Current Diabetes Reports (2024) 24:173–182
https://doi.org/10.1007/s11892-024-01545-3

REVIEW

Review Article – Diabetes Technology in the Hospital: An Update

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Accepted: 29 May 2024 / Published online: 6 June 2024

Abstract

Purpose of Review There have been many developments in diabetes technology in recent years, with continuous glucose monitoring (CGM), insulin pump therapy (CSII) and automated insulin delivery (AID) becoming progressively accepted in *outpatient* diabetes care. However, the use of such advanced diabetes technology in the *inpatient* setting is still limited for several reasons, including logistical challenges and staff training needs. On the other hand, hospital settings with altered diet and stress-induced hyperglycemia often pose challenges to tight glycemic control using conventional treatment tools. Integrating smarter glucose monitoring and insulin delivery devices into the increasingly technical hospital environment could reduce diabetes-related morbidity and mortality. This narrative review describes the most recent literature on the use of diabetes technology in the hospital and suggests avenues for further research.

Recent Findings Advanced diabetes technology has the potential to improve glycemic control in hospitalized people with and without diabetes, and could add particular value in certain conditions, such as nutrition therapy or perioperative management. Taken together, CGM allows for more accurate and patient-friendly follow-up and ad hoc titration of therapy. AID may also provide benefits, including improved glycemic control and reduced nursing workload.

Summary Before advanced diabetes technology can be used on a large scale in the hospital, further research is needed on efficacy, accuracy and safety, while implementation factors such as cost and staff training must also be overcome.

Keywords Diabetes Technology · Continuous Glucose Monitoring · Insulin Pump Therapy · Automated Insulin Delivery · In Hospital Setting

Introduction

Tight glycemic control is of paramount importance to prevent acute and chronic complications in both type 1 diabetes (T1D) [1] and type 2 diabetes (T2D) [2]. People with diabetes are at higher risk for hospitalization and complications due to hyper- or hypoglycemia, or metabolic comorbidities. Moreover, diabetes- or stress-induced hyperglycemia and hypoglycemia during critical illness are common in hospitalized patients and are associated with significant increases in morbidity, mortality, and healthcare costs [3–10]. Tight glycemic control, avoiding hyper- and hypoglycemia improves outcomes [11–15], but requires frequent monitoring and timely, appropriate treatment of glycemia.

In the past decade, several new classes of antidiabetic drugs have revolutionized the cardiometabolic field, and the use of technology to support diabetes management has increased significantly. The advent of continuous glucose monitoring (CGM), continuous subcutaneous insulin infusion (CSII or insulin pump therapy), and – more recently – automated insulin delivery (AID) has substantially improved care and quality of life for the majority of people with T1D [16], and is making its appearance in T2D [17]. Given the rapid evolution of diabetes technology in the *outpatient* setting, efforts are being made to determine the feasibility of transferring these technologies to the *inpatient* setting in diverse populations.

Previously in this journal, Yeh et al. provided an overview of managing hospitalized patients on CGM and insulin

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pump therapy [18•]. More recently, international experts in technology and hospital diabetes management discussed the progress of hospital use of CGM (including AID), and summarized not only the potential benefits but also the unmet needs in the use of diabetes technology in the hospital [19•]. The current narrative review aims to give an update on the most recent literature and guidelines on the use of advanced diabetes technology in the hospital with a special focus on the potential of CGM and AID, and suggests avenues for further research.

Continuous Glucose Monitoring

Commercially available CGM devices monitor glucose levels by measuring the glucose concentration in the interstitial fluid every 1–5 min. Most sensors use an enzyme-based electrochemical approach, where the sensor electrode is coated with glucose oxidase [20]. When this enzyme comes into contact with glucose, a redox reaction occurs producing hydrogen peroxide, which in turn generates an electrical current proportional to the glucose concentration. In general, two types of CGM devices are distinguished: intermittently scanned CGM (isCGM), which allows glucose levels to be checked on demand by actively scanning the sensor transmitter with a receiver or smartphone; and real-time CGM (rtCGM), which has a transmitter that automatically sends a new glucose reading every 1–5 min to a receiver, smartphone, or smartwatch. CGM is rapidly becoming standard of care in people with T1D and all others treated with insulin.

