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Advances in Continuous Glucose Monitoring: Clinical Applications

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Continuous glucose monitoring (CGM) has revolutionized diabetes management, significantly enhancing glycemic control across diverse patient populations. Recent evidence supports its effectiveness in both type 1 and type 2 diabetes management, with benefits extending beyond traditional glucose monitoring approaches. CGM has demonstrated substantial improvements in glycemic control across multiple metrics. Studies report consistent glycosylated hemoglobin reductions of 0.25%–3.0% and notable time in range improvements of 15%–34%. CGM effectively reduces hypoglycemic events, with studies reporting significant reductions in time spent in hypoglycemia. CGM also serves as an educational tool for lifestyle modification, providing real-time feedback that helps patients understand how diet and physical activity affect glucose levels. While skin-related complications remain a concern, technological advancements have addressed many initial concerns. High satisfaction rates and long-term use suggest that device-related issues are manageable with proper education and support. Despite high initial costs, CGM's prevention of complications and hospitalizations ultimately reduces healthcare expenditures. With appropriate training and support, CGM represents a transformative technology for comprehensive diabetes care.

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

INTRODUCTION

Diabetes management technology has advanced significantly in recent decades, with continuous glucose monitoring (CGM) leading this evolution. The development of CGM has brought about substantial changes in diabetes management, transforming how patients and healthcare providers approach glucose monitoring and therapeutic decision-making.

CGM has progressed from an optional technology to a recommended standard of care for many patients with diabetes [1,2]. Currently, it is not only strongly recommended for patients with type 1 diabetes (T1D) but also considered essential technology for patients with type 2 diabetes (T2D) on insulin therapy. Clinical guidelines now recognize CGM as a fundamental component of comprehensive diabetes care for these populations, recognizing its role in improving glycemic outcomes and reducing complications. This technology provides real-time glucose feedback, aiding decision-making, enhancing understanding of diabetes management, and minimizing the risks of hypoglycemia and hyperglycemia.

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This review aims to provide practical guidance on CGM implementation in clinical practice, examining features of currently available CGM devices, clinical evidence, benefits, and real-world challenges associated with CGM.

CURRENT CGM FEATURES

CGM has fundamentally transformed diabetes management by providing dynamic glucose data that enables more informed therapeutic decisions. This section compares the features of commercially available CGM devices across major markets, including North America, Europe, and Asia (Table 1).

Abbott's FreeStyle Libre series (Chicago, IL, USA) [3,4], widely available globally, is popular for its 14-day sensor duration and factory calibration, eliminating fingerstick testing. With a mean absolute relative difference (MARD) of 9.2% to 9.7%, these compact, waterproof systems ensure reliable accuracy for various patient populations.

The Dexcom G7 system (San Diego, CA, USA) [5], widely available in the United States and Europe and expanding in Asian markets, is a notable advancement in CGM technology. Though it has a shorter 10-day sensor duration Though it has a shorter 10-day sensor duration than that of the Libre series of the Libre series, it offers superior accuracy (MARD: 8.2% to 9.1%) with the shortest 30-minute warm-up period. Continuous automatic transmission and predictive hypoglycemia alerts make it particularly valuable for patients with intensive insulin therapy. Its integration with insulin pumps further enhances its utility in diabetes management.

The Medtronic Guardian 4 system (Minneapolis, MN, USA) has secured its position in the market through its integration with MiniMed insulin pumps [6]. Despite a more limited 7-day sensor duration, the system offers predictive alerts up to 60 minutes before critical glycemic events, benefitting closed-loop insulin delivery users. Its no-calibration design represents a significant improvement over previous Medtronic models, though its accuracy (MARD: 10.1% to 11.2%) is slightly behind those of Abbott and Dexcom devices.

Regionally developed systems have emerged in Asia to meet local needs. South Korea's Caresens Air and Barozen Fit offer a competitive 15-day sensor duration that requires daily fingerstick calibration, with basic alert functionalities and a MARD of 10.42% [7]. Designed for Asian body types, these systems are more affordable than their international competitors, making them accessible in cost-sensitive markets.

