# Guideline

## Chinese clinical guideline for continuous glucose monitoring (2012)

Chinese Diabetes Society

***Keywords:*** *guideline; continuous glucose monitoring; clinical application*

Glucose monitoring is an important component in diabetes treatment and management. The results of blood glucose monitoring are useful for determining the degree of glucose metabolic disturbance, evaluating therapeutic outcomes, and guiding adjustments of treatment regimens.[1] Self-monitoring of blood glucose (SMBG) still remains the most common form of in-home blood glucose monitoring with the glycosylated hemoglobin (HbA1c) as the "gold standard" for understanding the patients' average glucose over the last 3 months. However, both HbA1c and SMBG have certain limitations: HbA1c represents the average blood glucose level over the previous 2–3 months; therefore there may be a "delayed effect" when using it to guide therapy adjustments. Additionally, HbA1c does not provide information of hypoglycemia, nor does it reflect glycemic variability. Meanwhile, SMBG represents only a snapshot of the glucose concentration; and thus it is unable to demonstrate a patient's blood glucose profile for an entire day. Hence, since the continuous glucose monitoring (CGM) can provide additional information compared to SMBG, sensor technology has had iterative improvements in recent years, becoming an effective complement to traditional blood glucose monitoring methods, and has been widely used in the clinical setting. Nevertheless, the advantages, clinical indications, accuracy evaluation of the technology, and the interpretation of the CGM results are not well-known to Chinese clinicians. Under that circumstance, in December 2009, Chinese Diabetes Society has published *Guidelines on Continuous Glucose Monitoring Clinical Applications (2009),* the first guideline in China.[2] Since then, the past few years have witnessed the overwhelming adoption of CGM technology. In October 2010, American Association of Clinical Endocrinologists Consensus Panel (AACE) published the *Statement by the American Association of Clinical Endocrinologists Consensus Panel on Continuous Glucose Monitoring.*[3] In October 2011, committees and members of the Endocrine Society, the Diabetes Technology Society, and the European Society of Endocrinology published *Continuous Glucose Monitoring: an Endocrine Society Clinical Practice Guideline.*[4] At the same time, local clinical data in China has been published in several widely distributed peer-reviewed journals on CGM. These scientific efforts from the Chinese Diabetes community have provided the geographic specific information in revising the guideline on CGM for Chinese population. Based on that, Chinese Diabetes Society appointed a task force of experts to update and revise the *Chinese Clinical Guideline for Continuous Glucose Monitoring* again.

### OVERVIEW OF CGM

CGM system (CGMS) records continuous, comprehensive and reliable glucose levels using a subcutaneous sensor to monitor interstitial glucose levels; thus providing the trend of glucose change information, predicting hypo- and hyperglycemic events which is information that conventional blood glucose meters does not provide.

In comparison to monitoring via a blood glucose meter, the main characteristic of CGM technology is that it measures blood glucose using a glucose sensor. See Table 1 for the comparisons of two methods. There are two kinds of CGM technology, the retrospective CGM and the RT-CGM. The retrospective CGMS was approved by the United States FDA in 1999[5] and by China's SFDA in 2001, and is widely used in both clinical and research settings. The CGMS consists of a glucose sensor, cable, blood glucose recorder, information extractor, and analysis software. The sensor is comprised of a semi-permeable membrane, glucose oxidase and a micro electrode. It is inserted under the skin of the patient's abdomen near navel using a cannula, and the chemical reaction with the glucose and oxygen in the interstitial fluid creates an electrical current. The recorder receives a signal via the cable every 10 seconds, and the average recorded signal in every 5 minutes is converted into a blood glucose level and being saved. A total of 288 blood glucose level readings can be saved per day. Patients wear the recorder for 72 hours, during which time a minimum of 4 fingertip blood glucose readings must be entered a day in order to calibrate the device as well as the factors that can effect blood glucose fluctuations such as meals, exercise, anti-hyperglycemic drugs and hypoglycemic events. At the end of the 3 days, the sensor is removed, the data are downloaded to a computer via the information