Benefits of CGM in the Hospital

Compared to point-of-care glucose testing (POCT), which has been the standard for measuring glucose in the hospital setting, CGM offers potential benefits in the hospital setting (Table 1). First, CGM provides 24-h glucose insight, unlike bedside point-of-care glucose testing (POCT), which is often performed at a minimum of 3 to 4 times daily. Glucose can be easily determined directly by CGM without disturbing or waking the patient. Broad use of CGM in the ambulatory setting and clinical trials has revealed that glucose variability between 2 capillary finger-stick tests performed at different time points can be large, and increasing attention is being paid to 'time in range' (percent of time spent between a glucose of 70–180 mg/dL) as a measure of glycemic control [21, 22].

Second, CGM displays not only current glucose levels, but also a graph of past glucose values and trend arrows. These trend arrows are based on glucose variations over the past 15 min and provide an estimate of the rate at which glucose levels will increase or decrease over the next 30–60 min [23].

Third, next-generation CGM devices offer the option of alarm for high or low glucose levels. This is a highly relevant feature of second-generation isCGM [24] and rtCGM [24–27] which is expected to directly improve

Table 1 Diabetes technology in the hospital: (potential) benefits, challenges and guidelines

(Potential) benefits	Challenges	Guidelines
Continuous glucose monitoring (CGM)		
• improved glycemic control by - 24 h insight in glucose levels - trends - alert functionality • patient-friendly/empowerment • reduced nursing workload • shorter length of stay and fewer readmissions	• accuracy (lag time); POCT still needed • trained staff and diabetes team required in case of inexperience with technology • CGM data integration in electronic health record • costs (for material and training of staff)	• no official FDA clearance for in hospital use; home CGM may be continued on admission unless certain criteria are met
Continuous subcutaneous insulin infusion (CSII)		
• improved glycemic control by flexible insulin administration • reduced nursing workload • shorter length of stay and fewer readmissions	• frequent monitoring of pump functioning (material and settings) • trained staff and diabetes team required in case of inexperience with technology • costs (for material and training of staff)	• home CSII may be used unless certain criteria are met
Automated insulin delivery (AID)		
• improved glycemic control by automated insulin increase and/or decrease • reduced nursing workload • shorter length of stay and fewer readmissions	• depends on CGM for adequate functioning • frequent monitoring of pump functioning • algorithm requires extra caution • trained staff and diabetes team required in case of inexperience with technology • costs (for material and training of staff)	• home AID may be used unless certain criteria are met • consider use of CGM only/CSII only in case of safety issues

FDA = American Food and Drug Administration. POCT = point-of-care glucose testing

patient safety, as both hypoglycemia and prolonged episodes of hyperglycemia are more likely to go undetected in patients unaware or unable to complain during illness and/or altered food intake. A randomized controlled trial (RCT) by Singh et al. showed that rtCGM can decrease inpatient hypoglycemia among people with T2D at high risk of hypoglycemia [28]. An observational study also demonstrated the potential of CGM in preventing potential hypoglycemia in T2D [29].

Taken together, CGM allows for more accurate and patient-friendly follow-up and ad hoc titration of therapy. Two small RCTs in hospitalized people with T2D showed that CGM can be successfully used to improve glycemic control in the non-intensive care unit (ICU)) setting [28, 30]; mean glucose was lower with the use of CGM compared to POCT [30], with higher time in range [30] and lower time in hypoglycemia [28, 30]. Similar results were observed in two other small prospective studies comparing (is)CGM with POCT in people with T2D on intensive insulin therapy and admitted to general medical and/or surgical ward [31, 32].

