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REVIEW

# Continuous glucose monitoring (CGM) in a non-Icu hospital setting: The patient's journey

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**Abstract** *Aims:* Although consistent data support the outpatient use of continuous glucose monitoring (CGM) to improve glycemic control and reduce hypoglycemic burden, and clinical outcomes, there are limited data regarding its use in the hospital setting, particularly in the non-intensive care unit (non-ICU) setting. The emerging use of CGM in the non-critical care setting may be useful in increasing the efficiency of hospital care and reducing the length of stay for patients with diabetes while improving glycemic control.
*Data synthesis:* The purpose of this Expert Opinion paper was to evaluate the state of the art and provide a practical model of how CGM can be implemented in the hospital.
*Setting:* A patient's CGM journey from admission to the ward to the application of the sensor, from patient education on the device during hospitalization until discharge of the patient to maintain remote control.
*Conclusions:* This practical approach for the implementation and management of CGM in patients with diabetes admitted to non-ICUs could guide hospitals in their diabetes management initiatives using CGM, helping to identify patients most likely to benefit and suggesting how this technology can be implemented to maximize clinical benefits.


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## 1. Introduction

### 1.1. Background

Continuous glucose monitoring (CGM) systems are becoming an important tool for improving diabetes management. Compared with traditional capillary blood glucose testing (CBG), CGM can provide real-time glucose trends, detecting hyperglycemia and hypoglycemia before the onset of clinical symptoms. Recent generations of these devices offer improved accuracy, smaller form, extended sensor life, and new data presentation software for translating data into increasingly useful metrics on various mobile platforms.

Although the use of CGM is strongly suggested by international guidelines in the outpatient setting, data on its use in the inpatient setting are still limited. With the outbreak of the COVID pandemic, the Food and Drug Administration (FDA) issued enforcement discretion and did not object to the use of some factory-calibrated CGMs in the hospital setting, both to facilitate patient care and to obtain performance data that can be used for future regulatory submissions.

A hospital CGM program requires the cooperation of physicians, bedside nurses, diabetes educators, and hospital administrators to select, educate and manage patients appropriately. Processes for collecting, reviewing, storing, and responding to CGM data must be established for such a program to be successful.

### 1.2. Aim

The purpose of this Expert Opinion paper is to evaluate the state of the art and provide a practical approach through a patient journey for the implementation and management of CGM in adult patients with diabetes admitted to the non-intensive care unit (non-ICU), during hospitalization, at discharge and after. This article aims to build a practical model of how CGM can be implemented in a hospital setting to maximize clinical benefits: a hypothetical patient journey from admission to the ward to the application of the sensor, from patient education on the device during hospitalization until discharge of the patient to maintain remote control. This document is intended to support this technology for the management of adult patients with diabetes hospitalized in non-ICUs and to guide hospitals in their diabetes management initiatives using CGM.

### 1.3. Methods

In July 2022, the presidents of the main Italian Scientific Societies of Diabetology, Gerontology and Geriatrics, and Internal Medicine (SID, AMD, SIGG, SIMI) and the coordinator of the AMD-SID-SIEDP Study Group “Technology and Diabetes” met for a preliminary virtual meeting to discuss the current and potential future uses of CGM in the inpatient setting. The experts identified critical elements of the current hospital management model of diabetes care and appointed 4 members to the working group.

At a subsequent virtual meeting in October 2022, the working group addressed the current state of applicable uses of CGM in the hospital, potential future use, and current knowledge gaps related to the use of this technology in the hospital setting and prepared the manuscript following a thorough review of current literature using the PubMed/MEDLINE database and based on their personal suggestions and clinical experiences. The expert panel communicated via e-mail to prepare, discuss, review, and comment on the document. Based on these comments, the final version was circulated for approval.

## 2. Diabetes in the hospital

Diabetes is a condition highly prevalent in hospitalized patients and is itself responsible for hospitalization. In Italy, it has been estimated that about 1 in 6 people with diabetes are hospitalized at least once a year, and the average number of hospitalizations in patients with diabetes is 7 times higher than in non-diabetes patients (16% *vs* 9%) [1]. A recent survey by the Italian Society of Internal Medicine (SIMI) reported that 29% of patients admitted to internal medicine and geriatric wards have diabetes, and this result is in line with epidemiological data in the literature [2]. In addition, 12–25% of hospitalized patients without a known history of diabetes prior to admission experience hyperglycemia during hospitalization or stress hyperglycemia [3]. Stress hyperglycemia, or hospital-related hyperglycemia, is defined as any blood glucose concentration >140 mg/dL in patients without a prior history of diabetes and an $HbA_{1c}$ <6.5% (48 mmol/mol) [4].

Finally, 30% of patients discharged from non-ICU require further multiple hospitalizations (two or more stays), contributing to more than 50% of total hospitalizations and hospital costs [5,6].