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**Table 1.** Comparison of blood glucose meter and continuous glucose monitoring sensor

| Items | Blood glucose meter | CGM |
|---|---|---|
| Mechanism and performance | 1. Measures blood glucose level via a disposable test-strip.<br>2. Some blood glucose meters have a data storage function from which blood glucose information can be imported into a computer using software. | 1. Continuously monitors glucose levels over 24 hours via a subcutaneously implanted sensor.<br>2. Data stored in the blood glucose recorder can be downloaded to a computer via the information extractor, and analysis software is used to quantitatively and qualitatively describe the patient's blood glucose profile. |
| Data characteristics | 1. Immediately displays the current glucose level like a snapshot.<br>2. Diabetes management plan design is based on scattered data. These data can partially represent a patient's blood glucose changes in response to factors such as food/drink, drugs, exercise.<br>3. Records from a blood glucose meter can retrospectively explain a blood glucose profile. A blood glucose profile is composed from several scatted glucose levels. | 1. Continuously displays blood glucose changes like a movie.<br>2. Continuously represents a patient's blood glucose changes in response to factors such as food/drink, drugs, exercise.<br>3. Data represents blood glucose change trends (such as the rate and direction of changes) and helps the patient understand overall trend and individual characteristics of blood glucose changes. |
| Measurement method | 1. Glucose level in the measured blood.<br>2. Uses a blood collection needle and test-strip to take blood. Blood is generally collected from the finger but other body parts can be used. | 1. Measures a subcutaneous interstitial fluid signal that represents glucose concentration.<br>2. The sensor is usually implanted under the skin of the abdomen. Other body parts such as the arm can also be used. |

extractor, and specialized software is used to perform data analysis. This can yield information regarding the patient's blood glucose fluctuation changes over a consecutive three day period. Blood glucose levels are displayed as a line graph, pie chart, table, etc, incorporating the events and times of indicated factors that affected blood glucose. As long as the accuracy of the data is guaranteed, these readings both quantitatively and qualitatively represent the characteristics of the patient's blood glucose levels and fluctuations.[6]

Since CGM measures the subcutaneous interstitial glucose concentration instead of plasma or capillary glucose level, assessing its accuracy has been given high priority.[7] The accuracy of CGM includes both point accuracy and trend accuracy. Both contain two aspects, namely numerical accuracy and clinical accuracy.[8] Studies have suggested that both the retrospective and RT-CGM have high accuracy and safety.[9-12]

## CLINICAL APPICATIONS OF RETROSPECTIVE CGM

The main advantage of CGM is that it can discover hyperglycemia and hypoglycemia, which can be otherwise missed by traditional monitoring methods, especially when the postprandial hyperglycemia and asymptomatic nocturnal hypoglycemia occur. Therefore, it has a relatively wide range of clinical applications: (1) to detect blood glucose changes relating to factors such as food, exercise, medication, mental factors, and lifestyle; (2) to demonstrate postprandial hyperglycemia, asymptomatic nocturnal hypoglycemia, the dawn phenomenon, Somogyi effect, etc.;[13-15] (3) to aid in the design of individualized treatment plans;[16-19] (4) to increase treatment compliance; (5) to provide a visualized method for diabetes education. Particularly, CGM has advantages in assessing blood glucose fluctuations and detecting hypoglycemia.