The ICU brings specific circumstances, with periods of fasting, (par-)enteral nutrition and interventions. Only a few RCTs assessed the efficacy of CGM in people with diabetes in the ICU setting, which showed no significant differences in glycemic control between CGM and POCT in general [33]. However, it should be noted that most studies were small and underpowered to detect changes in patient-centered outcomes such as the incidence of hypoglycemia or complications. Only one study (n = 124) observed a significant reduction in the rate of severe hypoglycemia (glucose < 40 mg/dL) with rtCGM compared to POCT in patients with and without diabetes receiving mechanical ventilation [34]. A subgroup analysis of this study showed improved glycemic control in patients with higher illness severity indices [34]. Despite these findings, there were no differences in hospital length of stay or mortality between rtCGM and POCT.

In addition to detecting glycemic fluctuations, CGM devices have a sharing option that allows caregivers to remotely monitor glucose levels in real time (only with user consent), which can make diabetes management more efficient. During the COVID-19 pandemic, CGM demonstrated the potential to avoid bedside POCT and reduce the burden of diabetes care on healthcare providers, while reducing the risk of viral exposure [35]. Several (case) reports described the use of CGM in remote diabetes care in ICU [36–38] and non-ICU patients [39–41]. In the ICU, there was a meaningful reduction of POCT frequency [36–38], although confirmatory POCT was still necessary. In addition to a decrease in POCT frequency, nurses reported that CGM was helpful for improving care and led to a reduction in the use of personal protective equipment [38]. Similar outcomes were reported for non-ICU patients [39–41].

Challenges of CGM in the Hospital

Despite the potential advantages of CGM over POCT as described above, the use of CGM in the hospital is still limited, as one of the major concerns is the accuracy of CGM in (critically) ill people (Table 1). Most CGM devices are originally designed for home use and may not be optimized for the inpatient setting. As these devices measure glucose in the interstitial fluid, acute physiological disturbances (i.e., hypoxemia, vasoconstriction, severe dehydration, edema and rapid changes in glucose concentrations [42]) may cause a 10–15 min lag time in measurements. Also, chemical interferences in certain drugs (e.g., acetaminophen [paracetamol], salicylic acid [aspirin], and ascorbic acid [vitamin C]) can affect CGM accuracy as these substances oxidize hydrogen peroxide non-specifically, which can cause electrochemical sensors to give erroneous glucose readings [43, 44]. To overcome this interference, sensors of newer CGM devices are coated with a selective membrane [45]. Furthermore, most CGM devices are not compatible with certain medical procedures such as radiation (including X-rays and CT-scans) and magnetic resonance imaging (MRI). Because these procedures may also compromise sensor accuracy, CGM must be removed prior to these events. Standard operating procedures are needed for such conditions [19•].

Several studies have evaluated the use of CGM in the ICU for accuracy and reliability in patients with and without diabetes [33, 46]. Of these studies, some included older CGM technology or intravascular sensors; to date, two CGM devices (GlucoScout and OptiScanner 5000) have been cleared by the Food and Drug Administration (FDA) for frequent, intermittent venous blood sampling from a central or peripheral venous catheter for use in the hospital setting. However, intravenous sensors are invasive and can lead to complications such as thrombosis and infection [47], which is why these sensors are more cumbersome than subcutaneous sensors and are therefore limited to the critical care setting. Although final validation of CGM accuracy in the ICU setting is still pending, there appears a potential role for CGM to measure glucose in this population [46].

A second hurdle relates to the implementation of the rapidly evolving technology in a large-scale organization like a hospital. It is virtually impossible for all nurses, physicians and other healthcare professionals to be aware of the latest devices that people with diabetes may wear in everyday life. Especially when dealing with technical errors or unfamiliar devices, it is of utmost importance to have a specialized team available to support patients and staff in CGM data interpretation.