The mean cost of hospitalization in Italy among patients with diabetes has been estimated at €7688 per admission in the critical care units, €4408 in the Geriatric department, and €4308 in the Internal Medicine department. The mean cost of a severe hypoglycemic episode ranges from €665 to €2436 depending on age, with an average length of stay of 5–9 days [7].

The management of patients in the hospital could be complicated by the need to initiate insulin treatment, which in turn prolongs the length of stay, especially if hypoglycemic events occur.

Although some trials have shown that non-insulin drugs can be a valid alternative to insulin [8] insulin therapy is still considered the preferred treatment in the hospital. Insulin therapy should be initiated for the treatment of persistent hyperglycemia >180 mg/dL (10.0 mmol/L) and targeted to a glucose range of 140–180 mg/dL (7.8–10.0 mmol/L) for most critically ill patients. A more stringent target (110–140 mg/dL; 6.1–7.8 mmol/L) may be appropriate for non-critically or critically ill post-surgical patients [9]. Subcutaneous

insulin, with basal insulin alone or in combination with prandial insulin, is effective and safe and represents the preferred therapeutic agent for glycemic control in non-ICU settings (general medicine and surgery) [10].

The SIMI survey has reported that at admission, the 45% of the hospitalized diabetic patients were insulin-treated; this percentage increases to 48% during the hospitalization [2]. The 32% of individuals with diabetes continue insulin therapy after hospital discharge [2].

The failure achieving blood glucose goals during hospitalization is associated with adverse outcomes, such as infections, worsening of comorbidities, perioperative or peri-procedures complications, prolonged length of stay, and mortality [11–15]. Likewise, hyperglycemia on admission has been associated with increased morbidity and mortality in patients with acute critical illness, such as myocardial infarction and stroke, suggesting that glycemic control should be achieved as soon as possible [16,17]. Despite the effectiveness of insulin treatment, its use and implementation are hampered by a number of barriers (Table 1) [12].

Hypoglycemia is certainly one of the main barriers limiting the appropriate use of insulin treatment, but it can be prevented by intensive glucose monitoring. As is well known, hypoglycemia is as harmful as hyperglycemia during hospitalization. It is associated with poor outcomes, de-intensification of insulin treatment, and prolonged length of stay in the hospital [9].

In non-ICUs, the prevalence of hypoglycemia ranges from 12 to 38% in insulin-treated patients [34].

Elderly hospitalized patients are particularly vulnerable to the adverse effects of hypoglycemia [35] which is associated with a 2-fold increase in mortality during hospitalization and 3-month follow-up [36]. Thus, glycemic targets and therapeutic choices should be modified, simplified, and switched to a more moderate therapeutic regimen, depending on their level of frailty as well as HbA1c levels [37]. Frailty can be defined as a combination of physiological impairments due to decreased functional reserve in multiple systems and organs as part of the aging process, thus producing increased vulnerability that can in turn, affect responses to any stressful event such as hospitalization [38,39]. In particular, disability, frailty, and type 2 diabetes were the most frequent reason for hospital admission [40,41].

## 3. Glucose monitoring in the hospital

Point-of-care blood glucose testing (POC-BG) is the mainstay for monitoring glycemic control in the hospital and adjusting insulin therapy. As recommended by national guidelines, bedside POC should be performed before meals and at bedtime, matching meal intake and insulin administration, or every 4–6 h for patients not eating or on continuous enteral/parenteral feeding [4,42].

However, this approach fails to provide a complete assessment of the 24-h glycemic profile and in particular, to correctly detect hypoglycemia, especially nocturnal or asymptomatic episodes [4,43].

The use of CGM in non-ICU provides better glucose control than 3–4 POC-BG testing with improved detection of hypo- and hyperglycemia and increased chance of intensifying insulin treatment. CGM, as known, automatically measures glucose in the interstitial fluid (ISF) every

**Table 1** Barriers to glycemic control in hospitalized patients with diabetes.

| | |
|---|---|
| Inappropriate insulin treatment [18–20] | Sliding scale.<br>Non-use of insulin titration scheme. |
| **Hypoglycemia** [21,22] | Inappropriate insulin dosage.<br>Sliding scale.<br>Nausea and vomiting.<br>Frailty.<br>Older age.<br>Renal failure. |
| **Blood glucose control** [12,23] | Inadequate number of daily glucose tests. |
| **Diet** [24,25] | Changes in nutrition: variable meal times, different diet than at home.<br>“Nothing by mouth” orders before procedures.<br>Use of enteral or parenteral nutritional support. |
| **Medications** [26–29] | Different medication regimens.<br>Potential drug-drug interactions.<br>Change of previous dosages.<br>Use of medications associated with increased insulin resistance such as glucocorticoids. |
| **Physician and organizational factors** [24,30] | Lack of communication and/or knowledge about diabetes management among providers and caregivers.<br>Unavailability of a consultant for diabetes.<br>Different degrees of knowledge of evidence-based management of hyper- and hypoglycemia.<br>Impaired medication timing due to hospital logistics.<br>Lack of discharge planning to modify or implement the diabetes treatment plan after hospitalization. |
| **Physiologic factors** [24,31–33] | Physiological stress responses to illness.<br>Comorbidities. |

