Telemedicine: What more is needed for its integration in everyday life?


Abstract

The Health Authorities have huge expectations of telemedicine (TM): improved patient access to healthcare, a solution to the shortage of doctors in the face of an exponentially expanding disease, and reduced healthcare costs with improved quality.

There are a host of applications for TM in the area of diabetes. TM has been validated and has been widely used to screen for diabetic retinopathy, and a number of studies are currently underway for the follow-up of diabetic foot ulcers. However, the main indication of TM remains the follow-up and control of blood glucose. In this area, many studies have been conducted to improve glycaemic control. While most of these studies have failed to show any benefits vs. conventional care, a small number have demonstrated great efficacy of this approach with regard to glycaemia. Using these studies, we attempt to define the key qualities of a successful TM system.

How can we extend the results of these experiments beyond the framework of clinical studies and integrate them in daily practice so as to improve diabetes management?

This is the key challenge for TM, implementation of which will require reorganization of healthcare, given the evolution of medical demographics. This reorganization will involve healthcare providers specialized in diabetes that may intervene in assigning physicians for especially distressed patients. However, such reorganization will require medico-economic evaluation before it can be implemented on a larger scale.

Keywords: Telemedicine; Type 1 and type 2 diabetes; Medical device; Smart-phone; Education; Organization of healthcare; Review

Résumé

Télémédecine: que manque-t-il pour l’intégrer au quotidien?

Les attentes des Autorités de Santé vis-à-vis de la télémédecine (TM) sont considérables : améliorer l’accès aux soins des patients, pallier à la pénurie de médecins face à une maladie dont la prévalence explose et réduire les coûts de santé tout en améliorant la qualité.

Les champs d’application de la TM dans le domaine de la diabétologie sont nombreux. La TM est déjà largement utilisée pour le dépistage de la rétinopathie diabétique et des expériences sont en cours pour le suivi des lésions de pied. Sa principale indication reste toutefois le contrôle de la glycémie. Dans ce domaine, de nombreuses expériences ont été conduites visant l’amélioration du contrôle glycémique. Si la plupart d’entre elles ne sont pas parvenues à montrer de bénéfice vs une prise en charge conventionnelle, quelques-unes, peu nombreuses, ont toutefois fait la preuve de leur efficacité. A travers elles, nous définirons les qualités indispensables d’un système de TM performant.

Comment ensuite sortir ces expériences du cadre des études cliniques et les intégrer au quotidien pour renforcer la prise en charge des patients diabétiques ? C’est là le véritable enjeu de la TM dont le déploiement devra passer, compte tenu de l’évolution de la démographie médicale, par une réorganisation de l’offre de soins avec l’implication de paramédicaux formés à la diabétologie qui pourront intervenir par délégation médicale auprès des patients identifiés comme en difficultés. Une telle organisation devra toutefois être évaluée sur le plan médico-économique avant d’envisager sa transposition à large échelle sur le territoire national.

Mots clés : Télémédecine ; Diabète ; Dispositif medical ; Smart-phone ; Education ; Organisation de l’offre de soins ; Revue générale
1. Introduction

Health authorities currently have high expectations of telemedicine (TM). Telemedicine “can be a powerful lever for driving the restructuring of healthcare organization” as stipulated in the French HPST law (Hospital, Patients, Health, Territories). This is how the role of TM is presented within the “organization of healthcare” in the recent report of the DHOS [1] (Department of Hospitalization and of Healthcare Organization). The authors, P. Simon and D. Acker, define the four fields covered by telemedicine: tele-consultation, tele-expertise, tele-monitoring and tele-care. In the report, a major place has been accorded to diabetes. Generalists working in local institutions will be linked by telemedicine to specialists in reference institutions. The benefits of this type of approach with regard to certain cardiovascular (stroke, myocardial infarction) or metabolic (chronic renal failure, diabetes) emergencies are clear [...] . The most costly diseases in terms of current management likely to derive benefit in terms of both quality and safety of care while reducing health costs through remote monitoring at the patient’s home are: heart failure, kidney failure, diabetes and hypertension. Finally The French National Order of Physicians (CNOM: Conseil de l’Ordre des Médecins) has stated that “The act of telemedicine is an authentic medical procedure in itself” [2]. TM may serve a dual purpose: first, it may partly solve the problem of shortages of doctors, both specialists and generalists, as well as the problem of remoteness of many patients from healthcare centers in a context of limited budgetary resources. Second, it should also improve the quality of care thanks to the sophisticated electronic tools, now available. There are currently several possible applications for TM in diabetes:

- Transmission of information from a non-expert to an expert healthcare provider (HCP) with subsequent feedback in the opposite direction. A perfect application for such organization is screening for diabetic retinopathy, and possibly the follow-up and treatment of diabetic foot disease.
- The major application, however, is the provision of direct help to the patient, and in this case a different circuit is needed. Transmission of information from the patient to the caregiver and, after analysis of the data, feedback in the opposite direction with sending of instructions is far too time-consuming and cannot satisfy the immediate requirement. A two-level system is needed: 1) A “pocket” system for the patient that performs automatic analysis of the problem and provides an immediate automatic response based on preset algorithms determined by the caregiver, 2) Remote support by caregivers in predefined situations identified by automatic analysis of the data. For this TM application, a distinction must be made between type 1 or type 2 diabetes treated with multiple daily injections (MDI) or continuous subcutaneous insulin infusion (CSII) and T2DM treated with dietary measures or oral antidiabetic agents (OADs), possibly along with a single injection of basal insulin.

2. TM and management of diabetes complications

Telemedicine has already been widely used in screening for diabetic retinopathy. Although the international guidelines recommend regular fundoscopy for all diabetic patients, access to an ophthalmologist may be difficult. Non-mydriatic fundus photography is now considered a valid method for assessing diabetic retinopathy (DR) and tele-medical networks using digital non-mydriatic fundus cameras have been developed. In France, OPHDIAT comprises peripheral screening centers equipped with non-mydriatic cameras, where fundus photographs are taken by technicians and linked by telemedicine to a reference centre in which the images are graded by ophthalmologists. Such networks have proved very effective for retinopathy screening, increasing the number of patients undergoing fundus examination and reducing the mean time required by an ophthalmologist for each diagnosis of diabetic retinopathy [3]. This type of organization enables optimization of care since ophthalmologists can focus on patients with retinopathy, cataract and/or non-gradable photographs (about a quarter of patients) [4]. TM should also be of particular interest in the monitoring of chronic foot disease, through photographs transmitted to a physician at a referral center who can in turn make recommendations to nurses providing daily care. A number of pilot studies are currently underway. Provided they can demonstrate medico-economic benefits, these experiments will be extended to larger populations of patients with diabetic foot disease.

Beyond screening and management of diabetes complications, TM has been used mainly in the control of blood glucose (BG).

3. TM and blood glucose control

Experiments focusing on BG control have been extensively detailed in a recent review [5]. We will focus on experiments that have either shown real benefits in terms of glycaemic control or that appear promising, in both type 1 and type 2 diabetes.

3.1. TM in type 1 diabetes

DCCT has already shown that close management of T1 diabetic patients partly based on monthly visits but also on regular phone contacts led to significant improvement in HbA1c levels [6]. The same conclusion can be drawn from the study conducted by Thompson [7] in 46 insulin-treated diabetic patients with poor glycaemic control (HbA1c>8.5%). A 15-minute phone call three times a week by a specialized nurse focusing on adjustment of insulin doses resulted in significant improvement in glycaemic control compared to standard care (from 9.6 to 7.8% vs. 9.4 to 8.9%, \( P<0.01 \)). Although effective, this approach is time-consuming (17.25 h/w for 23 patients, for 6 months) and is thus unfeasible in large patient populations.