Currently, there is no industry standard that allows for direct integration of CGM data into electronic health records. This means that data collection and interpretation could also be a problem for physicians unfamiliar with

CGM use. Ideally, CGM data could be structurally transferred into electronic health records to facilitate review and interpretation by health care providers, and to periodically confirm that CGM readings used for patient care are within an acceptable range [18•]. Steps for successful in-hospital implementation have recently been described [46].

Finally, cost (of materials but also training of personnel) is another barrier to the widespread use of CGM in the routine care of hospitalized patients [48].

Current Guidelines on the Use of CGM in the Hospital

At present, no CGM system has FDA approval for inpatient use, although CGM has theoretical advantages over POCT as described above. However, the FDA did not object to inpatient CGM use during the COVID-19 pandemic [49]. The American Diabetes Association (ADA) and other expert groups do recommend continuation of home CGM in patients after hospital admission *unless* certain criteria can be met. These criteria include the patient is cognitively intact, that there is adequate supervision by specialized diabetes teams, and that there is no non-adjunctive use of CGM in the presence of conditions that could interfere with sensor accuracy [11, 46, 50, 51].

Continuous Subcutaneous Insulin Infusion and Automated Insulin Delivery

Insulin therapy remains the treatment of choice for hyperglycemia in many (non-)critically ill patients in the hospital with and without diabetes [11, 52]. In cases of severe hyperglycemia or diabetic ketoacidosis, insulin therapy is preferably administered intravenously. In less severe cases, insulin can be administered subcutaneously through multiple daily injections (MDI). An alternative to this is continuous subcutaneous insulin infusion (CSII), in which only short-acting insulin is administered in preset varying doses via an insulin pump. In general, insulin treatment with CSII is more flexible than with MDI.

CGM can be integrated with CSII, in which an algorithm controls insulin delivery by the pump based on CGM data, also known as automated insulin delivery (AID). In recent years, this technology has evolved from sensor-augmented pump (SAP) therapy with low glucose suspend (LGS; insulin delivery is suspended when a preset threshold for hypoglycemia is reached) to SAP with *predictive* low glucose suspend (PLGS; insulin delivery is suspended *before* a preset threshold for hypoglycemia is reached). The latest evolution in AID is closed-loop control, where a control algorithm automatically increases or decreases the insulin dose based on CGM data input. Most devices still require user input on carbohydrate intake for boluses (which is why they are called *hybrid* closed-loop systems) and confirmatory fingersticks for calibration. Hybrid closed-loop control is increasingly becoming the standard treatment for people with T1D, given its benefits on glycemic control and quality of life [16], and thus appears more frequently in the hospital.

Benefits of CSII and AID in the Hospital

Previous studies showed that CSII is not inferior to MDI in terms of achieving glucose targets in the hospital and patient satisfaction [53, 54]. As with CGM, AID may offer benefits in the inpatient setting, including improved glycemic control and reduced nursing workload (Table 1). The first studies evaluating AID in the hospital were small and focused on the ICU setting or the perioperative period. These studies demonstrated good efficacy of AID, given an improvement in time in target range and lower mean glucose levels, without an increased risk of hypoglycemia [55–57]. More recent studies support the use of closed-loop in selected groups of hospitalized people with T2D [58, 59].

There are limited data and guidance on use and safety of AID in the hospital [60]. Furthermore, many of the hospital-based RCTs on AID have been conducted in people with T2D, and therefore the safety profile may be different for other populations [60]. One observational study by Medina et al. described the performance of hybrid closed-loop and advanced hybrid closed-loop in 24 patients with T1D and a history of hospitalization, and concluded that active automatic mode led to > 70% time in range (70–180 mg/dL) without increasing hypoglycemia [61]. A real-world study by Boughton et al. demonstrated in 32 inpatients that the use of closed-loop insulin delivery (CamAPS HX algorithm) was safe and effective during their admission across medical and surgical wards [62]. A single-arm multicenter pilot trial demonstrated in 22 hospitalized patients with insulin-requiring diabetes at medical and surgical non-critical care units, that the use of automated insulin delivery with a disposable tubeless patch-pump (Omnipod® 5) resulted in an overall TIR of 68% with no diabetic ketoacidosis or severe hypoglycemia [63].