### Glycemic variability assessment

Independent of HbAlc, glycemic variability is another important assessment of blood glucose control.[20-34] CGM can reflect the characteristics of glycemic variability comprehensively and reliably. Glycemic variability indices are assessed from aspects such as intraday and interday variability. The intraday indices include blood glucose standard deviation (SDBG), the proportion of time spent within the blood glucose ranges and the area under blood glucose curve, largest amplitude of glycemic excursion (LAGE), the M-value, the mean amplitude of glycemic excursion (MAGE). The interday indices include coefficient of variation of fasting plasma glucose, the mean of daily differences (MODD). Postprandial fluctuations indices include postprandial glucose spike (PGS), time to PGS, postprandial glucose excursion (PPGE), duration of postprandial glucose (DUR) and incremental area under the curve of postprandial glucose (IAUC). Hypoglycemia indices includes hypoglycemia index.[35,36] Of the many indices for glycemic variability, MAGE has been applied in several studies in the literature.[37-39] MAGE was proposed by Service et al[37] during the 1970s but did not achieve widespread use due to the lack of subsequent breakthrough developments in CGM technology. It was not until Monnier et al[38] utilized MAGE to assess the association between blood glucose fluctuations and oxidative stress that it gradually gained acceptance.[40-42] Indices for glycemic variability such as MAGE have been used as potential markers to assess possible relationships with oxidative stress and diabetic chronic complications compared to traditional use of the HbA1c. Currently, the specialized software to calculate MAGE has been developed to assist in the formulation of results in order to avoid a laborious and manual process fraught with the potential for human error. Glycemic variability indices based on CGM are detailed below (Usage regulations of CGMS).

### Hypoglycemia

Severe hypoglycemia requiring assistance is an acute complication of diabetes mellitus. CGM can be used to monitor hypoglycemia, particularly the occurrence of nocturnal hypoglycemia, and assess the efficacy and safety of hypoglycemic treatment approaches. It can also

be used to analyze the time distribution, type and causes of hypoglycemia. Studies have shown that compared to SMBG, hypoglycemic treatments designed based on CGM results can effectively decrease the hypoglycemia occurrence rate in type 1 diabetic patients, and can shorten the duration of hypoglycemia.[43-45]

## INDICATIONS FOR CLINICAL APPLICATION OF RETROSPECTIVE CGM

Retrospective CGM is mainly applicable for use in the following patients or situations: (1) Type 1 diabetes mellitus. (2) Type 2 diabetes mellitus that requires intensive insulin therapy including multiple daily injections and continuous subcutaneous insulin infusion therapy. (3) Type 2 diabetes mellitus patients who use hypoglycemic treatment under SMBG guidance, but still encounter one of the following situations: severe hypoglycemia or repeated hypoglycemia, asymptomatic hypoglycemia and nocturnal hypoglycemia; refractory hyperglycemia, especially when fasting; large blood glucose excursions; diabetic patients who maintain a state of hyperglycemia due to the fear of hypoglycemia. (4) Gestational diabetes or diabetes in pregnancy.[46,47] (5) Diabetes education: CGM can help patients to understand blood glucose fluctuations caused by factors such as exercise, meals, stress, and hypoglycemic treatment, etc.[48-50] It can therefore urge patients to make healthy lifestyle choices, increase compliance, and promote more effective communication between patients and doctors.

In addition, diabetic gastroparesis patients, fulminant type 1 diabetic patients and special types of diabetic patients can use CGM to understand the characteristics and fluctuation patterns of their blood glucose profile.[51-54] CGM can also be applied to other endocrine and metabolic disorders including insulinoma.[55-60]

## USAGE REGULATIONS OF CGMS

### Accuracy evaluation

*Accuracy evaluation standards*[61-63]

The clinicians can use analysis software to conduct an evaluation of the accuracy of CGMS data. The standards for optimal accuracy are as follows: (1) three or more pairs of sensor glucose value and meter glucose value per day; (2) the correlation between paired sensor glucose values and meter glucose values is $\geq 0.79$; (3) when the difference between the largest and smallest meter glucose values is $\geq$5.6 mmol/L, the mean absolute difference (MAD) is $\leq$28%. When the difference between the largest and smallest meter glucose values is <5.6 mmol/L, the MAD is $\leq$18%, and the correlation (R value) between the sensor glucose value and meter glucose value should be reported as n/a.

If CGMS data do not meet the optimal accuracy requirements above, it must be indicated in the CGMS report. Should CGM data have inaccuracies, the clinician must use discretion in the adjustment of diabetes management.