Systems involving uploading of BG values from a glucose meter with a memory function via the patient’s cellular phone to the physician’s computer with delayed feedback have
yielded rather disappointing results. While these tools, usually developed by firms that market BG meters, undoubtedly facilitate the caregiver’s work by transmitting data in an easily accessible format, they rarely improve metabolic control. The weakness of the feedback chain to the patient (often \textit{via} SMS) and the attendant time lapse may account for the negative, or at best, weakly positive, results. More complex systems involving a PDA instead of a phone have also proved disappointing in terms of metabolic control [8-10].

In type 1 diabetes, the way forward clearly involves active electronic diaries in smartphones that will effectively replace the traditional paper diaries. All of these embedded systems for patients on a basal-bolus insulin regimen incorporate a “bolus calculator” comparable to those used in insulin pumps. The latter provides the patient with immediate assistance in calculating prandial insulin doses at mealtimes, taking into account pre-prandial blood glucose value, carbohydrate load and level of physical activity, if any. The calculation is made on the basis of adjustment rules set by the physician. All data collected by the PDA are automatically transmitted to the caregiver and can be read on a computer screen, thereby allowing remote monitoring, and where necessary, provision of feedback to the patient, in accordance with the type of system used (e.g. SMS, phone consultations, e-mail). This dual feedback system allows day-to-day management of diabetes by the patient to be kept separate from longer-term supportive interventions by the HCP (motivational support). Two main systems have currently reached the stage of large-scale validation in populations of 130-180 patients.

The “Diabetes Interactive Diary” (DID) is a software package loaded onto a mobile phone that can help patients quantify their carbohydrate intake during meals by selecting the specific food and the amount consumed from a set of pictures. Like any bolus calculator, it can help patients determine the appropriate bolus of insulin needed based on the carbohydrate-to-insulin ratio and the insulin-sensitivity factor previously determined by the HCP. The system can also integrate additional data such as physical activity levels that require adjustment of either insulin dose or diet, and an algorithm has also been added for adjustment of the basal insulin dose. Data stored in the mobile device can be sent at regular intervals in the form of short messages and reviewed by the physician on his personal computer, and any new therapeutic and behavioral prescriptions can be sent from the physician’s computer to the patient’s mobile phone.

Despite these functions, studies to evaluate the DID have not yet shown any real benefit in terms of metabolic control. In the 3-month pilot study conducted in 50 fairly well-controlled T1DM patients (mean HbA1c >7.2%) following a basal–bolus regimen, diabetes remained well controlled at the end of the study and the DID system was considered “excellent” or “good” by 96% of patients, and “extremely useful” or “very useful” by 72% [11]. The function considered most useful was carbohydrate counting using the electronic illustrated food list, followed by insulin-bolus calculation. However, the results of the validation study were rather disappointing [12]. This 6-month international, open-label, multicentre, parallel-group study was conducted in 130 T1DM patients not used to carbohydrate counting, with HbA1c of between 7.5% and 10%, and randomized to either an intervention group (IG) or a control group (CG). Both groups showed a 0.5% reduction in HbA1c (from 8.2% to 7.8% in the IG and from 8.4% to 7.9% in the CG), with no significant differences in terms of between-group analyses. Also, at the very most, the time devoted to carbohydrate-counting education in the IG was halved compared to the CG (6 h vs. 12 h, respectively; \textit{P}=0.07) [13]. Although the provision of dual feedback to patients (consisting of: 1) automatic and immediate determination of carbohydrate intake and appropriate insulin dose; and 2) feedback from the HCP) initially appeared extremely valuable, the limited possibilities of expression \textit{via} SMS may partly explain these first results. A multicentre, national, randomized parallel-group study involving 130 patients is underway to compare the impact of standardized DID education vs. usual practice on HbA1c levels, incidence of hypoglycaemic events and glycaemic variability [14] (NCT01192711).

