



Latest Practical Development of Continuous Glucose Monitoring (CGM) for Evaluating Time in Range (TIR)

Noi Fukushima¹, Atsuko Kawahito¹, Etsuko Sueki¹, Fumiko Fujii¹, Setsuko Kanazawa¹, Aya Aihara¹, Momoko Ikezoe¹, Yoshinobu Kato¹, Hiroshi Bando^{1,2,3}^{ID*}

¹Kanaiso Hospital, Tokushima, Japan

²Japan Low Carbohydrate Diet Promotion Association, Kyoto, Japan

³Medical Research/Tokushima University, Tokushima, Japan

Corresponding Author: **Hiroshi Bando** ^{ORCID ID}

Address: Tokushima University /Medical Research, Nakashowa 1-61, Tokushima 770-0943, Japan; Email: pianomed@bronze.ocn.ne.jp

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Abstract

During recent diabetic practice, continuous glucose monitoring (CGM) has become prevalent. The current case was a 70-year-old male with type 2 diabetes (T2D). He has used CGM for a long time and recently began using the novel FreeStyle Libre 3 system, which includes a sensor and an app for a smartphone. The benefits include painless, affordable, discreet, accurate, and real-time glucose readings at a glance. He successfully measured glucose variability for one month, which was associated with an average glucose of 148 mg/dL, a time in range (TIR) of 80%, and a time above range (TAR) of 20%. This apparatus would be convenient for beneficial clinical diabetic research.

Keywords

Continuous Glucose Monitoring, FreeStyle Libre 3 System, Time in Range, Time Above Range, Time Below Range

Abbreviations

CGM: Continuous Glucose Monitoring; TIR: Time in Range; TAR: Time Above Range; TBR: Time Below Range

Introduction

Recently, bioelectronic medicines have attracted attention for diagnosing and treating various diseased states, such as obesity, diabetes, ischemia, bleeding, rheumatoid arthritis, cancer, cardiovascular disease, and others [1]. They have applied information technologies, electrical signaling, artificial intelligence (AI), and related mechanisms. In the medical education

and health care fields, the role of smart technology and wearable health devices has been discussed [2]. Wearable devices have been reshaping the current health management system across the world. Many people have used such devices for tracking their vital changes, including blood pressure, heart rate, oxygen saturation, and so on. Wearable health gadgets have been recently developed and will be able to monitor

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blood glucose values on the skin in the future.

The American Diabetes Association (ADA) Professional Practice Committee announced the 2025 version of the Standards of Care (SoC) on January 1, 2025. Among them, recent developments in diabetes technology have been presented [3]. In the latest system, testing and training of each personalized model can be obtained [4]. The reported system can show high values of 30- and 60-minute forecasting predictions for diabetic patients.

For a detailed evaluation of glucose variability, blood glucose monitoring (BGM) and intermittently scanned continuous glucose monitoring (isCGM) have been applied to various patients with type 2 diabetes (T2D) treated with multiple daily injections (MDI) [5]. As part of the protocol, a 24-week multi-center trial and a randomized study included T2D cases. The isCGM has shown a greater decrease in HbA_{1c}, where adequate education was observed for the evaluation of CGM data. The authors and the diabetes group have continued medical diabetic research and practice for a long time under the Japan Low Carbohydrate Diet Promotion Association (JLCDPA) [6]. During our studies, various reports have been found on T2D, CGM, meal tolerance tests (MTT), and low carbohydrate diets (LCD) [7-9]. We have encountered a meaningful male case with T2D, and he has continued CGM using the novel version of FreeStyle Libre [10]. The clinical course and its related perspectives are described here.

Medical History

The current patient is a 70-year-old male with T2D. Regarding his past medical history, he did not have any particular health problems in his youth. He was diagnosed with diabetes at the age of 50. He has been prescribed some oral hypoglycemic agents (OHAs). He started insulin treatment nine years ago, and his diabetic condition has been mostly stable, with HbA_{1c} levels ranging from 6.4% to 7.3%. His current medication includes various OHAs, antihypertensive agents (AHAs), and MDI. These include Valsartan, Rosuvastatin, Ipragliflozin L-proline, Degludec (12 units once daily), and NovoRapid insulin (8-8-8 units three times a day).

Several Examinations

This case showed unremarkable physical findings, vital signs, or consciousness. His body measurements were 171 cm in height, 74 kg in weight, and a BMI of 25.3 kg/m². Regarding his physical status, no abnormalities were observed in the heart, lungs, abdomen, or neurological findings. Concerning diabetic complications, he was treated for pre-proliferative retinopathy. He did not have sensory or motor disturbances. No significant changes were observed in blood chemistry tests, chest X-rays, or electrocardiograms (ECG).