Challenges of CSII and AID in the Hospital

Both CSII and AID require additional monitoring to detect insulin infusion issues (such as canula dislocation or kinking of tubing), as well as monitoring of adequate insulin supply in the reservoir to avoid abrupt cessation of insulin delivery leading to severe hyperglycemia (Table 1). In addition, insulin pump settings may need to be adjusted more frequently, necessary pump supplies should be available, and pumps should be removed during certain radiologic procedures such as MRI [64]. Because AID is based on CGM data

(both in automatic mode and in manual mode), one must be aware of conditions described above that could interfere with sensor accuracy and therefore potentially compromise adequate insulin delivery.

Healthcare professionals must be familiar with troubleshooting and switching to alternative modes of insulin delivery in the event of insulin pump failure. Given the complexity of the different algorithms, AID certainly requires involvement of an experienced endocrinology team, which may to date limit widespread adoption of AID in the hospital setting. Other challenges of AID in the hospital setting include the use of certain medications (e.g. glucocorticoids) and (par)enteral nutrition, which can be challenging for certain AID algorithms [46].

To date, none of the AID systems and their algorithms are specifically adapted to in-hospital use in (critically) ill patients.

Current Guidelines on CSII and AID in the Hospital

In the case of insulin pump therapy on admission, professional societies support the continuation of CSII in appropriate hospitalized patients, with the backing of hospital policies, inpatient diabetes management teams, and a signed patient consent form [33, 53, 65]. In the absence of these key elements that allow a patient to remain on insulin pump therapy, the alternative is to switch to MDI [52]. Contraindications to the use of CSII in the hospital include impaired level of consciousness, inability to use appropriate pump settings, inability to self-manage, hyperglycemic crisis, lack of pump supplies, and lack of trained healthcare providers [33, 53, 64, 65]. One consensus statement on the inpatient use of diabetes technology recommended disabling (P)LGS features of SAP in the hospital [66] because CGM data are not currently approved for inpatient insulin dosing.

Consensus guidelines only recommend the use of AID in the hospital in patients already using the system in the outpatient setting, provided that the device can be used properly and safely as in the case of CSII [46, 60]. However, in case of safety concerns, AID should be switched from automatic mode to manual mode [60], and should be continued as CGM only or CSII only.

The Potential of Diabetes Technology in the Hospital: Special Populations and Conditions

High-Risk Populations

In addition to the use of CGM in people with established diabetes on admission, CGM could also be used to screen or (temporarily) monitor patients at risk of developing hyperglycemia, such as during critical illness, medical nutrition support or corticosteroid treatment. Repeated random blood glucose values above 200 mg/dL are considered to be diabetes according to the ADA definition [67]. Again, the advantage of CGM might be that the likelihood of capturing hyperglycemia will be increased compared to standard early morning fasting glucose levels, given the day-to-day glycemic variability due to scheduled examinations, evolving inflammation and dietary changes. Decreased appetite and dietary intake are a major challenge for all patients with diabetes and acute illnesses, which is also reflected in the 'sick day' rules for some therapies such as SGLT2-inhibitors and insulin. Full closed-loop control based on subcutaneous glucose measurements is feasible and may provide efficacious and hypoglycemia-free glucose control in critically ill adults [68].

At the ICU of our hospital, a control algorithm that regulates insulin delivery based on blood glucose measurements was evaluated in the prospective LOGIC-1 study, in which a heterogeneous group of critically ill patients was randomized to nurse-directed glycemic control or algorithm-guided glycemic control (LOGIC-C) [69]. Compared with expert nurses, LOGIC-C improved the efficacy of tight glycemic control without increasing the rate of hypoglycemia.

Important to note is that if people start using diabetes technology for any reason during their hospital stay, a clear workflow regarding glucose follow-up (possibly with continuation of the technology) after discharge is needed [19•].

