Flash Glucose Monitoring for Glucose Control in Type 1 Diabetes: The CORRIDA Randomized Controlled Trial. Diabetes Care. 2020;43(11):2744-2750.
27. Rubelj K, Stipančić G, La Grasta Sabolić L et al. Continuous Glucose Monitoring And Type 1 Diabetes Mellitus Control In Child, Adolescent And Young Adult Population - Arguments For Its Use And Effects. Acta Clinica Croatica. 2021;60(4):609-616
28. Beck RW, Riddlesworth T, Ruedy K et al. Effect of continuous glucose monitoring on glycemic control in adults with type 1 diabetes using insulin injections: the DIAMOND randomized clinical trial. JAMA. 2017; 317(4):371-8.
29. Reddy M, Jugnee N, El Laboudi A et al. A randomized controlled pilot study of continuous glucose monitoring and flash glucose monitoring in people with type 1 diabetes and impaired awareness of hypoglycaemia. Diabetic Medicine. 2018 35(4):483-90.
30. Steven V. Edelman, Nicholas B. Argento J et al. Clinical Implications of Real-time and Intermittently Scanned Continuous Glucose Monitoring. *Diabetes Care*. 2018; 41 (11): 2265–2274.
31. Lee JY, Nguyen JT, Arroyo J, et al. Feasibility and acceptability of using Flash Glucose Monitoring System sensors to empower lifestyle changes in people with prediabetes. *Diabetes Care*. 2023;46 (1):e10–e11
32. Yost O, DeJonckheere M, Stonebraker S, et al. Continuous glucose monitoring with low-carbohydrate diet coaching in adults with prediabetes: Mixed Methods Pilot Study. *JMIR Diabetes*. 2020;5(4):e21551.
33. Mohan, V., Joshi, S., Mithal, A. et al. Expert Consensus Recommendations on Time in Range for Monitoring Glucose Levels in People with Diabetes: An Indian Perspective. Diabetes Therapy. 2023;14: 237–249.
34. RSSDI.in. RSSDI Clinical Practice Recommendations 2022. Summary Document For Training. Inernet.
35. American Diabetes Association Professional Practice Committee; 7. Diabetes Technology: *Standards of Care in Diabetes—2024. Diabetes Care*. 2024; 47 (Supplement_1): S126–S144.
36. Grunberger G, et al. American Association of Clinical Endocrinology Clinical Practice Guideline: The Use of Advanced Technology in the Management of Persons with Diabetes Mellitus. *Endocrine Practice*. 2021;27:505-537.