*Time difference between CGMS value and blood glucose value*

CGMS measures the glucose concentration in subcutaneous interstitial fluid, not the glucose level in plasma or serum. The glucose concentration in interstitial fluid lags behind the glucose level in plasma. This lag is generally 4–10 minutes, particularly during rapid blood glucose fluctuations. It is for this reason that the combined use of both CGM and traditional blood glucose monitoring methods is the best approach for obtaining a comprehensive and prompt understanding of blood glucose levels.

### Indices based on CGMS

*Introduction of CGM indices*

CGM indices can reflect both average blood glucose levels and glycemic variability. See Table 2 for the calculation and clinical significance of most commonly used CGM indices. With the exceptions of MAGE and MODD which require artificial calculation, all of the other indices can be obtained via the CGMS analysis software. The indices are usually used in researches, and their clinical significance and the role in guiding diabetes treatments are still under investigation.

*Normal reference values for CGM indices*

To date, normal reference values for CGM have been remained a focus of research.[64-66] Ongoing validation with CGM for glycemic reference ranges in patients without diabetes should be determined based on long-term prospective follow-up results from large-sample population studies. Before that, setting normal reference ranges for CGM indices based on healthy populations remains a feasible approach. As demonstrated by a multicenter study conducted in China, the normal reference ranges of a 20–60-year-old population for CGM indices are shown in Table 3.[67,68]

### CGM reports

Currently, the contents and formats of CGM reports are not unified. A regulated CGM report should contain the following three items: (1) general information: basic patient information, clinical diagnosis, signature of reporting personnel, and the date of the report; (2) CGM results; (3) CGM instructions (Table 4). Recently, specialized software for CGM reports management is developed to relieve doctors from complicated work.

### Data analysis

If CGM data are confirmed valid, the results are used to guide treatment plans. In order to communicate with patients more efficiently, clinicians should present the CGM results in an easy form (e.g. statistical reports or statistical graphs). If the situation permits, downloading the data before follow-up is a good way to save time.

**Table 2.** Calculation methods and clinical significance of the main continuous glucose monitoring indices

| Indices | Calculation method | Characteristics and/or clinical importance |
|---|---|---|
| Blood glucose level | | |
| Average blood glucose level | Average level of CGMS measurement values | Assessment of overall blood glucose levels |
| 1-hour preprandial average blood glucose level | Average blood glucose level at 1–60 minutes preprandial | Reflects the characteristics of preprandial and postprandial blood glucose. i.e. the effects of meals on blood glucose |
| 3-hour postprandial average blood glucose level | Average blood glucose level at 1–180 minutes postprandial | |
| Percentage of time (PT) | The number of times or total time (pie chart and statistics) above, below, and within the target range | Specifically reflects the temporal characteristics of blood glucose changes. This index is more intuitive to understand and suitable for the education of diabetes mellitus patients. |
| Area under the curve (AUC) | The area between the CGMS monitoring blood glucose curve and the target blood glucose curve | A more comprehensive statistical method of analyzing the times and extents of blood glucose changes |
| Blood glucose fluctuation | | |
| Standard deviation of blood glucose (SDBG) | The standard deviation of measured values during the CGMS monitoring period | Analysis of the extent of the total deviation of average blood glucose values but unable to differentiate between major and minor fluctuations |
| Largest amplitude of glycemic excursions (LAGE) | The difference between the largest and smallest blood glucose value during the CGMS monitoring period | Analysis of the magnitude of the largest blood glucose fluctuation |
| Mean amplitude of glycemic excursions (MAGE) | An average value obtained by eliminating blood glucose data for which the magnitudes do not exceed a certain magnitude (usually SDBG), and then calculating blood glucose fluctuation magnitude based on the direction of the first valid fluctuation | Using a filtering method can truly reflect major blood glucose fluctuations |
| Mean of daily difference (MODD) | The average level of absolute value differences between corresponding blood glucose values measured at the same times on two consecutive days | Evaluation of the extent of daily blood glucose fluctuations. Reflecting the repetition of blood glucose levels between days |

