Original paper

Customizing of types of technologies used by T1D patients for diabetes treatment: exemplification made by set of case series

Anna Holubová¹,², Martina Vlasáková¹, Jan Mužík¹,², Jan Brož³

¹Spin-off Company and Research Results Commercialization Center, First Faculty of Medicine, Charles University, Prague, Czech Republic.
²Faculty of Biomedical Engineering, Czech Technical University in Prague, Prague, Czech Republic.
³Department of Internal Medicine, Second Faculty of Medicine, Charles University, Prague, Czech Republic

Corresponding author:

Ing. Anna Holubová
PhD candidate/Researcher
Spin-off Company and Research Results Commercialization Center
First Faculty of Medicine
Charles University in Prague
Studničkova 7
128 00
Prague
Czech Republic
Phone: +420 224 968 574
Email: holubann@gmail.com
Abstract

Background: Despite the fact there are many wearable and mobile medical devices that enable patients to better self-manage their diabetes, not many patients are aware of all the options they have. In addition, there are those, who are not fully satisfied with the devices they use and, besides that, they often do not use them effectively.

Objective: Deeper understanding of patients’ needs and abilities can help to both tailor a given device for a particular group of patients and assemble sets and types of devices that best comply with the needs of the patients.

Methods: 6 specific patients (3 men and 3 women), who have been using the Diani telemedicine system for at least 3 month up to 4 years, were properly instructed by a technology educator in how to operate each of the system components. Before starting to use the system and during the monitoring phase, the patients took interviews with a doctor and the educator about their daily regimen, technology capabilities, life preferences and similar topics. The technology educator was also tracking patterns of handling the devices 1) by observation while educating the patients on how to use them, and 2) via the Diani web application during the monitoring phase. Informed consent was signed and obtained from each of the patients included.

Results: Each of the presented case study describes how a given patient is handling the system and its particular parts based on his/her lifestyle, level of education, manners in diabetes management, personality type and other factors. At the conclusion of each case study, the best composition of devices for patients with similar personal description is suggested.

Conclusions: Except for the input information we get about a patient, it is obvious that there is a substantial need for proper education of both patients and healthcare providers. We believe this article can provide a relevant guidance on how to help particular patients choose the best technology that is likely to fit them the most, based on specific patient information we are able to obtain from them.

Keywords Type 1 Diabetes, T1D, technology, customizing, diabetes therapy, education, telemedicine
Introduction

Increased current use of wearable technology and home-based systems for diabetes self-management brings an opportunity to collect, track and analyze multiple parameters, such as blood glucose, carbs intake, insulin dosing, physical activity, and others [1-4]. In addition, the struggle of the most active patients for better interoperability of devices and real-time sharing of data partially forces developers to come up with telemedicine solutions that would satisfy the needs of the most advanced users as well [4-6]. Moreover, huge amount of data we are nowadays able to measure and track can help us discover the way the patients manage their disease, and instead of reactively treating their complications, we can rather proactively prevent them from development of upcoming comorbidities [7].

Even though there are many different types of mobile and web apps, wearable technology, fitness devices, medical devices and telemedicine solutions [7], not many patients are aware of all the options they have, or they are not fully satisfied with those they use and, besides that, they often do not use them effectively [8-12].

The way patients use a given technology can differ from person to person due to his or her level of education, workload, technical capabilities, motivation to use it and self-manage the disease, and also individual personality of each patient [12-14].

It is, therefore, very important to learn from how different types of patients use a given technology, in order to understand what does truly help them in their self-management, what increases their adherence, what are their preferences, or otherwise what are the drawbacks and limitations that keep them from using the technology itself. Deeper understanding of a patient’s needs and abilities with respect to the self-management can help us to both tailor a given device for a particular group of patients and assemble the set and types of devices that comply with a patient’s needs the most.

Methods

The telemedicine system

The Diani telemedicine system consists of a wearable technology, namely an activity tracker, a blood glucose meter, a diabetes diary mobile app, a smartwatch, and a web application into which all the data from the wearables is synchronized automatically. The blood glucose meter transfers measured glucose values into the diary mobile app via Bluetooth. The data from the activity tracker is synchronized via smartphone as well. Using the smartwatch the user can not only track his/her last data registrations about blood glucose, carbs intake, insulin dose and physical activity, but can also use the watch to make these registrations, which are then transferred to the mobile app via Bluetooth [15]. Occasionally, some of the patients had also the ability to wear the continuous glucose monitoring system (CGM) that enabled them to transfer data to the Diani web application (see Multimedia Appendix 1) either automatically (using the xDrip device, Nightscout) or manually (uploading the raw data file through the Diani web app). [16-19]

Intervention and patient instructions

6 specific patients (3 men and 3 women), who have been using the Diani telemedicine system for at least 3 month up to 4 years, were properly instructed by a technology educator in how to operate each of the system components, and they were free to decide, which data and how frequently they want to enter the data into the diary. They were also allowed not to use any of the devices they would not feel comfortable with.

