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editorial-office@sciformat.ca

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ADVANCES AND CHALLENGES IN CONTINUOUS GLUCOSE MONITORING FOR DIABETES MANAGEMENT. A NARRATIVE REVIEW

Joanna Ciemięga *(Corresponding Author, Email: joannaciemiega1@gmail.com)*
University of Rzeszów, Rzeszów, Poland
ORCID ID: 0009-0009-0041-1671

Jakub Klecha
Saint Queen Jadwiga Clinical Regional Hospital in Rzeszów, Rzeszów, Poland
ORCID ID: 0009-0003-8909-9181

Emilia Kucab
University Clinical Hospital F. Chopin in Rzeszów, Rzeszów, Poland
ORCID ID: 0000-0003-4320-6327

Kacper Szpanelewski
Saint Queen Jadwiga Clinical Regional Hospital in Rzeszów, Rzeszów, Poland
ORCID ID: 0009-0006-2517-4535

Radosław Kołodziej
Saint Queen Jadwiga Clinical Regional Hospital in Rzeszów, Rzeszów, Poland
ORCID ID: 0009-0009-1767-5956

Anna Kołodziej
Saint Queen Jadwiga Clinical Regional Hospital in Rzeszów, Rzeszów, Poland
ORCID ID: 0009-0001-0969-5211

Katarzyna Dziki
University Clinical Hospital F. Chopin in Rzeszów, Rzeszów, Poland
ORCID ID: 0009-0003-9380-1244

Izabella Kula
City Hospital of John Paul II in Rzeszów, Rzeszów, Poland
ORCID ID: 0009-0002-7379-5062

Wiktor Adamiec
City Hospital of John Paul II in Rzeszów, Rzeszów, Poland
ORCID ID: 0009-0002-3322-5479

Damian Danilczuk
City Hospital of John Paul II in Rzeszów, Rzeszów, Poland
ORCID ID: 0009-0005-5755-1115

Szczepan Półchłopek
City Hospital of John Paul II in Rzeszów, Rzeszów, Poland
ORCID ID: 0000-0003-1188-2830

Szymon Lulek
Saint Queen Jadwiga Clinical Regional Hospital in Rzeszów, Rzeszów, Poland
ORCID ID: 0009-0000-3827-2907

ABSTRACT

Diabetes mellitus is a major challenge for global health. It is characterized by rising prevalence, often delayed diagnosis, and significant clinical and economic burden. During the last two decades, Continuous Glucose Monitoring systems have become one of the most important developments in the management of DM. In this short review, we will describe the importance of the research on CGM systems, their advantages over previously available monitoring methods, as well as their limitations that still need to be addressed by manufacturers and physicians managing patients' treatment. We also dedicate a section of this article to newly emerging solutions, including insulin therapy with CGMs as a base and new directions in CGM applications across the medical field.

KEYWORDS

Diabetes Mellitus, Continuous Glucose Monitoring (CGM), Self-Monitoring of Blood Glucose (SMBG), Mobile Health, Insulin Therapy

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Introduction

Diabetes, due to its constantly increasing incidence, has become a major challenge for modern medicine. According to data gathered by the International Diabetes Federation (IDF) in 2025, the number of adults living with diabetes is 589–590 million, which means that as many as 1 in 9 people are affected. Projections for 2050 indicate that this number will rise to 853 million. It is also worth noting that more than 4 out of 10 people are unaware that they have the disease [1].

Diabetes is a chronic metabolic disease characterized by an elevated level of blood glucose. In many cases, DM remains asymptomatic for a long period of time, making diagnosis more difficult. Nevertheless, persistent hyperglycemia leads to serious organ damage, particularly affecting the eyes, kidneys, and heart, as well as causing nerve damage and vascular complications [2].

Because of the high prevalence of the disease and the numerous adverse consequences associated with its inadequate control, the use of modern technologies for monitoring diabetes is becoming increasingly warranted. Clinical studies show that the implementation of continuous glucose monitoring systems (CGMs) improves glycemic control, effectively prevents hypoglycemia, and significantly enhances patients' quality of life [3].

Technology behind the CGMs

The traditional method of diabetes control involves self-monitoring of blood glucose (SMBG), in which glucose levels are measured using test strips and capillary blood glucose meters. These devices are based on an electrochemical method that uses a colorimetric enzymatic reaction involving glucose oxidase. A patient's blood is applied to a test strip, and in the presence of glucose, an oxidation reaction occurs [3]. Self-monitoring of glycemia with a glucose meter provides valuable information about how meals, medications, stress, and physical activity affect blood glucose levels.