Nutrition Therapy

It is particularly difficult to maintain normoglycemia during medical nutrition therapy to supplement or replace oral intake. As such, metabolic complications are common in hospitalized patients receiving medical nutrition, with up to 30% of patients receiving enteral nutrition and up to 50% of patients receiving parenteral nutrition developing hyperglycemia [70]. Frequent POCT and insulin dose titration are indispensable but labor intensive, as some report 2 h of nursing time per patient per day [71]. Technological innovation may help reducing the workload. However, clinical guidelines on nutritional support in people with diabetes are outdated; the latest guidelines from the European (ESPEN) or American (ASPEN) societies for clinical nutrition for polymorbid or hospitalized patients do not specifically mention diabetes or insulin, and the latest standards by the ADA give guidance on (par)enteral nutrition in diabetes care in the hospital, but do not discuss the role of technology [11]. Current literature suggests that for the treatment of total parenteral nutrition (TPN)-associated hyperglycemia, continuous intravenous insulin infusion is the most effective compared to other routes of insulin infusion (including CSII) because it reduces the incidence of hyperglycemia and shortens length of hospital stay, without increasing the incidence

of hypoglycemia [72]. However, other routes of insulin infusion, including CSII, are better in terms of efficacy and safety [72]. One RCT by Boughton et al. studied the use of AID in 43 people from non-critical care surgical and medical units, who were receiving nutrition therapy [73]. This trial concluded that closed-loop is an effective treatment option in such settings, given a higher percentage of time within the target range in the closed-loop group compared to the control group (68.4% versus 36.4% respectively), without episodes of severe hypoglycemia or hyperglycemia, or treatment-related serious adverse events.

Perioperative Management

While previous studies with early-generation CGM faced many challenges regarding device performance during surgery [74], more recent studies have shown satisfactory accuracy of a next-generation rtCGM (Dexcom G6®) in the intraoperative setting [75, 76].

Studies on the use of CSII during surgery are sparse, uncontrolled, and mostly retrospective. One retrospective study in people T1D and T2D undergoing surgery compared continued use of CSII with conversion to intravenous insulin infusion intraoperatively, and found no difference in mean glucose [77]. Another retrospective analysis showed that CSII is both safe and effective for postoperative glycemic control in patients admitted for elective surgery [78].

There are few case reports of using AID in surgery, but overall data on safety are limited [46]. A Japanese company has developed a full closed-loop system (STG-55) that integrates intravascular CGM with continuous intravascular insulin infusion, and has demonstrated superior effects on glycemic control compared to conventional intraoperative insulin infusion [79]. However, the complexity and invasiveness of this closed-loop system preclude its use in general wards. As AID would be particularly useful in maintaining adequate glycemic control during transfers from ICUs to general wards, a system requiring only subcutaneous access would be preferable [80].

Diabetes Technology in the Hospital: Avenues for Future Research

Despite the evidence described above, large studies are still needed to determine the efficacy of advanced diabetes technology in hospital settings in terms of improving glycemic control (including detection and reduction of hypoglycemia), impact on hospital stay and clinical outcomes [66]. Identifying people who would benefit the most from such devices and cost-effectiveness analyses remain unexplored areas of research [18•, 19•]. It is important to note that it is still not clear what the optimal glucose target should be in (critically) ill patients [19•, 81], and that standardized alert and alarm thresholds with corresponding instructions for nursing actions should also be established [19•]. Future studies should routinely report implementation factors, including the impact of the introduction of advanced diabetes technology introduction on caregiver and patient satisfaction**.** Regarding CGM, (standards for) accuracy issues in the inpatient setting need be overcome, especially in the ICU population. As for AID, results must be reproduced for different systems in different settings and populations, as all systems have different algorithms.

Conclusions

As the popularity of CGM and AID increases in the outpatient setting, it appears very likely that hospitals will be faced with the need to integrate these technologies into clinical workflows for diabetes management. However, before advanced diabetes technology can be used on a large scale in the hospital setting, further research is needed on efficacy (including cost-effectiveness), accuracy and safety of these systems.