The second electronic diary on a smartphone is the \textit{Diabeo system} developed through a partnership between the French Study and Research Centre for Improvement of Diabetes Therapy (CERITD) and Voluntis, an information technology and services company. In addition to the bolus calculator, based on the algorithms and glycaemic targets initially set by the physician, Diabeo also includes a basal insulin adjustment function that may be used even by patients on pump therapy with several different basal rates. One of its main novel features is an algorithm for self-improvement of functional insulin therapy (FIT) parameters based on blood glucose values. Again, this algorithm is preset by the physician. Finally, all data collected in the PDA can be transmitted to a secure website \textit{via} GPRS, and authorized caregivers can consult the data directly in a readily interpretable format. This allows short but regular tele-consultations aimed at the reinforcement of therapeutic follow-up. Such consultations allow physicians to remain within the mean allocated time for each patient (approximately 30 min/patient/semester).

The first two evaluations of the Diabeo system conducted respectively in 10 and 35 DT1 patients showed good results for blood glucose profiles [15-16], with the same mean blood glucose values before and after each meal, reflecting the efficacy of both the bolus calculator and the algorithm for self-improvement of functional insulin therapy (FIT) parameters. Patient satisfaction was very good, with a large majority wishing to continue using the system even at their own expense, rather than returning to a traditional passive glycaemic diary. The 6-month multicentre randomized Telediab-1 study clearly showed marked metabolic improvement with the Diabeo system [17]. The study included 180 adults with T1DM on a basal-bolus insulin regimen (for >6 months and with CSII or MDI) with chronic poor blood glucose control (HbA1c>8% twice consecutively, initial HbA1c 9.1±1.1%).
These patients were randomized to three groups that were regularly monitored respectively by: 1) quarterly face-to-face consultations (G1 = control group); 2) the Diabeo system with quarterly face-to-face consultations (G2); and 3) the Diabeo system coupled with brief fortnightly telephone consultations (G3). Patients in G2 showed a 0.7% improvement in HbA1c (P<0.01) at 6 months compared with the G1 controls, whereas in G3 (Diabeo system plus tele-consultations), HbA1c was reduced by 0.9% (P<0.001) vs. G1, with no increase in the incidence of hypoglycaemia. In the latter group, the total time spent by the physician on telephone consultations was similar to the time spent on face-to-face consultations in the first two groups (1.2 h), but far less time was “lost” by patients on their consultations in G3, in addition to which there were no transport costs and no lost work time. This system is now routinely available and accessible to all patients equipped with a smartphone who wish to have it. There have been some developments concerning both the embedded system (smartphone) and the website. A major change involves the introduction of automatic analysis of patient data with identification of potential difficulties for the patient (failure to comply with the proposed insulin dose adjustment, no transmission of data within a given period, etc.). This generates a warning to the HCP, who can then call the patient and mainly encourage them to start using the system again (if they so wish, of course) so as to benefit both from the insulin doses automatically proposed according to preset parameters and from the self-adjustment of these parameters in the event of BG values outside the target range. The automatic warning system prevents the HCP from being overwhelmed with too much data, which is unmanageable in practice, and allows him to target his actions on those patients having the greatest difficulty in coping with their diabetes treatment, while streamlining his available time. Compatibility of the Diabeo system with the main industrial standards is currently being implemented, and discussions are ongoing with the French national health insurance agency regarding reimbursement levels for the system.

3.2. What about TM for T2D diabetes?

Given the large number of patients with T2DM, efficient management of T2 diabetes using an adapted TM device should be of particular interest to optimize care in a context of limited budgetary resources.