1–5 min (depending on the device), increasing the number of glucose measurements and also providing trend information on the direction and rate of change in glucose concentrations. Moreover, some newer CGM devices that no longer require calibration with POC glucose testing (factory-calibrated) have the potential to reduce the nursing workload associated with frequent POC glucose testing in the hospital [44]. CGM provides significantly more data to evaluate and also provides the direction of glucose change, the magnitude of the change, and predictive and actual alerts of hypoglycemia and hyperglycemia.

As recently suggested by national guidelines, in patients with diabetes/hyperglycemia hospitalized in a non-critical care setting, both classic capillary glycemic monitoring and, where possible, CGM systems can be used [45].

Two types of CGM systems are currently available and eligible for the use in the hospital: the real-time CGM (rt-CGM) and the Flash Glucose Monitoring (FGM) or intermittently scanned CGM (isCGM). All CGM consists of three elements: the sensor, the transmitter, and the receiver, which is an additional device or a mobile medical App that can be downloaded on a smart-phone.

A summary of benefits and limitations of CGM in the non-ICU setting compared with the standard POC glucose testing is reported in Table 2.

CGM sensors have an accuracy, as assessed by the Mean Absolute Relative Difference (MARD), close to that of most traditional glucose meters. However, it should be emphasized that several factors occurring during hospitalization may affect the accuracy of the glucose sensor [46]. Recent studies have reported a MARD of CGM in the hospital setting between 10% and 14%, with the lower percentage in the hypoglycemic range [47]. A large multicenter pooled accuracy analysis of CGM data from 218 hospitalized general medicine and surgery patients with diabetes revealed a median Absolute Relative Difference (ARD) of 10.1%. A trend toward lower accuracy was observed in the first 12 and 24 h of sensor use, during hypoglycemia (<70 mg/dL) and severe anemia (hemoglobin <7 g/dL) [48]. The percentage of glucose concentration within the ±15% or ±15 mg/dL, ±20% or ±20 mg/dL, and ±30% or ±30 mg/dL was 62%, 76%, and 91%, respectively. The Clarke-Parkes error grid has showed a clinical accuracy with 98% of glucose concentration falling in the Zones A + B [47].

## 4. Continuous glucose monitoring studies in non-icu setting

Although consistent data support the outpatient use of CGM to improve glycemic control and reduce hypoglycemic burden, and clinical outcomes, there are limited data regarding its use in the inpatient setting. The utility of these devices in the hospital setting, particularly in the non-ICU setting, is less understood, given the paucity of safety and efficacy evidence currently available [49].

Most of the studies conducted in non-ICU settings have evaluated the accuracy, efficacy, and safety of CGM devices compared with the POC-BG test. A summary of the studies characteristics and results have been listed in Table 3.

In conclusion, current research data suggest that CGM technology is a reliable tool for hospital use and can help improve glucose monitoring in non-critically ill hospitalized patients with diabetes. However, additional, larger randomized studies in more diverse populations are needed to establish efficacy and safety for stand-alone use.

**Table 2** Summary of potential benefits and limitations of CGM in Non-ICU hospital settings.

| Benefits | Limitations |
|---|---|
| Increased frequency of glucose monitoring: glucose levels can be monitored at any time without disturbing the patient | Lack of approval for inpatient use by regulatory agencies |
| Frequency of finger prick checks may be reduced | Some finger prick checks remain necessary as CGM systems measure interstitial fluid |
| Improved glycemic control, providing data on glucose variability, magnitude of glucose change, and real-time direction of glucose change | General hospital staff unfamiliarity with CGM leading to misinterpretation of data |
| Less pain and patient discomfort | Significant costs may be incurred for the sensors, for hospital staff/patient training, and for development of infrastructure to support inpatient use |
| Greater rate of detection of hypoglycemia and hyperglycemia | Sensor drift and need for blood glucose calibration requirement depending on CGM system |
| Prediction of hypoglycemia and hyperglycemia | Sensor time-lag |
| Ease of application and use of CGM make it user-friendly and low-risk | Potential interference with glucose accuracy from medications and substances (acetaminophen, heparin, salicylic acid, dopamine, uric acid, ascorbic acid, maltose, and mannitol, hydroxyurea, tetracycline) |
| Reduces nursing exposure to highly contagious infectious diseases (e.g., COVID-19) | |
| Decrease the amount of time required for obtaining blood glucose measurements and the amount of personal protective equipment necessary for interacting with patients during the blood glucose testing | |