Recently, a consensus statement for continuous glucose monitoring metrics for inpatient clinical trials was published to develop metrics for research on the use of CGM in the hospital setting [82•]. The goal of the panel was to develop consensus definitions in anticipation of greater use of CGM devices in hospital settings in the future. Terms related to 10 dimensions of CGM measurements were defined, including in-hospital time in ranges, in-hospital glycemic variability, and in-hospital CGM data sufficiency. Establishing such consensus definitions for inpatient analytical metrics will make it easier to compare outcomes between studies [82•].

Current limitations to inpatient use of CGM and AID include lack of regulatory approval, inexperience with diabetes technology among healthcare providers which requires supervision from specialized endocrinology teams, and costs associated with supplies, training, and infrastructure. An important issue here is liability, i.e. who is responsible in the event of management errors or undetected technology failures that lead to severe hypo- or hyperglycemia. Thompson et al. argue that each institution must weigh the risks and benefits of inpatient CGM use based on their hospital's infrastructure [65]. Nevertheless, data on inpatient use of diabetes technology is evolving, suggesting that CGM and AID have the potential to improve glycemic control (including reduced risk of adverse events related to severe hypoglycemia or hyperglycemia) and patient-centered outcomes such as decreased length of stay.

Author Contribution This article was written by invitation. MMV and RG performed the literature search. The first draft of the manuscript was written by MMV and RG. CM and PG assisted with the literature review and writing the manuscript. Als authors read and approved the final manuscript.

Data Availability No datasets were generated or analysed during the current study.

Declarations

Competing Interests UZ Leuven received non-financial support for travel from Novo Nordisk, and support from Boehringer Ingelheim for MMV. MMV has served on the speakers bureau for Dexcom, and financial compensation for these activities has been received by KU Leuven.

RV serves or has served on advisory panels for Boehringer Ingelheim, Eli Lily, and Sanofi. Financial compensation for these activities has been received by KU Leuven. RV has served on the speakers bureau for Menarini, Boehringer Ingelheim, Eli Lily, Goodlife, Novo Nordisk, Prowell, and Sanofi, and financial compensation for these activities has been received by KU Leuven.
PG serves or has served on advisory panels for Novo Nordisk, Sanofi-Aventis, Boehringer Ingelheim, Janssen Pharmaceuticals, Roche, Medtronic, Abbott and Bayer. Financial compensation for these activities has been received by KU Leuven. PG serves or has served on the speakers bureaux for Merck Sharp and Dohme, Boehringer Ingelheim, Bayer, Medtronic, Insulet, Novo Nordisk, Abbott, Roche, VitalAire and Dexcom. Financial compensation for these activities has been received by KU Leuven. KU Leuven received non-financial support for travel for PG from Sanofi-Aventis, A. Menarini Diagnostics, Novo Nordisk, Medtronic and Roche.
CM serves or has served on advisory panels for Novo Nordisk, Sanofi, Merck Sharp and Dohme, Eli Lilly, Novartis, AstraZeneca, Boehringer Ingelheim, Roche, Medtronic, ActoBio Therapeutics, Pfizer, Imcyse, Insulet, Zealand Pharma, Avotres, Mannkind, Sandoz and Vertex. Financial compensation for these activities has been received by KU Leuven; KU Leuven has also received research support for CM from Medtronic, Imcyse, Novo Nordisk, Sanofi and ActoBio Therapeutics. CM also serves or has served on the speakers bureaux for Novo Nordisk, Sanofi, Eli Lilly, Boehringer Ingelheim, AstraZeneca and Novartis. Financial compensation for these activities has been received by KU Leuven.

Human and Animal Rights and Informed Consent This article is a review that summarizes studies that have been previously published involving human or animal subjects. It does not contain any original experiments with human or animal subjects performed by any of the authors.

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