RECENT CLINICAL EVIDENCE OF CGM IN PEOPLE WITH DIABETES

Evidence supports CGM use in diabetes management. Studies show that people with diabetes (PwD) using CGM achieve better glycemic outcomes and greater satisfaction with their diabetes management. Notably, its benefits extend across diverse PwD, regardless of treatment regimen (multiple daily insulin injections [1], continuous subcutaneous insulin infusion, basal insulin, or non-insulin), diabetes type, or age group (Table 2).

Effectiveness of CGM in patients with type 1 diabetes

Strong evidence supports CGM use in patients with T1D in both randomized controlled trials (RCTs) and real-world studies. RCTs for adults with poorly controlled T1D (baseline mean glycosylated hemoglobin [HbA1c]: 8.6% to 8.9%) consistently

Table 1. Comparison of Continuous Glucose Monitoring Feature

CGM sensor (manufacturer)	Size, cm	Duration, day	Glucose range, mg/dL	Warm-up time, min	Memory storage	Calibration required	MARD, %
FreeStyle Libre 2 (Abbott)	3.5 diameter×0.5	14	40–500	60	8 hr	No	9.2–9.7
FreeStyle Libre 3 (Abbott)	2.1 diameter×0.28	14	40–500	60	14 days	No	7.9–9.4
Dexcom G7 (Dexcom)	2.7×2.4×0.46 (without required overpatch)	10 (12-hr grace period)	40–400	30	24 hr	No (optional)	8.2–9.1
Medtronic Guardian 4 (Medtronic)	6.6×5.1×3.8	7	40–400	120	Not available	No	10.1–11.2
Caresens Air (i-SENS)/ Barozen Fit (Handok)	3.5×1.9×0.5	15	40–500	120	12 hr	Yes (every 24 hr)	9.4–10.42

CGM, continuous glucose monitoring; MARD, mean absolute relative difference.

Table 2. Key Outcome Studies Providing Evidence of the Efficacy of Continuous Glucose Monitoring

Study	Population	Treatment	Study design and duration	Baseline glycemic status: CGM vs. BGM	Results (CGM vs. BGM)
Beck et al. (2017) [8]	158 adults with T1D	MDI	RCT, 24 wk	Mean HbA1c: 8.6% vs. 8.6%	Adjusted between-group difference in HbA1c: –0.6%, $P<0.001$ (7.7% vs. 8.2%)
Lind et al. (2017) [9]	161 adults with T1D	MDI	RCT, 26 wk	Mean HbA1c: 8.71% vs. 8.70%	Adjusted between-group difference in HbA1c: –0.43%, $P<0.001$ (7.92% vs. 8.35%)
Laffel et al. (2020) [10]	153 adolescents and young adults (14–24 yr) with T1D	MDI, CSII	RCT, 26 wk	Mean HbA1c: 8.9% vs. 8.9%	Adjusted between-group difference in HbA1c: –0.37%, $P=0.01$ (8.5% vs. 8.9%)
SENCE study group (2021) [14]	143 children with T1D	MDI, CSII	RCT, 6 mo	Mean TBR <70 mg/dL: 5.2% vs. 5.4%	Adjusted between-group difference in TBR <70 mg/dL: –2.6%, $P<0.001$ (2.6% vs. 5.8%)
Pratley et al. (2020) [13]	203 elderly (>60 yr) with T1D	MDI, CSII	RCT, 6 mo	Mean TBR <70 mg/dL: 5.1% vs. 4.7%	Adjusted between-group difference in TBR <70 mg/dL: –1.9%, $P<0.001$ (2.7% vs. 4.9%)
Beck et al. (2017) [24]	158 adults with T2D	MDI	RCT, 6 mo	Mean HbA1c: 8.5%	Adjusted between-group difference in HbA1c: –0.3%, $P=0.022$ (7.7% vs. 8.0%)
Martens et al. (2021) [25]	175 adults with T2D	Basal insulin	RCT, 8 mo	Mean HbA1c: 9.1% vs. 9.0%	Adjusted between-group difference in HbA1c: –0.4%, $P<0.001$ (8.0% vs. 8.4%)
Moon et al. (2023) [30]	61 adults with T2D	OHA	RCT, 3 mo	Mean HbA1c: 8.2% vs. 8.1%	Adjusted between-group difference in HbA1c: –0.68%, $P=0.018$
Karter et al. (2021) [15]	41,753 patients with T1D/T2D	Any	Retrospective cohort, 12 mo	Mean HbA1c: 8.17% vs. 8.28%	Adjusted between-group difference in HbA1c: –0.4%, $P<0.001$ (7.76% vs. 8.19%)
Layne et al. (2024) [28]	3,840 adults with T2D	OHA	Retrospective single-arm, 12 mo	Mean TIR: 41.7%	Mean TIR increased by 17.3% (from 41.7% to 59.0%)
Feig et al. (2017) [32]	325 Pregnant patients with T1D	MDI, CSII	RCT, 34 wk, gestation	Mean HbA1c: 6.83% vs. 6.95%	Adjusted between-group difference in HbA1c: –0.19%, $P=0.0207$ (6.35% vs. 6.53%)