Experiments with telephone consultations have been conducted in large populations of T2DM patients. They have necessarily led to attempts to focus the activity of nurses on those patients identified as the most distressed. In a randomized study by Piette et al. [18] involving veterans with diabetes, the IG (n = 124) received a series of automated telephone assessments to identify the most distressed patients likely to derive the greatest benefit from targeted intervention by a nurse (telephone monitoring). The nurse was not present at the clinic and had no direct physical contact with patients or indeed access to their medical records. The intervention was centered on blood glucose results and provided general educational information. The CG group (n = 124) was followed up as usual (traditional care). HbA1c values at baseline were similar between the two groups (IG vs. CG: 8.8±1.8% vs. 8.6±1.8%) and the 12-month assessment showed no differences (ΔHbA1c [IG vs. CG] = -0.3%; P = 0.1). The number of IG patients achieving an HbA1c level <7% was twice that in the CG (17% vs. 8%, respectively; P = 0.04). However, the nurse who was not in the clinic and did not have access to medical records spent only 6 min/month/patient focusing on BG results while at the same time providing general educational information. The extremely brief nature of the intervention doubtless accounts for the disappointing results in terms of HbA1c levels, with no difference being seen in the between-groups analysis at 12 months (ΔHbA1c [IG vs. CG] = -0.3%; P = 0.1). Moreover, it seems clear that the method of identifying the most distressed patients was not really efficient.

In France, there has been renewed interest in the telephone consultation system with the Sophia program [19], an assistance program for diabetic patients launched in early 2008 by the French Health Insurance Fund for Employees (Caisse nationale d’assurance maladie des travailleurs salariés [CNAMTS]) in 10 metropolitan regions. The program involves dealing with patients according to their individual risk level, as assessed by the severity of their diabetes complications. Patients considered at low risk were sent information about their disease. Patients at intermediate or high risk, in whom the aim is to reduce the severity of complications and prevent the occurrence of new complications, received telephone calls from trained nurses. Although the evaluation results of the pilot program in a target population of 136,000 diabetic patients have not yet been published, it is already known that these results show no real benefit with regard to HbA1c. Nevertheless, the program has been extended to other areas of France.

Finally, experiments involving low-cost phone consultations have also been conducted with call centers employing non-caregivers. It appears that such interventions may be useful, especially in deprived areas where access to care is limited, and in cases in which metabolic control is not too poor and treatment is relatively straightforward. Benefits in terms of reduction of HbA1c are modest at around 0.4 to 0.5% [20]. However, this kind of intervention has proven to be ineffective in cases of severe blood glucose imbalance, which are frequently related to poor acceptance of diabetes.

What about the internet? Thanks to widespread internet access, very simple systems of communication via the web have been tested in Korea. Data (BG values, but also body weight, BP and treatment details) were transmitted to a medical team, which then advised patients via the internet. In T2D patients with fairly good metabolic control (n=110, baseline HbA1c =7.5%), this kind of intervention showed benefits in terms of HbA1c reduction at 3 months (-0.5% in the IG group vs. +0.3% in the CG group, P<0.001) [21], which persisted at 30 months [22]. However, these patients were fairly compliant regarding baseline HbA1c and patients with more severe glucose imbalance were not assessed. Furthermore, it is
likely that the time spent by team members reviewing all the data and providing patients with advice or recommendations was consistent, as they also had to answer questions from patients via the internet (on average 14 questions per patient in the IG). Conversely, a recent study has been published of an automated clinical-decision support system (CDSS) for T2D patients with no direct involvement of healthcare professionals to manage BG values [23]. Glucometer data are transmitted by landline through a public switched telephone network (PSTN) and the CDSS engine automatically generates instructions tailored to each patient in response to their BG results and these appear directly on the screen of their mobile phone. A diabetes management team including diabetologists, nurses, dieticians and exercise trainers organized and directed patient education. In the intervention group, education was provided to help patients use the system and interpret messages correctly. On testing in a population of 144 T2D obese patients aged >60 years, the reduction in HbA1c was 0.4% in the intervention group (n=49; HbA1c from 7.8 to 7.4%, P<0.001) vs. 0.1% in the control group (n=48; HbA1c from 7.9 to 7.8%, P<0.05), with an intermediate result in the SMBG group. However, the system only allows small adjustments (lifestyle changes or a small increase in insulin dosage: ± 2 insulin units), which explains the modest gain in terms of HbA1c for a relatively sophisticated system.