Despite its many advantages, SMBG also has several limitations. First, there are inconsistencies regarding the effectiveness of this method in patients with type 2 diabetes who are treated with oral antidiabetic medications [4,5].

Moreover, SMBG does not allow for the assessment of the full daily glycemic profile, as measurements are taken only at specific time points and may miss important fluctuations in glucose levels throughout the day and night [6]. Another limitation is the relatively high margin of error associated with glucose meters— in most countries, it is required that this error should remain within ±20% compared to laboratory reference measurements [3]. Additionally, a major drawback of SMBG is the need for frequent finger pricking, which can be uncomfortable and burdensome for patients. This often leads to reduced adherence, lower quality of life, and decreased satisfaction with treatment [7].

Due to the numerous limitations associated with traditional glucose monitoring using glucometers, the introduction of continuous glucose monitoring (CGM) systems has completely revolutionized diabetes management and control over the past two decades [8].

CGM devices operate using a sensor typically placed on the arm, which contains a thin filament inserted under the skin to measure glucose levels in the interstitial fluid. This filament includes a platinum or polymer electrode coated with the enzyme (glucose oxidase), which reacts with glucose to generate an electrical signal proportional to its concentration. This signal is transmitted via radio waves to a receiver, where it is processed and stored as averaged values at regular time intervals. The measured glucose levels are then displayed on a handheld monitor used by the patient [9].

It should be emphasized, however, that glucose values obtained using CGM may differ from those measured in the blood. These discrepancies are particularly noticeable during rapid changes in glycemia, when a mismatch can be observed between plasma glucose levels and glucose levels in the interstitial fluid. This phenomenon results from both the physiological delay in glucose diffusion between blood vessels and the interstitial space, as well as the instrumental delay of the measurement system, which together amount to approximately 5–10 minutes [10].

Strengths and limitations of CGM use

The key parameters used in the control of diabetes mellitus (DM) include the current blood glucose level at the time of measurement and glycated hemoglobin (HbA1c), which reflects the average blood glucose concentration over the past three months.

Daily use of CGM as part of self-monitoring of glycemia not only provides immediate feedback on current glucose levels—similar to standard capillary blood glucose measurements—but also offers information on the direction and rate of glycemic changes [11]. Moreover, beyond simply identifying unfavorable trends, CGM systems are equipped with intelligent features such as alerts and alarms that warn patients of impending hypoglycemia or hyperglycemia. This enables timely and appropriate action to prevent complications of poor glycemic control, which may be life-threatening [12].

CGM also helps patients achieve lower HbA1c values. A randomized clinical trial showed that the use of continuous glucose monitoring in adults with poorly controlled type 2 diabetes treated with insulin resulted in significantly lower HbA1c levels after 8 months compared with a group using self-monitoring of blood glucose with a glucometer [13]. The use of CGM therefore complements previously established monitoring methods; however, it is important to note that, due to frequent glucose measurements at short intervals, it also enables the introduction of a new parameter: Time in Range (TIR), which represents the amount of time per day that glucose levels remain within the target range. Consequently, additional metrics such as Time Below Range (TBR) and Time Above Range (TAR) are also monitored. The main goal of effective and safe glycemic control is to increase the patient's TIR while simultaneously reducing TBR.

Here, another benefit of CGM systems becomes apparent: their motivational function. By showing patients how their daily choices affect blood glucose levels, the system can encourage lifestyle modifications. According to research, CGM promotes changes in everyday habits and supports more rational decision-making. CGM systems can also significantly improve the quality of life of patients and their families.

Stress related to episodes of hypoglycemia and sudden fluctuations in glucose levels can be particularly burdensome. Among patients with type 1 diabetes using CGM systems, not only has improved glycemic control been demonstrated, but also better management of diet and physical activity, as well as enhanced quality of life and physical and psychological well-being. Parents of children using CGM have likewise reported reduced levels of stress and anxiety [14].

Despite its many benefits, CGM—like any technology—also has limitations. CGM devices are very expensive, and reimbursement for sensors depends on the country. The limited lifespan of CGM sensors is also an important factor in terms of cost and overall expenditure. Currently, the market includes longer-term solutions such as the Eversense 365 system, which can function for up to one year [15]. However, most used CGM systems (e.g., FreeStyle Libre or Dexcom G7 systems) offer sensors with a lifespan of approximately 15 days.

Moreover, the previously mentioned alarms are not always an advantage, especially when they occur frequently. In a qualitative meta-synthesis examining experiences of CGM use in patients with type 1 diabetes, "frustrating" was a commonly used term to describe the impact of alerts. Patients reported that the devices could disrupt daily functioning to such an extent that they even became a reason for discontinuing use of the system altogether. Over time, when false or unnecessary alarms predominate, a phenomenon known as "alarm fatigue" may develop, in which CGM users begin to ignore alerts, and their trust in the device decreases. [16].