CGM, continuous glucose monitoring system; BGM, blood glucose monitoring; T1D, type 1 diabetes mellitus; MDI, multiple daily insulin injection; RCT, randomized controlled trial; HbA1c, glycosylated hemoglobin; CSII, continuous subcutaneous insulin infusion; SENCE, Strategies to Enhance New CGM Use in Early Childhood; TBR, percent time below range; T2D, type 2 diabetes mellitus; OHA, oral hypoglycemic agents; TIR, percent time in range.

show significant improvements in HbA1c with CGM use compared to self-monitoring of blood glucose (SMBG; mean HbA1c reduction: –0.4% to –1.0%; between-group difference: 0.37% to 0.6%), along with a 5% to 11% increase in time in range (TIR) without worsening hypoglycemia [8-10]. In contrast, studies on patients with T1D and frequent hypoglycemia or impaired hypoglycemia awareness indicate that CGM reduces hypoglycemic episodes without compromising HbA1c levels [11,12]. Hermanns et al. [11] reported a 72% reduction in hypoglycemic events (≤54 mg/dL for ≥20 minutes) with CGM use compared to SMBG, without worsening HbA1c. Van Beers et al. [12] reported a 59% reduction in severe hypoglycemia, defined as an event requiring third-party assistance, in CGM users compared to the SMBG group. Similar benefits were observed in RCTs for elderly and very young patients with T1D, where CGM use effectively reduced hypoglycemia-related outcomes [13,14].

Beyond RCTs, retrospective cohort and real-world studies of adults with T1D have consistently demonstrated comparable HbA1c improvements and greater reductions in hypoglycemia-related outcomes with CGM over extended follow-up periods [15-18]. A large retrospective cohort analysis found that CGM users had a –0.39% HbA1c reduction (between-group difference: –0.34%, $P<0.001$) compared to non-users [15]. Similarly, long-term observational studies report sustained HbA1c improvements (–0.3% to –0.6%) over 12 months [16-18] and a lower risk of severe hypoglycemia with CGM use. Charleer et al. [16] report a fourfold decrease in severe hypoglycemia-related hospitalizations. Another study indicates that severe hypoglycemia incidence decreased from 14.6% to 7.8% after CGM adoption [19].

Effectiveness of CGM in patients with type 2 diabetes

T2D involves diverse pathophysiological mechanisms and treatment strategies, from lifestyle modifications and oral hypoglycemics to basal insulin alone or intensive insulin therapy. Recent evidence suggests that CGM is clinically beneficial across various T2D treatment strategies [20]. Initially recommended for individuals on intensive insulin therapy, CGM is now backed by data showing its effectiveness in patients on basal insulin alone or non-insulin treatments [2].

Multiple RCTs show that CGM use in patients with T2D on intensive insulin therapy significantly reduces HbA1c compared to SMBG (mean HbA1c reduction: –0.53% to –0.82%; between-group difference: 0.3% to 0.5%), while hypoglycemia either significantly reduces or remains unchanged [21-24]. In a large retrospective cohort study of patients with T2D on intensive insulin therapy, the CGM group demonstrated a between-group HbA1c reduction of –0.56% compared to non-CGM users ($P<0.001$) [15].

CGM is also effective in basal insulin-only users compared to SMBG. Martens et al. [25] reported that patients with T2D on basal insulin had significant HbA1c reductions (9.1% to 8.0%) compared to the SMBG group (9.0% to 8.4%), with an adjusted between-group difference of –0.4% ($P=0.02$), while severe hypoglycemia was rare and similar between groups. A real-world retrospective study and meta-analysis linked CGM use in this population with significant HbA1c reduction (–1.1%, $P<0.001$), demonstrating its potential to improve glycemic control without bolus insulin initiation [26].