Results

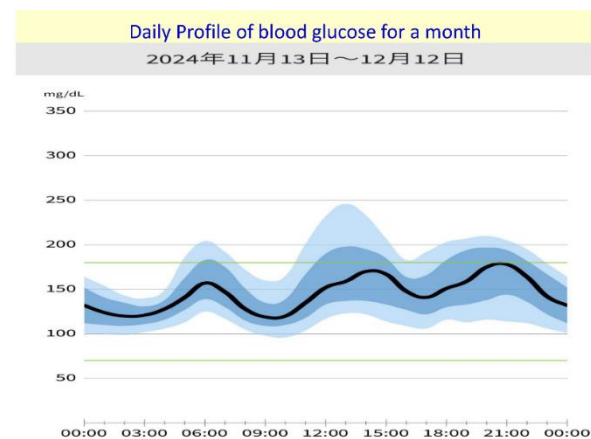


Fig-1: Blood glucose profile by CGM for a month using FreeStyle Libre

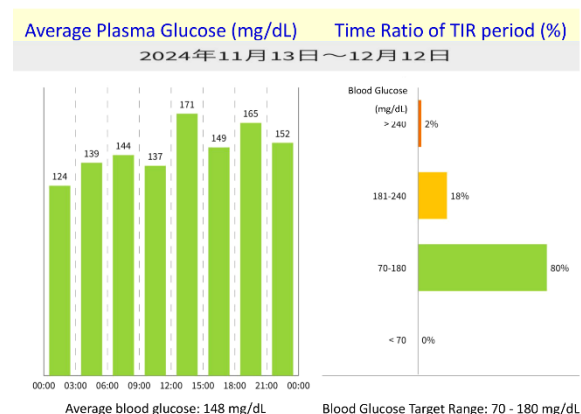


Fig-2: Analysis of blood glucose variability

2a: Average plasma glucose value for 3 hours each

2b: Time Ratio of TAR, TIR and TBR

The daily profile of blood glucose was measured by CGM using the latest model of the FreeStyle Libre 3 system. It can monitor detailed changes in blood glucose throughout the day, and the data can be stored in the

apparatus and a related smartphone. From November 13 to December 12, the average blood glucose variability data was analyzed and downloaded from the device (Fig-1). The ideal range of blood glucose variability was from 70 mg/dL to 180 mg/dL. The average glucose value was 148 mg/dL, with each value calculated every three hours (Fig-2a). Analysis of the obtained data showed that time above range (TAR), time in range (TIR), and time below range (TBR) were 20%, 80%, and 0%, respectively (Fig-2b).

Ethical Considerations

This article follows the basic principles of the Helsinki Declaration. Moreover, some commentaries are related to the Ethical Guidelines for Human Research. For this study, the authors established an ethical committee at Kanaiso Hospital, Tokushima, Japan. The committee included necessary professionals such as the hospital president, the physician in charge, the head nurse, a pharmacist, a dietitian, and a legal specialist. After thorough discussions, an agreement was reached on the study protocol. Informed consent was obtained from the patient in written form.

Discussion

For better control of blood glucose variability, continuous glucose monitoring (CGM) has become gradually prevalent. Medical technology has made it possible for more detailed investigations with its evolution [11]. The real-time (rt)-CGM system has improved accuracy, usability, and design and has played a role in integrated personalized diabetes management (iPDM) [12]. Along with the increasing usage of CGM in medical practice, adequate assessment of glycemic control has gone beyond HbA1c measurement. TIR has been evaluated as a useful and simple metric [13]. Consequently, the parameters such as TIR, TAR, and TBR are evaluated in relation to human daily activities as the ambulatory glucose profile (AGP). TIR has been understood as an indicator of ideal glycemic management, with a range of 70 mg/dL to 180 mg/dL. Recently, another borderline has been presented, known as time in tight range (TITR), ranging from 70-140 mg/dL [14]. However, since this represents a narrower ideal range, maintaining such a strict range seems rather challenging.

When comparing biomarkers related to CGM, therapeutic efficacy was measured as an alternative to HbA1c values. Multiple data points from 5,210 T2D patients were analyzed [15]. As a result, three biomarkers were selected: mean glucose, %TAR, and %TIR. They were found to have relationships with HbA1c levels and can be used for evaluating clinical effects. Mean glucose showed a higher relationship with %TAR ($r=-0.91$) and a weaker relationship with %TIR ($r=-0.83$). A high correlation was found between %TAR and %TIR ($r=-0.91$). Thus, %TAR and %TIR showed a higher relationship with mean glucose values than with HbA1c. Consequently, mean glucose appears to be the most sensitive biomarker, showing a consistently higher relationship with %TAR than with %TIR.

The current patient is a 70-year-old male and showed TAR 20% and TIR 80% over one month. These results would be considered rather satisfactory, with no episodes of hypoglycemia. He has been using FreeStyle Libre for years and has become accustomed to managing the CGM procedure. This time, the CGM system has been upgraded to a novel method that always uses a smartphone. The data are stored on the smartphone, and the results can be sent via the internet. At present, the FreeStyle Libre 3 system is a CGM system that includes a sensor and an app [16]. The sensor is applied painlessly to the back of the upper arm and can stream glucose readings automatically to the patient's smartphone, allowing the patient to check glucose values at any time with a quick glance. The beneficial aspects include being painless, affordable, discreet, accurate, and providing real-time glucose readings with a glance at the smartphone.

In summary, CGM has become more convenient for diabetic patients, supported by advancements in CGM technology [17]. With the progress of data analytics and AI, healthcare has undergone a revolution, enhancing well-being, addressing deep-rooted health challenges, and improving system performance [18]. General trends include precision medicine, real-time blood glucose monitoring through intelligent wearables, rapid drug delivery systems (DDS), and more. AI applications hold significant potential for improving patient care,

operational efficiency, health outcomes, and innovative health solutions.

Conflict of Interest

The authors have read and approved the final version of the manuscript. The authors have no conflicts of interest to declare.

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