**Table 3** Clinical trials of CGM use in Non-ICU settings for adult patients.

| Reference | Patient Population | CGM/FGM | Study Design | Outcomes | Results |
|---|---|---|---|---|---|
| Burt et al. 2013 [50] | Type 1 and Type 2 diabetes admitted to general wards on basal bolus insulin (n = 26) | CGM System Gold Medtronic | Observational Prospective Cohort: blinded CGM *vs* POC glucose testing | Accuracy and glycemic control | No significant difference in glycemic control<br>CGM detected more post-prandial hyperglycemic episodes than POC (88 *vs* 61)<br>CGM detected more hypoglycemic episodes (including nocturnal) than POC (10 *vs* 1) |
| Gomez et al. 2015 [51] | Type 2 diabetes or hyperglycemia admitted to general ward on basal-bolus insulin (n = 38) | CGM iPro2 system Medtronic | Prospective Pilot study: blinded CGM *vs* POC glucose testing | Accuracy, glycemic control, and hypoglycemia detection | Good agreement between CGM and POC measurements<br>Clarke Error Grid analysis with 91.9% of values in Zone A or Zone B.<br>CGM detected a higher number of hypoglycemic episodes than POC (55 *vs* 12, $P < 0.01$) |
| Schaupp et al. 2015 [52] | Type 2 diabetes admitted to general wards on basal-bolus insulin (n = 84) | CGM iPro2 system | Observational Prospective Cohort: blinded CGM *vs* POC glucose testing | Accuracy and glycemic control | Good agreement between CGM and POC measurements<br>Clarke Error Grid analysis with 98.7% of values in Zone A or Zone B<br>A 15- and 12.5-fold increase in the detection of nocturnal hypoglycemia and nocturnal hyperglycemia with CGM, respectively. |
| Galindo et al. 2020 [47] | Type 2 diabetes admitted to general medicine and surgery wards on basal-bolus insulin (n = 97) | FGM FreeStyle Libre Pro | Prospective Cohort: blinded FGM vs POC glucose testing | Accuracy and hypoglycemia detection | The FGM group demonstrated lower mean glucose, −12.8 mg/dL ($P < 0.001$), a lower percentage of time in hyperglycemia >180 mg/dL, −8.1 mg/dL ($P < 0.001$) and higher TIR 70−180 mg/dL, +5.1% ($P = 0.001$) compared with POC.<br>FGM detected a higher number of hypoglycemic events particularly nocturnal and prolonged hypoglycemia than POC.<br>FGM had an overall MARD of 14.8%. |
| Davis et al. 2021 [48] | Type 1 and Type 2 diabetes admitted to general medicine and surgery wards treated with basal and/or rapid-acting insulin (n = 218) | CGM Dexcom G6 | Pooled analysis of clinical studies (two interventional and one observational) | Accuracy | CGM had an overall MARD of 12.8% and median ARD of 10.1%. |

(*continued on next page*)

**Table 3** (*continued*)

| Reference | Patient Population | CGM/FGM | Study Design | Outcomes | Results |
|---|---|---|---|---|---|
| Spanakis et al. 2018 [53] | Type 2 diabetes admitted to general wards on basal-bolus insulin (n = 5) | CGM Dexcom G4 with Share2 application | Single-arm pilot study: unblinded CGM using GTS | Feasibility of GTS | Prevention of potential hypoglycemia (<85 mg/dL) captured by alarm occurred in 2 patients (3 events). |
| Singh et al. 2020 [54] | Type 2 diabetes admitted to general wards on basal-bolus insulin (n = 72) | CGM Dexcom G6 | Prospective, Randomized controlled trial | Effectiveness RT-CGM/GTS for prevention of hypoglycemia | The RT-CGM/GTS group experienced fewer hypoglycemic events (<70 mg/dL) per patient compared with the POC group (0.67 *vs* 1.69, P = 0.024). |
| Fortmann et al. 2020 [55] | Type 2 diabetes admitted to a non-ICU on subcutaneous insulin (n = 110) | CGM Dexcom G6 | Randomized controlled trial | Effectiveness RT-CGM for management of acute hyper-/hypoglycemia | The RT-CGM group demonstrated significantly lower mean glucose (−18.5 mg/dL), a lower percentage of time in hyperglycemia >250 mg/dL (−11.41%) and higher TIR 70 −250 mg/dL (+11.26%) compared with POC (P < 0.05) |
| Spanakis et al. 2022 [56] | Type 1 and Type 2 diabetes admitted to general medicine and surgery wards on basal-bolus insulin (n = 185) | CGM Dexcom G6 | Randomized controlled trial | Effectiveness of RT-CGM in adjusting inpatient insulin therapy | No significant difference in glycemic control between the CGM-guided and POC groups. Compared with POC, the CGM group experienced a significant reduction in hypoglycemia reoccurrence (1.80 ± 1.54 *vs* 2.94 ± 2.76 events/patient; P = 0.03). |
| Dillmann et al. 2022 [57] | Type 1 and Type 2 diabetes admitted to general medicine (n = 53) | CGM Guardian Connect | Observational Prospective Pilot study | Feasibility of GTS | TIR significantly increased between the start of the hospitalization and end of hospitalization, from 75.7% to 82.2% (P = 0.043) |
| Wright et al. 2022 [58] | Type 1 and Type 2 diabetes admitted to general medicine (n = 77) | FGM FreeStyle Libre 1 and 2 | Prospective study: FGM *vs* POC glucose testing | Accuracy | Overall Libre 1 MARD, 21.4% Overall Libre 2 MARD, 17.7% Libre 2 accuracy relative to POC improved compared with Libre 1 (P < 0.0001) |
| Singh et al. 2020 [59] | Type 2 diabetes admitted to general medicine on basal-bolus insulin (n = 77) | CGM Dexcom G4 Platinum | Prospective, randomized pilot study: POC glucose testing alone *vs* CGM using GTS in addition to POC | Prevention of hypoglycemia | No difference in glycemia |