In non-insulin-treated T2D, CGM outperforms SMBG. Wada et al. [27] report that CGM users achieved a sustained and greater reduction in HbA1c at 24 weeks (–0.46% vs. –0.17%) compared with SMBG users, with a significant between-group difference of –0.29% ($P=0.022$). Similarly, Layne et al. [28] report that among patients with suboptimal glycemic control not using insulin, CGM use increased TIR by 17.3% ($P<0.001$) over 12 months. Two recent RCTs of non-insulin-treated T2D indicate that even intermittent CGM improves glycemic control over SMBG [29,30]. Price et al. [29] report that a 10-day CGM session per month for 3 months reduced HbA1c by –0.5% versus –0.2% with SMBG (between-group difference: –0.29%, $P=0.74$). Moon et al. [30] show that patients receiving two CGM sessions with a 3-month interval achieved a significant HbA1c reduction (between-group difference: –0.68%, $P=0.018$).

Effectiveness of CGM in pregnancy

Recent studies link CGM metrics to improved pregnancy outcomes in women with T1D. Less time spent in the target range (63 to 140 mg/dL) correlates with increased neonatal risks such as large for gestational age (LGA) and neonatal hypoglycemia [31]. Feig et al. [32] reported that CGM use significantly improved glycemic outcomes for T1D compared to SMBG, with a lower third-trimester mean HbA1c (mean difference: LGA 0.19%, $P=0.0207$) and increased TIR (68% vs. 61%, $P=0.0034$). These improvements translated into clinically meaningful neonatal benefits, including reduced incidence of LGA infants (odds ratio [OR], 0.51; 95% confidence interval [CI], 0.28 to 0.90). Similarly, Murphy et al. [33] evaluated 71 pregnant women with pre-gestational diabetes (46 with T1D and 25 with T2D) and found that CGM use was associated with significantly lower third-trimester HbA1c levels (5.8% vs. 6.4%) and reduced

risk of macrosomia (OR, 0.36; 95% CI, 0.13 to 0.98) compared to the SMBG group.

In contrast, data on CGM use in gestational diabetes mellitus (GDM) remains limited. A recent RCT involving women with well-controlled GDM (HbA1c <6%) found no significant differences in TIR or HbA1c between CGM and SMBG users [34]. However, since participants had optimal baseline glycemic control, the potential impact of CGM on glycemic improvement may have been minimal. Despite this, CGM use correlated with better gestational weight gain outcomes [34]. Given the limited evidence in T2D and GDM pregnancies, further studies are needed to assess its impact on these populations.

BENEFITS OF CGM USE IN CLINICAL PRACTICE

Monitoring for better glycemic control

CGM improves glycemic control through continuous glucose data collection and analysis, unlike fingerstick tests that provide isolated glucose readings. This continuous data stream reveals otherwise unnoticed patterns and fluctuations. This enables clinicians to make more informed treatment decisions and helping patients understand how daily activities affect their glucose levels.

Clinical research confirms that CGM effectively improves glycemic control. A meta-analysis of 21 studies involving 2,149 individuals with T1D revealed that CGM significantly decreased HbA1c levels compared to SMBG (mean difference: –0.23%) [35]. This improvement in glycemic control was even more pronounced in individuals with higher baseline HbA1c levels above 8%, with a mean reduction of –0.43% [35]. These findings highlight the value of CGM for patients with suboptimal glucose control.

In real-world clinical settings, CGM significantly improves glycemic management. A propensity-matched cohort study involving patients with T1D showed that CGM use for over 1 year significantly reduced HbA1c levels by 0.5% from baseline compared to matched non-users [36]. This improvement remained significant after adjusting for confounders, confirming the robust effect of CGM on glycemic outcomes.

Alarm or alert for immediate correction

Advances in CGM features enhance diabetes management by providing real-time notifications for high and low-glucose levels, enabling timely intervention to treat or prevent acute glycemic events [37].

Low-glucose prediction mitigates diabetes distress by addressing hypoglycemia-related concerns and potential complications, including hypoglycemia recurrence, unawareness, accidents, and exacerbation of secondary diseases due to fluctuating glucose levels [38]. High-specificity alerts help prevent 'alarm fatigue,' while high-sensitivity alerts help prevent missed hypoglycemia events, improving the safety of patients [38,39].