Continuous monitoring can be overwhelming for some patients and, paradoxically, may even lead to increased feelings of anxiety [14]. On the other hand, many users appreciate the ability to monitor glucose levels during sleep, and the implementation of CGM systems has been associated with a perceived improvement in their well-being and sense of safety [17].

Therefore, proper patient education and individualized device settings are crucial. For example, in individuals who have difficulty recognizing symptoms of hypoglycemia, it is particularly important to carefully configure alerts warning against low glucose levels, while limiting or disabling notifications for hyperglycemia in order to reduce the number of stimuli that may disrupt daily functioning [16].

Even issues that may seem trivial for some patients can become significant problems in practice. Pain during sensor application, skin reactions, accidental removal, or sensors falling off due to sweating are everyday challenges faced by users. With the currently extended lifespan of sensors—and therefore the use of stronger adhesive materials and longer wear time—the occurrence of allergic skin reactions may become even more frequent, and they will need to be addressed [18, 19].

Integration of CGM with insulin therapy

One of the most important directions in the development of CGM systems is their integration with diabetes treatment methods. An example of such a solution is automated insulin delivery (AID) systems, which adjust insulin doses based on CGM measurements as well as additional data such as food intake and physical activity. These systems enable significantly improved glycemic regulation [20]. For patients who prefer injection therapy instead of insulin pumps, an alternative option is using insulin pens, which can integrate with CGM systems, allow data transfer, and include built-in memory for recording insulin doses [21]. Thanks to this, patients can track administered insulin doses and, additionally, receive calculated recommendations for optimal dosing based on glucose values and insulin therapy settings. Such an approach, as shown in studies, contributes to better adherence to therapeutic recommendations, improved glycemic control, and greater patient satisfaction with treatment [22].

New directions in CGM applications

Continuous glucose monitoring systems, in addition to their use in diabetes management, also have potential in prevention and in maintaining optimal metabolic control. In a scoping review by Zheng et al. (2023), it was indicated that mobile health technologies, including CGM, may support individualized dietary choices. CGM provides feedback on how specific food products affect changes in glycemia [23].

As previously mentioned, CGM may prove to be a better tool for the early detection of abnormal blood glucose levels than currently used laboratory measurements of glucose or glycated hemoglobin (HbA1c). This is because CGM enables continuous, real-time monitoring of glucose concentration, allowing the identification of short-term fluctuations that standard laboratory tests are unable to detect. As a result, it provides information on early metabolic disturbances that may precede prediabetes [24].

A significant problem among people with diabetes is fatigue and mood disturbances, resulting, among other factors, from fluctuations in blood glucose levels. Therefore, a potential direction for the use of CGM is the analysis of the relationship between a patient's glycemia and their well-being, which allows for more accurate adaptation of therapy to individual needs [25].

Another interesting field for the use of CGM is monitoring glycemic fluctuations in women in relation to the phases of the menstrual cycle. This is related to the fact that female sex hormones—estrogens and progesterone—significantly influence insulin sensitivity. A study by Tatulashvili et al. (2022) showed that glucose levels increase linearly throughout the menstrual cycle; therefore, insulin demand and glycemic control vary over the course of the month. The highest glucose concentrations are observed during the luteal phase, while the lowest occur at the beginning of menstruation [26]. This creates potential for using CGM as a tool for diagnosing and monitoring metabolic disorders in women, including those with PCOS, which is associated with insulin resistance.

Conclusions

Due to the continuously increasing number of diabetes cases, continuous glucose monitoring systems have become a valuable tool for monitoring insulin therapy in diabetic patients [27]. Their use is associated with a reduced risk of hypoglycemia and improved quality of glycemic control, which enables targeting lower HbA1c levels [28]. Compared with traditional self-monitoring of blood glucose (SMBG), CGM provides a significantly larger amount of data on glucose fluctuations and is also associated with increased time spent in the target glycemic range [29].

Continuous glucose monitoring systems are rapidly evolving, indicating that their application is not limited solely to assessing the effectiveness of diabetes treatment, but may also enable analysis of how factors such as diet and lifestyle influence blood glucose levels [23]. CGM may also find application in the diagnosis of metabolic disorders in women.

CGMs have limitations, some of which we addressed in this short review, but they will certainly remain one of the most important ways to assist patients with their therapy. Given the large number of benefits, in our opinion, efforts should be made to improve the accessibility of these systems for patients.

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