Abbreviations: CGM, continuous glucose monitoring; FGM, Flash Glucose Monitoring; TIR, time in range; POC, point-of-care; MARD, mean absolute relative difference; GTS, glucose telemetry system.

### *4.1. Recommendations for the use of continuous glucose monitoring in the hospital*

The growing interest in the use of CGM systems has led to the need for guidance on the continuation of these technologies in the hospital setting.

In 2016 the Diabetes Technology Society convened a panel of experts in endocrinology to discuss the current and potential future uses of CGM in the inpatient setting [44]. Panel members agreed that, compared with POC BG testing, CGM technology offers advantages in the prevention of severe hyperglycemia and hypoglycemia by identifying glucose trends and allowing insulin doses to be adjusted more accurately than would be possible with blood glucose testing. However, the expansion of CGM into the hospitals has been limited by several factors, including the paucity of randomized clinical trials comparing CGM with POC in hospital settings that could provide guidance on the implementation of CGM in this setting [44].

In 2020, the Diabetes Technology Society organized a consensus guideline panel of 24 international experts to provide recommendations on the use of CGM in the hospital setting [60]. The guideline strongly recommended that clinicians consider initiating CGM in the hospital to reduce the need for frequent nurse contact for POC glucose testing and the use of personal protective equipment (PPE) for patients on isolation with highly contagious infectious diseases, such as COVID-19. It has also been suggested to avoid initiating CGMs in patients with severe hypoglycemia or hyperglycemia (e.g., BG $\geq$ 500 mg/dL) or during periods of rapid glucose fluctuations. The panel also recommended that healthcare providers (HCPs) should avoid using CGM for the management of patients with diabetic ketoacidosis, patients with skin infections or edema near the sensor site, and those treated with vasoactive agents or poor tissue perfusion [60].

The American Association of Clinical Endocrinology (AACE) recommended the continuation of personal CGM device in cognitively intact hospitalized patients and, ideally, with the presence of an experienced and educated family member in the use of these devices or with a specialized inpatient diabetes team available for advice and support [61].

The Endocrine Society in collaboration with other societies published an updated guideline that considers glycemic management using continuous glucose monitoring devices in combination with POC-BG measurement for non-critically ill hospitalized patients with diabetes [62]. Specifically, they recommended the use of CGM in adults with insulin-treated diabetes hospitalized for non-critical illness and at high risk of developing hypoglycemia, in addition to confirmatory bedside POC-BG monitoring for insulin dosage adjustment, rather than bedside capillary blood glucose testing alone in hospital settings where resources and training are available. Therefore, CGM systems can guide effective glycemic management that reduces the risk of hypoglycemia in hospitalized patients. This recommendation does not apply to situations in which CGM may not be accurate, including patients with extensive skin infections, hypoperfusion or hypovolemia, or those undergoing vasoactive drugs [62].

The American Diabetes Association (ADA) in 2022 produced an updated set of recommendations covering several aspects of inpatient diabetes care as part of their annual "standards of medical care in diabetes" [63]. The ADA recommended that patients using diabetes devices can continue to use them in the hospital with proper supervision but caution that CGM has not been approved by the FDA for inpatient use. The latest version of these guidelines recommends the use of CGM in the hospitals with an established glucose management team and in selected inpatients educated in the use of CGM technology, mostly in the non-critical care setting [9].

In early April 2020, the Food and Drug Administration (FDA) issued guidance to expand the indications of CGM devices in inpatient hospital settings during the COVID-19 pandemic [63]. This change was made to preserve the use of PPE and reduce repeated exposure of HCPs to the new coronavirus in the inpatient hospital setting [64].