In silico simulations showed that consuming 15 g carbohydrate in response to low-glucose prediction alerts reduced the time below range (<70 mg/dL) by 92% compared to no alerts and 47% compared to standard hypoglycemia threshold alerts. Similarly, nocturnal low-glucose prediction algorithms reduced nightly time below range by 37% from baseline [38].

Motivation for personalized lifestyle modification

CGM motivate patients by illustrating how daily choices affect glucose levels. Studies show that CGM improves disease understanding and encourages self-management [40,41]. By visualizing immediate glucose responses to meals, physical activity, and other behaviors, patients can make informed decisions about their diabetes management [41].

This continuous feedback provided by CGM enables patients to understand how specific foods, exercise, and stress affect glucose patterns, and adjust their lifestyle accordingly. This real-time education is more impactful than traditional diabetes education methods, as it provides personalized insights specific to each individual's unique physiological responses.

PRIORITY POPULATIONS FOR CGM IMPLEMENTATION

Greater glycemic efficacy in poorly controlled cases

Patients with higher baseline HbA1c levels show greater improvements with CGM use. A study involving non-insulin-treated patients with T2D uncontrolled with oral antidiabetic drugs (baseline HbA1c 8.2%±0.5%) reported significant HbA1c reductions after CGM use [30]. This suggests that CGM may be beneficial for patients struggling to meet glycemic targets with conventional monitoring approaches.

Enhanced protection for hypoglycemia-prone patients

CGM is especially valuable for patients at increased risk of hypoglycemia, providing continuous monitoring and predictive alerts as an essential safety net. CGM use significantly reduces nocturnal hypoglycemia, a particularly dangerous condition caused by reduced awareness during sleep [35]. By enabling

proactive management of nocturnal hypoglycemia, CGM alerts minimize sleep interruptions and associated health risks, improving sleep quality and overall health [35].

Optimized monitoring for time in tight range candidates

Time in tight range (TITR), the percentage of time glucose levels remain within 70 to 140 mg/dL (3.9 to 7.8 mmol/L), is a stricter glycemic metric that closely reflects normal glucose patterns in healthy individuals, with studies showing that non-diabetic individuals maintain a median TITR of 96% [42,43]. TITR is particularly more beneficial over standard TIR for patients requiring precise glycemic control, especially pregnant women with diabetes, who need stricter targets (3.5 to 7.8 mmol/L) to reduce fetal risks [44]. Recent studies show that women with gestational diabetes maintain 87%±11% TIR within this narrow range [45], highlighting the value of TITR in risk stratification during pregnancy. TITR also benefits patients using automated insulin delivery systems or advanced glucose-lowering medications, as these technologies support near-normoglycemic states [46]. With CGM becoming available over-the-counter, TITR provides an intuitive scale for individuals with pre-diabetes or those monitoring diet-exercise effects on glucose levels, although further research is needed to establish predictive thresholds for diabetes onset in these populations [43].

CGM EXPANDABILITY: INTEGRATION WITH VARIOUS INSULIN DELIVERY DEVICES AND MOBILE APPLICATIONS

Integrating CGM with insulin delivery systems marks a significant advance in diabetes technology, creating a connected system that enhances diabetes management (Fig. 1) [41].

Automated insulin delivery systems

Automated insulin delivery systems, also known as hybrid closed-loop systems, mimic physiological glucose regulation by using algorithms to continuously adjust insulin based on CGM readings, residual insulin action, and other inputs such as meal intake and exercise announcement [41,47].