**Table 3**. Reference values for continuous glucose monitoring indices in adult Chinese subjects (24 h calculations)

| Index type | Index name | Normal reference value |
|---|---|---|
| Blood glucose level | Mean blood glucose (MBG) | <6.6 mmol/L |
| | Percentage time (PT) of blood glucose ≥7.8 mmol/L | <17% (4 hours) |
| | Percentage time (PT) of blood glucose ≤3.9 mmol/L | <12% (3 hours) |
| Blood glucose fluctuation | Standard deviation of blood glucose (SDBG) | <1.4 mmol/L |
| | Mean amplitude of glycemic excursions (MAGE) | < 3.9 mmol/L |

**Table 4.** Sample of continuous glucose monitoring report

| | | | | | | |
|---|---|---|---|---|---|---|
| Name: | Sex: | Age: | | Test date: | | |
| Room: | Ward: | Bed: | | Hospital No./ Case No.: | | |
| Clinical Diagnosis | | | | | | |
| Items | Normal reference values (24 hours) | Date | Date | Date | Date | |
| Blood glucose measurement frequency | – | | | | | |
| Average blood glucose level (mmol/L) | <6/6 | | | | | |
| Blood glucose standard deviation (mmol/L) | <1.4 | | | | | |
| Highest blood glucose value (mmol/L) | – | | | | | |
| Lowest blood glucose value (mmol/L) | – | | | | | |
| Time (hours:mins) when blood glucose is ≥11.1 mmol/L | – | | | | | |
| Time (hours:mins) when blood glucose is ≥10.0 mmol/L | – | | | | | |
| Time (hours:mins) when blood glucose is ≥7.8 mmol/L | <4 h (17%) | | | | | |
| Time (hours:mins) when blood glucose is ≤3.9 mmol/L | <3 h (12%) | | | | | |
| Time (hours:mins) when blood glucose is ≤2.8 mmol/L | – | | | | | |
| CGM instructions: | | | | | | |
| Total blood glucose measurements: ____ | | | | | | |
| Mean absolute difference (MAD): ____% | | | | | | |
| Average blood glucose: ____ mmol/L | | | | | | |
| Blood glucose standard deviation: ____ mmol/L | | | | | | |
| Highest blood glucose value and lowest blood glucose value: ____ mmol/L and ____ mmol/L | | | | | | |
| Times when blood glucose ≥7.8 mmol/L, ≥10.0 mmol/L and ≥11.1 mmol/L: __h__m (__%), __h__m (__%), __h__m (__%) | | | | | | |
| Times when blood glucose ≤3.9 mmol/L and ≤2.8 mmol/L: __h__m (__%), __h__m (__%) | | | | | | |
| Reporter: | Evaluator: | | Report date: | | | |

Also, it is necessary to confirm that the time on the recorder is correct, otherwise all the downloaded results will inevitably been mistaken, particularly with regard to postprandial blood glucose data. Additionally, when doctors and patients use the CGM data to discuss and evaluate the short-term glucose control, they should pay attention to glucose fluctuation trends instead of absolute blood glucose levels at certain time, as well as the factors causing abnormal glucose fluctuations, such as abnormal rises when the patient eats nothing, hypoglycemic events and glucose fluctuations related to strenuous activity. In summary, in order to use CGM technology more efficiently, we should unify the clinical indication, regulate CGM reports and interpret results correctly.

**Table 5**. Comparisons between retrospective continuous glucose monitoring and real-time continuous glucose monitoring

| Items | Device feature | Utility requirement |
|---|---|---|
| Retrospective-CGM (r-CGM) | 1. Monitor for consecutive 3 days and review data retrospectively after download | 1. Use CGM monitor intermittently, following-up and communicate with doctors regularly |
| | 2. Provide accuracy evaluation of results | 2. SMBG as required |
| | 3. Record glucose levels related to "major events" | 3. Record life events related to glucose fluctuation |
| Real-time CGM (RT-CGM) | 1. Report glucose levels and trends | 1. Good treatment compliance |
| | 2. Hypoglycemic and hyperglycemic events alarms | 2. The ability to interpret RT-CGM data to intervene acute hyperglycemic or hypoglycemic events immediately |
| | 3. Save data for downloading and reviewing retrospectively | 3. SMBG as required and promptly make adjustments to possible hypoglycemic and hyperglycemic alarms |
| | 4. Record glucose levels related to "major events" | 4. Record life events related to glucose fluctuation |
| | 5. Ability to integrate with pump | 5. Consult doctors immediately when hyperglycemic or hypoglycemic alarms during the use of sensor-augmented pump therapy |