The FDA informed Abbott Diabetes Care [65] and Dexcom [66] that it would issue temporary allowances known as "enforcement discretion", and it would not object if these companies provided devices and technical support to hospitals using CGMs for off-label use during the pandemic. FDA clearance has enabled many hospitals to use CGM to minimize contact between HCPs and patients by remotely monitoring glucose concentrations in COVID-19 diabetic patients and reducing the use of PPE. In addition, expanding the use of CGM to the inpatient setting provides insight into the benefits and limitations of this technology in real-world practice [67–70]. To date, most published studies (observational studies or case reports) have focused on the feasibility and accuracy of CGM in COVID-19 patients to improve glycemic outcomes and reduce the burden for HCPs [71–78].

## 5. CGM hospital protocol: the Patient's CGM journey

We propose a practical model of how CGM can be implemented in the hospital setting: a patient's CGM journey from admission to the ward to the application of the sensor, from patient education on the device during hospitalization until discharge of the patient to maintain remote control. This practical approach for the implementation and management of CGM in patients with diabetes admitted to non-ICUs could guide hospitals in their diabetes management initiatives using CGM, helping to identify patients most likely to benefit and suggesting how this technology can be implemented to maximize clinical benefits.

First, it is necessary to define and train a CGM management team within the hospital that is prepared to select, educate, and appropriately manage patients from admission to discharge and to support during hospitalization those already wearing a CGM sensor.

The team consists of the CGM manager, who is the diabetologist who takes care of diabetes in the hospital, the head nurse, designated nurse(s), and eventually, the

specialist of the wards eligible using the CGM. The manager organizes a disciplinary meeting to instruct the team about the management of the CGM system, the use of POC-BG, and the identification of patients who can wear the sensor during hospitalization. It is advisable to involve hospital pharmacy staff who deal with the sensor supply.

The CGM management team should hold periodic briefings to review the effectiveness of the CGM system, its safety, and feasibility, highlighting any barriers that might limit its use and assessing its benefits during hospitalization.

Four steps have been identified for effective implementation of CGM in a non-ICU setting (Fig. 1).

### *5.1. 1st step: patient selection and sensor insertion*

We list below the salient information to be shared with the CGM team.

- ***Patient selection*:** All patients with the following characteristics should be eligible for CGM use:
  - insulin-treated (basal insulin or basal-bolus insulin) patients
  - patients with moderate (≥180 mg/dL) or severe hyperglycemia (≥200 < 500 mg/dL) requiring insulin treatment
  - patients requiring corticosteroid treatment
  - elderly and frail patients
  - patients with COVID-19
  - patients with significant glucotoxicity (persistent severe hyperglycemia) related to current infection
  - patients with foot ulcer
  - patients requiring parenteral or enteral nutrition
  - patients with a high risk of hypoglycemia (i.e., poor nutrition, renal failure, older age, nausea, vomiting, history of severe hypoglycemia, or frequent level 2 hypoglycemia)
  - patients undergoing minor or major surgery
  - patients in pre-hospitalization (i.e., before surgery)
  - patients in post-hospitalization (i.e., wound care, medication administration, physical therapy)
  - patients already using CGM in the outpatient setting
- ***Sensor insertion*:** The sensor is inserted upon admission to the ward by the designated nurse or other specialist involved in the care of the eligible patient. The preferred site for insertion during hospitalization is the upper arm. However, there are other sensors that have an indication for the abdomen as an insertion site, although it may be more inconvenient if the patient has to undergo instrumental examinations such as an ultrasound or gastroscopy.
- ***Transmitter characteristics*:** The transmitter wirelessly sends glucose data from the sensor to a reader. For some CGM systems, the transmitter is part of the disposable sensor (all-in-one system), while for others, the transmitter is reusable and attaches to each new sensor from the same patient. Some transmitters are rechargeable, while others do not require charging but need to be replaced every 3 months. The all-in-one disposable system lasts for two weeks and can be more manageable during hospitalization compared to the separate rechargeable transmitter or the 3-month transmitter for personal use.
- ***Receiver/Reader characteristics*:** Both rtCGM and FGM sensors continuously collect real-time glucose readings. However, while the FGM system provides an immediate reading whenever the user actively scans the sensor with the device reader or via an app on the smart-phone, the rtCGM system continuously transmits the data to the reader or a smart-phone. The App on the smart-phone sends glucose data wirelessly to the cloud, allowing to view the results on a computer through a secure website. The reader can be connected to a computer, and the data downloaded into dedicated