Connected insulin pens and software for life coaching

Connected insulin pens offer a major advancement for patients

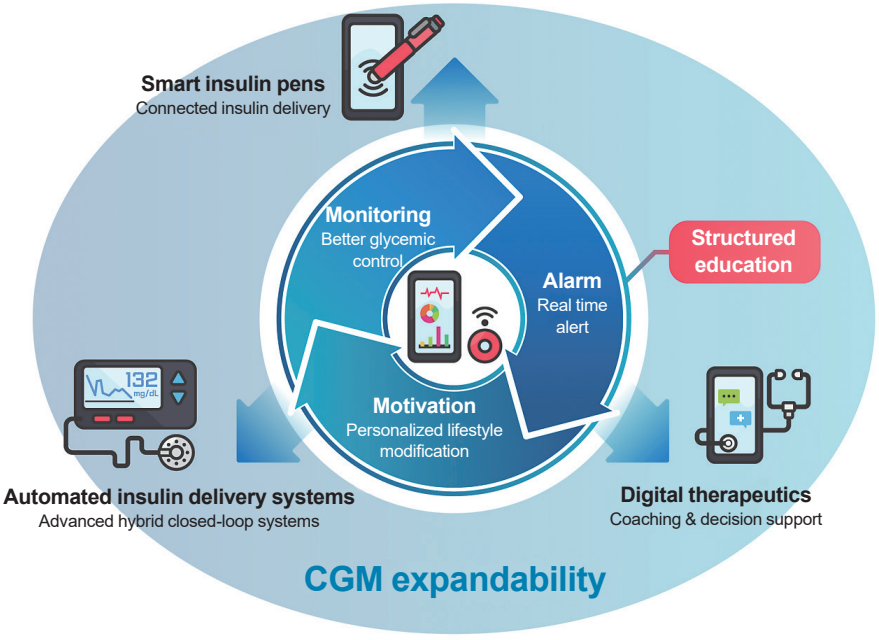

Fig. 1. Clinical implications and expandability of continuous glucose monitoring (CGM) in diabetes management. The diagram illustrates the CGM expandability and its clinical applications. At its core, three interconnected elements—monitoring (enabling better glycemic control), alarm (providing real-time alerts), and motivation (facilitating personalized lifestyle modification)—drive CGM effectiveness. These extend to smart insulin pens (top) for connected insulin therapy, automated insulin delivery systems (left) for hybrid closed-loop glucose management, and digital therapeutics (right) for coaching and decision support to enhance clinical outcomes. The entire ecosystem is supported by structured education (indicated in red), which enhances patient understanding and engagement. This ecosystem demonstrates how CGM innovation, personalization, and integration improve clinical care.

needing intensive insulin therapy but preferring injections over pumps [48]. These 'smart' pens offer connectivity with CGM systems and blood glucose meters, built-in memory, and data download capabilities [49]. They allow users to track insulin dosages, provide dose reminders, and calculate optimal doses based on individualized insulin therapy settings and glucose levels. Studies show they improve adherence, enhance glycemic control, and boost patient satisfaction [50]. Cost-effectiveness analyses demonstrate associations between connected pen use and potential economic benefits from improved A1c levels and reduced diabetes-related complications [51,52].

Digital health applications have become important tools in diabetes management, with over 2,200 diabetes-related mobile health apps available. Many of these apps can be integrated with CGM systems to display glucose data and information about physical activity, nutrition, stress, and weight management [41]. This integration enables patients to visualize how lifestyle modifications impact their glycemic control. For example, partnerships between CGM manufacturers and weight management programs such as WeightWatchers or the PASTA app (Kakaohealthcare, Seongnam, Korea) allow users to access their glucose data directly within the app, creating a comprehensive feedback system. Studies show that the use of these digital health apps is associated with significant reductions in mean HbA1c (approximately 0.8% [53]) and can help address health disparities by connecting people in underserved communities with expert care and support for diabetes management [54].

ADVERSE EVENTS ASSOCIATED WITH CGM USE AND MANAGEMENT STRATEGIES

Non-dermatological complications

Local infections, though rare (0.7% incidence), result from improper insertion or prolonged sensor wear [55]. They range from superficial erythema to abscess formation, necessitating sensor removal and antibiotics. Bleeding/hematomas occur in 37.6% of insertions, particularly in anticoagulated patients, and typically resolve with pressure, though hematomas >2 cm require sensor relocation [55].

Technical failures account for 82.7% of non-dermatological issues, with signal loss (53.8%) and inaccuracies (10.5%) often caused by sleep-related compression or electromagnetic interference from magnetic resonance imaging/computed tomography scans [56]. For example, pressure-induced hypoglycemia artifacts may lead to unnecessary insulin dosing.

Premature dislodgement occurs in 9.2% of users, driven by sweat, friction, or adhesive failure. Adhesion-promoting products (e.g., skin tac wipes) and climate-specific tapes (e.g., hydrocolloid patches for humid regions) help reduce this risk [56].