### CGM warnings

The three most commonly encountered CGM warnings are calibration error warnings, no power warnings and high-voltage warnings.[69] Specialized clinicians should be assigned for CGMS management, including regulating its clinical use and resolving malfunction warnings.[70,71]

## DIABETES EDUCATION DURING RETROSPECTIVE CGM PERIOD

### Multiple daily self-monitoring of blood glucose

Some patients regard CGMS as a replacement for glucose meter and believe that if they are wearing CGMS, there is no need to perform SMBG four times a day. This mistaken view will affect the quality of CGMS data. Patients should perform SMBG four times a day and make sure the results are entered into the CGMS monitor timely and correctly. When testing blood glucose and entering values, it is necessary to pay attention to the following tips. (1) Use the same blood glucose meter and the same batch of test-strips. (2) The times when SMBG is performed should be dispersed throughout the day, preferably at times when blood glucose is relatively stable (e.g. before each meal and before sleep). (3) After performing SMBG, the blood glucose values should be immediately entered into the RT-CGM. If more than 5 minutes passes between the readings being taken and being entered, one should perform SMBG again. (4) Only blood glucose values within the range 2.2–22.2 mmol/L can be entered. If this range is exceeded, treatment of hypoglycemia or hyperglycemia should be considered. (5) If an error occurs when blood glucose values are entered, immediately enter correct blood glucose values to perform calibration.

### Meal records and events input

During the CGM period, the patient should record events such as meals, exercise and treatment in detail. Depending on patients' preference, one can write down or enter major events related to blood glucose levels into the CGMS.

### Device maintenance and others

Patients should keep away from strong magnetic fields during CGM period. X-ray photography and imaging scans such as computed tomography (CT) or magnetic resonance imaging (MRI) should be avoided. While bathing, it is necessary to wear a special shower bag to refrain it from immersing in the water.

## INTRODUCTION OF RT-CGM

RT-CGM technology has been recently adopted by some centers after its recent approval for use in China. The retrospective review of glucose profiles with RT-CGM is similar as retrospective CGM, but the real-time devices also provide alerts when the glucose level meets or predicts a glucose threshold. These alerts may be helpful to address current or future hypoglycemia or hyperglycemia and adjust treatment plans accordingly. Evidence-based medicine has proven that RT-CGM can achieve optimal diabetes management, and the improvement of HbA1c after using RT-CGM is positively correlated to the frequency of usage.[72,73] But RT-CGM requires patients who had experience with retrospective CGMS before and owned the ability to interpret monitoring results to adjust treatment plan when hyperglycemic or hypoglycemic events happened.

Table 5 shows the comparisons between retrospective CGM and RT-CGM. The indications for using RT-CGM in the *Continuous glucose monitoring: an Endocrine Society Clinical Practice Guideline*[4] published by the Endocrine Society, the Diabetes Technology Society, and the European Society of Endocrinology are as follows: (1) children and adolescents with type 1 diabetes mellitus who have achieved HbA1c levels below 7.0%; (2) children and adolescents with type 1 diabetes mellitus who have HbA1c levels more than 7.0% but are able to use the device on a daily basis; (3) adult patients with type 1 diabetes mellitus who demonstrated they can use the device on a daily basis, whether they achieve target HbA1c levels or not; (4) No recommendations for or against the use of RT-CGM by children with type 1 diabetes mellitus who are younger than 8 years of age; (5) the use of RT-CGM alone for glucose management in the ICU or operating room is not recommended until further studies provide sufficient evidence for its accuracy and safety in those settings. Because the evidence of RT-CGM usage in China is still lacking, the Chinese indication for RT-CGM is not defined until further studies are carried out.

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