4. Systems incorporating a cellular phone show more promise

Systems connecting a cellular phone with internet appear much more promising thanks to the handiness of cellular phones and their ability to communicate data in real time.

In the WellDoc™ system, BG values were transmitted via Bluetooth from a blood glucose meter to a mobile phone, and then from the mobile phone to a remote server; automated messages were immediately generated by comparison of the value with patient-specific target levels. When patients’ blood glucose levels were above or below their target levels, they received real-time feedback on how to correct them via messages on their mobile phone screen. Patients were also prompted to enter other information (e.g. medication dosages and carbohydrate intake at meals). All suggested changes to patients’ therapeutic regimes were communicated to their HCP. Also, each patient’s logbook was sent electronically to the HCP every 4 weeks, or more frequently if necessary. Patients’ data were analyzed by automated algorithms and by the research team.

In the 3-month US pilot study reported by Quinn et al. [24], 30 T2DM patients were randomized to an IG (n=15), which received a cell-phone system connected to the internet, or to a CG (n=15), which simply received the standard care. The average decrease in HbA1c for IG patients was -2.03% vs. -0.68% in the CG (P<0.02), although baseline HbA1c levels were high in both groups (9.5% and 9.05%, respectively). In the IG, physicians were four times more likely to titrate/add drugs than in the CG. From the patient’s point of view, immediate feedback and the ability to receive advice from a nurse regarding treatment adjustments based on blood glucose results was greatly appreciated. The HCPs, meanwhile, reported that the system facilitated treatment decisions, provided organized data, and reduced logbook-review time. A cluster-randomized clinical trial including three treatment groups (a tiered IG and a CG) has also been conducted using the WellDoc system [25]. Twenty-six primary care practices were randomized to either the control group receiving usual care (UC: providers were asked to care for patients in the usual way) or to one of the three treatment groups: 1) Coach-only (CO: a mobile diabetes management software application); 2) Coach Primary Care Provider (PCP) portal (CPP), the latter consisting of a secure messaging center; 3) Coach PCP portal with decisional support (CPDS); 163 T2 diabetic patients with HbA1c ≥7.5% within 3 months of the study start were included (mean HbA1c = 9.4% at baseline). The mean reduction in HbA1c was 1.9% (95% CI 1.5-2.3) in the maximal treatment group and 0.7% (95% CI 0.3-1.1) in the UC group, with a difference of 1.2% (p<0.001) over 12 months. Furthermore the CPDS patients had a significantly greater decrease in mean HbA1c than the UC patients for all follow-up times. Even with stratified analysis of HbA1c at baseline (HbA1c<9% or ≥9%), a greater reduction was found in the CPDS group than in the UC group. However, any suggested change in a patient’s treatment had to be validated by the HCP and patients could act directly on their BG value; this study did not collect person-specific data on dietary, physical activity and pharmacological management adjustments made for individual patients, and no profiling of patients is possible.

In the field of smart-phones, a version of the Diabeo system has been customized specifically for T2DM patients. This system, the result of collaboration between CERITD and Voluntis, is geared towards patients inadequately controlled by OADs and in whom the introduction of a basal insulin injection at bedtime is warranted. To overcome inadequate titration of basal insulin, the Diabeo system was adapted to provide automated proposals for insulin dose based on an algorithm preset by the physician. However, its chief value remains educational coaching to provide patients with advice on diet and physical activity by way of automatic messages if the results of postprandial blood glucose values or blood glucose values at the end of the afternoon fall outside the target range; advice can also be given to patients in the event of hypoglycaemia. This system is currently being evaluated in the multicentre Telediab-2 study [26] (ClinicalTrials.gov Identifier: NCT00937703). However, it should be recalled that in T2DM, although the amount of carbohydrates consumed is a key element of meal glucose excursion, the relationship between both is not necessarily linear, and we can thus already predict that reducing carbohydrate intake at meals will not always be effective in reducing post-prandial BG values [27].