Common skin-related complications

Cutaneous adverse events are the most common complications of CGM, potentially affecting treatment adherence and quality of life. Dermatological complications occur approximately once every 8 weeks of sensor wear, with approximately 1.5% classified as severe [55]. Erythema is the most common reaction (55.2%), followed by pruritus (11.2%), induration (8.5%), edema (6.9%), and rash (6.4%). These reactions are a major cause of discontinuation, with 41% of adult and 40% of pediatric users citing skin reactions as their primary reason for CGM discontinuation.

CGM-related cutaneous adverse events arise from two distinct pathophysiological mechanisms: irritant contact dermatitis and allergic contact dermatitis. Irritant contact dermatitis results from direct skin toxicity without immune involvement, while allergic contact dermatitis involves immunological sensitization to specific allergens present in adhesive components.

Isobornyl acrylate (IBOA), a key allergen in CGM adhesives, was named 'Allergen of the year' in 2020 by the American Contact Dermatitis Society. Multiple case series identify IBOA as the leading cause of CGM-related allergic contact dermatitis [57].

Several factors increase susceptibility to CGM-related skin reactions. Patients with atopic dermatitis have a 3.7-fold higher likelihood of developing cutaneous complications. Other risk factors include sensitive skin phenotype, prolonged sensor wear, and concurrent use of insulin pumps. Careful patient selection and monitoring can help minimize these adverse cutaneous events.

Selecting appropriate sensor sites is crucial for preventing adverse events [58]. Patients should be advised to utilize anatomical areas with adequate subcutaneous tissue, including the upper arm, abdomen, or thigh. Systematic site rotation allows sufficient skin recovery between applications, reducing irritation and tissue damage at frequently used locations. Proper skin preparation before sensor application, including gentle cleansing with non-irritating cleansers and ensuring complete drying, minimizes complications [58] by preventing adhesive reactions and improving sensor adherence.

Topical corticosteroids are the first-line treatment for established reactions, effectively suppressing the inflammatory cascade and relieving pruritus and erythema. The potency of corticosteroid preparation should match severity, with mild to moderate preparations generally sufficient for most CGM-related

dermatitis. Barrier products, including hydrocolloid dressings, silicone-based barriers, and specialized medical adhesive protectants, protect the skin from device adhesives. These measures help mitigate reactions while allowing continued CGM use. Recent studies suggest that pre-application of these barriers may significantly reduce cutaneous complication rates [59].

For refractory cases, switching to CGM with different adhesive formulations may be necessary. Dermatology or allergy consultation and patch testing for acrylate compounds help identify specific allergens. This multidisciplinary approach supports continued glycemic monitoring in affected individuals while ensuring comprehensive care.

IMPORTANCE OF STRUCTURED EDUCATION ON CGM

While CGM improves glycemic outcomes, most studies incorporate structured education and training. In the GOLD and DIAMOND trials [8,9], participants received individualized training on insulin dosing adjustments and CGM data interpretation. The CONCEPTT trial [32] educated pregnant women with T1D on modifying their insulin regimen using CGM data.

Recent studies show that structured CGM education significantly improves glycemic outcomes [23,60,61]. Hermanns et al. [60] reported greater HbA1c reductions in PwD who received structured education (–0.28% vs. –0.11%, $P=0.033$) and reduced diabetes-related distress. Yoo et al. [61] showed that CGM combined with structured, individualized education in patients with T1D led to significantly higher TIR (63.4% vs. 44.5%, $P<0.001$) and greater HbA1c reduction (–1.3% vs. –0.8%, $P=0.024$) than CGM use alone. Kim et al. [23] found that among patients with T2D on intensive insulin therapy, CGM with structured education achieved the greatest improvements in glycemic control, with a significantly reduced HbA1c (–1.00% vs. –0.63% [CGM with conventional education] and –0.58% [blood glucose monitoring], $P<0.05$). The benefits of structured education extend to youth with T1D and their families. Parental education focused on managing CGM benefits and barriers correlates with significant reductions in time below range, fewer severe hypoglycemic events, and improved glucose variability [14].