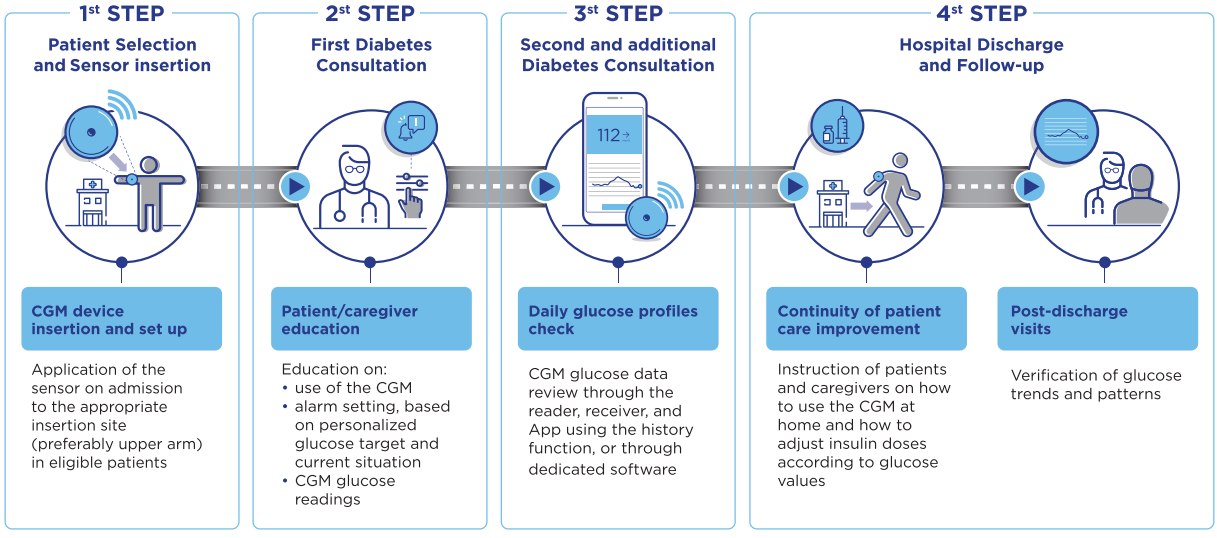


**Figure 1** Implementation and management of CGM (FGM/rtCGM) in patients with diabetes in non-ICU departments: the journey from sensor insertion on admission, through patient education about the device during admission to patient discharge to maintaining remote control, operated by the CGM management team.

software. All data can also be reviewed on the reader or on the smart-phone app. Finally, glucose data can be reviewed on the Electronic Medical Record (ECR). More generally, a less expensive and easy to use system can be preferred.

- ***POC-BG*:** The number of daily capillary glucose testing with the traditional meter can be limited while using CGM. Since the CGM MARD largely varies during hospitalization, a twice-daily POC-BG check is advisable, regardless of the need for calibration. The glucose sensor values can be used during hospitalization without BG confirmation (use non-adjunctive) when for BG value $<$ 100 mg/dL, the difference is less than 20 mg/dL, and for BG value $>$ 100 mg/dL, the difference is less than 20%. POC-BG should also be performed if a low value occurs without symptoms. Nurses should be aware that a time lag between the sensor and BG measurement exists.

### *5.2. 2nd step: first diabetes consultation*

At the time of the first consultation, the CGM manager/diabetologist, together with the designated nurse, will educate the patient in the CGM use, if collaborative, or reinforce general suggestions to the nurse, if required. Then the CGM manager/diabetologist will set up the alarms and establish the number of instantaneous CGM glucose readings and treatment.

- ***Alarm setting*:** The alarm will be activated according to the individualized glucose target and current situation. For example, in patients who require strict glycemic control (i.e., post-surgery) the alarm will be set at 180–200 mg/dL. In general, the high alarm will be activated at the threshold requiring an intervention (correction boluses). The high alarm should also not be activated in those situations where frequent glucose monitoring is suggested. (i.e., enteral or parenteral nutrition, corticosteroid therapy). The low alarm will always be activated, preferably at 75–80 mg/dL or at a higher threshold (85–90 mg/dL) in elderly and frail patients or when using CGM without a predictive alarm. Repeated alarms or delayed alarms can also be set if available. They allow to confirm the persistence of hypo- or hyper-glycemia and draw the attention of the ward staff or the patient.
- ***CGM glucose readings*:** Glucose values are detected in the following situations.
  - before breakfast, lunch, and dinner to titrate insulin according to the diabetologist prescription
  - at bedtime for safety reasons (suggested glucose value $\geq$ 130–140 mg/dL)
  - every 15 min after the administration of carbohydrates to treat hypoglycemia until the resolution of the event
  - every 2 h in case of skipped or delayed meal
  - every 3–4 h during enteral and parenteral nutrition
  - every 3–4 h during intravenous corticosteroid infusion
  - after oral corticosteroids according to the half-life of the drug administered
  - when sudden symptom or sign occurs during hospitalization

### *5.3. 3rd step: second and additional diabetes consultations*

The CGM manager/diabetologist reviews the glucose data and adjusts the treatment accordingly.