5. Conclusion

To date, most studies of TM conducted in diabetes care have failed to demonstrate any superiority over traditional care. If we consider only the randomized clinical trials for
metabolic status, the result remains the same [28]. The chief reason is that meta-analyses have brought together studies of variable quality, regardless of methodology, type of diabetes, study populations and type of device. However, certain studies differ considerably from the others and show a clear benefit in favor of TM (Well Doc, Telediab1). In the light of this review, what are the characteristics of an effective TM system? An easy-to-use hand-held system, like “a pocket doctor”, allowing immediate data entry and immediate feedback about problems and/or a reminder for the patient. In short, the solution will always involve a smart-phone.

Automatic transmission of data to caregivers with automatic data analysis, producing “warnings” to avoid overwhelming the caregiver with too much data, which is impossible to analyze properly in practice.

Such a system would promote tele-monitoring in the event of warnings, with personalized tele-consultations performed by an HCP under the responsibility of a physician. Call centers with non-healthcare providers are of only limited use in this context. Delegation of tasks from the physician to nurses should allow optimization of healthcare by ensuring that caregivers focus on the most distressed patients.

What role could social networks play in this context? Social networks like Facebook or Twitter could help provide education and motivational support by allowing a group of patients to interact with each other and with a caregiver. Such networks could also be involved in supporting a therapeutic solution with proven efficacy. Used together with software designed to manage insulin therapy, this approach could allow immediate, easy and convivial communication with the HCP [29]. However, there may be concerns regarding the lack of confidentiality of the system.

In the specific context of this article, improvements in existing technology and the design of new studies should focus on the question “What new use of electronics and communication technologies will enable patients to improve their blood glucose values by themselves?” This approach should increasingly favor empowerment of patients with respect to diabetes. The first major development is a blood glucose meter directly connected to the data analysis software and to the data transmission system so that patients need not manually enter their blood glucose values. The future thus belongs to glucose meters “plugged” into a smartphone, onto which the telemedicine software would be loaded.

In the case of type-2 diabetes patients treated by dietary measures and oral agents, what are the BG values that can be immediately corrected? Patients can have only a small effect on fasting BG values unless they are treated with basal insulin, in which case an embedded software program can help them adjust their basal insulin doses. Otherwise, they can easily act on moderately elevated blood glucose levels in the late morning or in the late afternoon by means of exercise during both periods; a personalized coaching program enabled by elevated BG values should help them increase their physical activity. The same is true of high postprandial BG values: patients can at least partly reduce some of their postprandial blood glucose levels on their own by reducing carbohydrate load during meals. Simple and customized coaching software packages activated by elevated postprandial BG values are currently being evaluated (Telediab2). However, more elaborate systems of coaching based on dietary self-assessment could be of value here.

For patients with type 1 diabetes, the key objective is proper determination of the correct dose of insulin at any given time. Techniques devoted to functional insulin therapy require accurate CHO counting at each meal. The addition to existing systems such as DIABEO of a program with a support system for immediate determination of carbohydrate amounts should prove valuable. The same is true of patient quantification of physical activity, which is obviously very basic for now, i.e. “moderate”, “intensive” and in some cases “intensive” and “prolonged” physical activity. The potentially significant contribution of accurate and miniaturized accelerometers connected to decision support systems for insulin dose determination has still to be considered. Finally, the main reason for the modest (≈0.5%) improvement in HbA1c in most studies assessing continuous glucose monitoring systems (CGMS) is that it is practically impossible, even for a well-trained patient, to properly interpret unaided the 288 blood-glucose values provided daily by the device and to anticipate any changes required in insulin dose, especially for patients on pump therapy. Future developments in this area should clearly focus on software that provides accurate and reliable indications for insulin dose adjustments and then transmits these indications directly to the pump, ultimately leading to an artificial pancreas.

Conflicts of interest statement

S. Franc and certain of the authors of the manuscript work for CERITID, which has jointly developed the Diabeo system.

References


[26] ClinicalTrials.gov Identifier: NCT00937703.