When prescribing CGM, healthcare providers should provide individualized structured education on diabetes self-management, covering glucose targets, insulin dosing adjustments, carbohydrate counting, the effect of physical activity on glycemia, and hypoglycemia management [62]. CGM-specific education should address device operation, data interpretation, insulin regimen optimization using Ambulatory Glucose Profile (AGP) data and glucose patterns, and trend arrows for insulin dosing adjustments. Additionally, patients should be taught to respond to alarms, identify substances that interfere with CGM readings, and address common challenges associated with CGM use [2,63-65]. Patients and educators should also set realistic expectations regarding CGM capabilities and limitations [64]. This education should be reinforced periodically, particularly when additional support is needed, or glycemic goals are unmet [66]. A multidisciplinary team, including certified diabetes educators, endocrinologists, and dietitians, should provide structured education to ensure comprehensive guidance on CGM and holistic diabetes care [64].

SOCIO-ECONOMIC BURDEN OF CGM

Despite the proven benefits of CGM for glycemic control, its high upfront cost limits widespread adoption and long-term use. Without insurance coverage, its higher cost, compared to SMBG, can impose a financial burden on PwD. Since suboptimal glucose control leads to increased healthcare expenses from frequent hospitalizations and chronic complications [67-69], CGM may ultimately be cost-effective by reducing these complications and overall healthcare costs.

The cost-effectiveness of CGM has been evaluated across different countries, insulin regimens, and healthcare settings [70-79]. Studies on intensive insulin therapy indicate that CGM is cost-effective long-term compared to SMBG. Ajjan et al. [70] found that CGM users in the United Kingdom (UK) gained 0.731 additional quality-adjusted life years (QALYs), a measure of the quality and length of life for an individual, compared to SMBG users (7.897 QALYs vs. 7.166 QALYs). This study reported an incremental cost-effectiveness ratio (ICER, the additional cost required to gain one QALY) of £3,684 per QALY, well below the UK willingness-to-pay (WTP) threshold of £20,000 per QALY, indicating high cost-effectiveness. Similarly, in South Korea, CGM use in patients with intensive insulin-treated T2D yielded 0.683 more QALYs compared to SMBG users (7.526 QALYs vs. 6.843 QALYs) and an ICER of Korean won (KRW) 24.0 million per QALY, also below the KRW 46 million WTP threshold [78]. A Swedish study further confirmed the cost-effectiveness of CGM in patients on an intensive insulin regimen, with an ICER of Swedish krona (SEK) 306,082 per QALY, below the WTP threshold of SEK 400,000 to 500,000 per QALY [74]. Del Prato et al. [75] found CGM cost-effective even for PwD on basal insulin, compared to SMBG, with a gain

of 0.51 QALYs and an ICER of €10,556/QALY, well below the €20,000 WTP threshold.

Beyond financial modeling, real-world data support the economic value of CGM. Zhao et al. [79] and Isaacson et al. [76] linked CGM use to fewer hospitalizations, while Kim et al. [78] projected a 31% reduction in end-stage renal disease and a 23% decrease in proliferative diabetic retinopathy compared to SMBG, ultimately lowering healthcare costs over time. Additionally, in T1D pregnancy, CGM use reduced the frequency and duration of neonatal intensive care unit admissions compared to SMBG (mean 6.6 days vs. 9.1 days, respectively), further supporting its cost-effectiveness [80,81].

Across multiple healthcare systems, CGM has consistently proven cost-effective for insulin-treated PwD compared to SMBG. Despite higher initial costs, it improves glycemic control, reduces hypoglycemia risk and hospitalizations, and reduces long-term healthcare expenditures. Educating patients on its cost-effectiveness may improve compliance and long-term adherence by highlighting its clinical and financial benefits.

CONCLUSION

CGM has established itself as revolutionary technologies that are transforming the paradigm of diabetes management. As reviewed in this article, CGM provides various clinical benefits for patients with T1D, T2D, and GDM, including lower HbA1c levels, increased TIR, and decreased frequency of hypoglycemic events. It has proven particularly effective for patients receiving intensive insulin therapy, those with poor glycemic control, and individuals at high risk for hypoglycemia.

The benefits of CGM extend beyond improving glycemic metrics to include patient education, self-management empowerment, and real-time decision-making. Additionally, integration with insulin pumps through automated insulin delivery systems represents the future of diabetes management. However, challenges, including skin-related complications, technical errors, and cost, persist.

Addressing these challenges requires structured patient education, multidisciplinary approaches, and healthcare provider technical expertise. Furthermore, despite favorable cost-effectiveness, broader insurance coverage is required for wider adoption.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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