- ***CGM glucose data review*:** The data can be reviewed through the reader, receiver, and App using the history function or through dedicated software. Ongoing treatment is modified according to the daily profiles that help to evaluate glucose values and trends. Unlike the outpatient setting, the evaluation of CGM data during hospitalization does not include the analysis of new glucose metrics such as time in range, time below range, and time above range, which can instead be useful during a remote visit in case of pre- or post-hospitalization. Indeed, the new metrics, as known, should have to be evaluated in a 2-week time interval, which is not applicable during hospitalization, when decisions should have to be taken in a shorter time frame.

  It is desirable, however, that nurses and other specialists check the daily glucose profiles to detected asymptomatic hypoglycemic events.

  Finally, in the case of pre- and post-hospitalization, the evaluation of the time in range during the remote visit is helpful for assessing overall glycemic control and could be used as a prognostic factor for clinical outcomes. Indeed, some works have recently demonstrated that a time in range $>$70% is associated with better outcomes after cardiac surgery, toe amputation, and wound healing of diabetic foot ulcer [79–81].

### *5.4. 4th step: hospital discharge and follow-up*

Insulin-treated patients and those who require insulin treatment during hospitalization can continue to use the sensor at home until acceptable glucose values are achieved or, if reached during hospitalization, remain stable. The indication for prolonged use of the sensor is eventually suggested by the diabetologist who assist the patients after discharge.

At the time of discharge, patients and caregivers will be (re)instructed on how to use the CGM at home and informed on how to adjust insulin doses according to glucose values. In this regard, as recently suggested by national guidelines, in patients with diabetes/hyperglycemia admitted to a non-critical care setting, a structured discharge plan is recommended versus a discharge mode without a structured plan [45]. It is advisable to schedule a follow-up visit after two weeks in order to verify the glucose metrics as well as the hypoglycemic events that can occur as a consequence of the rapid change in lifestyle habits after discharge. The follow-up visit can also be planned in remotely if data sharing has been activated.

## 6. Conclusion

The use of CGM in adult inpatients confers numerous benefits with minimal risks. With the COVID-19 pandemic, the importance of remote glucose monitoring is highlighted more than ever.

The CGM technology has been shown to be useful in the early diagnosis and prevention of hypoglycemia, as well as a tool to decrease hyperglycemia. In fact, it provides glycemic trends that can be used to enable more proactive and timely decisions in diabetes management to reduce clinically significant events such as hypoglycemia or hyperglycemia. CGM devices also decrease the need for healthcare providers to enter the patients' rooms and reduce frequent POC-BG checks, which can be uncomfortable and painful for patients and increase the workload of nurses. Furthermore, CGM use has led to a reduction in personal protective equipment use and significantly mitigates the risk of exposure for healthcare staff.

We believe that the emerging use of CGM in the non-critical care setting may be useful in increasing the efficiency of hospital care and reducing the length of stay for patients with diabetes while improving glycemic control. This has become particularly pertinent in light of the fact that diabetes increases the risk of hospitalization and death. A structured CGM hospital protocol, as that we propose, and metaphorically defined as the patient's journey, can favor the implementation of the CGM in the hospital, help to identify the advantages of the systems and patients who may have benefit from its use and reduce the time for data interpretation.

However, further research is needed to quantify the changes to nursing workflow, the burden of implementation, and the associated economic implications.

## Ethical statement

No human or animal studies involved or no ethical statement for the study.

## Author contributions

CI contributed to the conception and design of the manuscript, which was discussed and approved at the expert meeting by all the other authors. ES provided a special contribution on the paragraph "diabetes in the hospital". CS provided a special contribution on the paragraph "glucose monitoring in the hospital". EF provided a special contribution on the state of the art of continuous glucose monitoring in non-ICU setting. CI wrote the paragraph "CGM hospital protocol: the patient's CGM journey". All authors contributed to the revision of the manuscript, and have read and approved the submitted version.

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## Declaration of competing interest

CI provided advisory board services for Novo Nordisk, Lilly, Abbott, Menarini, Ascensia, and Senseonics, and received speaker fees for Novo Nordisk, Abbott, Ascensia, Lilly, and Boehringer Ingelheim Pharmaceuticals. SC provided advisory board services for Abbott and Novo Nordisk. GDC, EF, FL and MMR provided advisory board services for Abbott. GS received speaker's fee from Novo Nordisk, Servier, Sanofi, Daiichi Sankyo, Teva, Janssen and Eli Lilly, and provided advisory board services for Abbott. ES received speaker's fees from Novo Nordisk and Eli Lilly and provided advisory board services for Abbott. AC received grants from Astra Zeneca, Lilly, Novo-Nordisk. He also received speaker fees, and provided advisory board services for Abbott, AstraZeneca, Boehringer Ingelheim Pharmaceuticals, Lilly, Merck Sharp & Dhome, Menarini, Novo-Nordisk, Sanofi, Sigma-Tau, Takeda. No other potential conflicts of interest relevant to this article were reported. The sponsor had no role in the design, execution, interpretation, or writing of this review.

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