Before starting to use the system and during the monitoring phase, the patients took interviews with a doctor and the technology educator about their daily regimen, technology capabilities, life preferences and similar topics. The technology educator was also tracking patterns of handling the devices while educating the patients on how to use them. During the phase, in which the patients were using the system in their daily life, the educator was also monitoring their behavior of entering and collecting the data via the Diani web application. These types of interventions represented the most important approaches to get a relevant feedback about the usability of the system.
The study involving human participants was conducted in accordance with the Helsinki Declaration and has been approved by the ethics committee of the Motol University Hospital in Prague. Informed consent was signed and obtained from each of the patients included.

Results
Each of the 6 case studies describes how given patient was handling the system and its particular parts based on his/her lifestyle, level of education, manners in diabetes management, personality type and other factors. At the end of each case study, we then suggest what might be the best composition of devices for patients with the similar personal needs.

Case study no. 1: extremely physically active patient hiding her disease

Patient information
45 years old woman was diagnosed with Type 1 Diabetes in 2013 and since then she has been on MDI (multiple daily injection) therapy. For the last year she has been using 3 sensors for CGM monitoring, but besides that she has relied on SMBG (self-measured blood glucose) only. Her HbA1c when starting to use the Diani system was 51 mmol/mol. Besides her diabetes, she is not suffering from any other diseases or diabetes complications.

Daily regimen and self-management
This patient performs high-intensity PA (physical activity), such as cycling, workouts in a gym and others, for 2-4 hours on a daily basis. Being a teacher with a stable daily schedule, she can include regular PA into her daily activities. In order to keep her blood glucose within target range and maintain a slim figure she keeps on lower-carb diet (approx. 100g/day) and healthy food intake, besides the PA performance. Despite that, she is able to maintain her blood glucose mostly within target range with a very rare occurrence of glycaemia lower than 3mmol/l. The only problem she has is higher blood glucose at night caused by the later effect of fatty cheese and nuts she is used to eating later in the evening.

Attitude to technology and its use
Considering her higher educational level and age, she is familiar with using smartphone and wearable technologies and has no problem to intuitively and quickly learn how to operate a new mobile app or a device for self-management. She has no problems wearing an activity tracker on a full-time basis (during the day and at night). She is also conscientious with respect to registering data into diabetes diary app and regularly reviews her data via both mobile and web applications. She is used to discussing her diabetes difficulties with a clinician, using collected data. Many of these features can be seen on a one-day graph (Figure 1) representing her regular day.
However, what troubles her are devices that are uncomfortable to wear when performing physical activity (for this reason she was not willing to use the smartwatch), or treatment-related devices that are visible to other people. She tends to hide her disease from the people around her very carefully and makes any treatment actions as discretely as possible. Therefore, she fully refuses to use an insulin pump and prefers to inject the insulin with a pen in private areas (despite the usefulness of flexible dosing during PA the insulin pump could enable her). She occasionally wears CGM and is willing to wear the sensor only in places that are not visible behind the clothes from the outside.

The biggest profit she gained from the telemedicine system after she started to use it was that she realized her blood glucose was affected by certain foods and drinks she hadn’t been used to inject insulin for before. Another new information was a post-meal spike after a larger portion of carbs intake, which was connected to a too short time span between the insulin dose and carb intake. In the long run, she can profit from controlling her stable total daily dose of carbs and total daily step count, in addition to the blood glucose measurements. By tracking her daily step counts and intensity of physical activity for a specific sport, she was able to compare her activity level with other friends. The knowledge that there had been nobody, who would make better performance, made her feel even more motivated to continue in such an active regimen. Wearing a CGM helped her especially to control her blood glucose during PA and discover the post-meal spikes. The receiver clipped on her pants did not represent any obstacle for her.
HbA1c outcomes

After a 3-month period of using the telemedicine system this patient reduced her HbA1c from 51 mmol/mol to 48 mmol/mol.

Suggestions for optimal combination of devices

Ideal tailored system for such type of patients could be a combination of devices that would transfer all the data into a mobile app or display the values on a screen of devices, which would not represent a stigma for them or be visible to the people around them. Thin wristband sensor for tracking activity and a sensor for glucose control would certainly be a good choice. No kind of frequent notifications or alarms from the data analysis would probably be necessary, since such patient is able to review the data regularly. The alarms coming from the CGM system would need to be in vibration mode only to comply with the discretion requirements. Another option could be switching for a flash glucose monitoring, which would be a secret form of data capturing in case the patient would not mind not receiving alarms at night and could wear it on alternative places of the body. Implantable sensor could also work if being implanted in places, which the patient could cover with summer clothes. Regarding the insulin therapy, insulin pen treatment still seems to be an option number one for such patient, due to her rejection of wearing an insulin pump. However, improvement in this area might be at least a pen enabling to transfer data to an app via Bluetooth. Since the patient is capable of operating digital technologies, we could also try to shift the patient to a patch pump therapy, if that would be acceptable for her to wear, rather than the traditional pumps with tubing. She could then effectively reduce nighttime highs using a squared bolus or temporary basal rate settings for the high fat snacks she has a difficulty to control. Personal account for a web application connected to a clinician’s account for automatic data synchronization would be matter of course.

Case study no. 2: Young woman preparing for pregnancy

Patient information

29 years old woman has T1D since 2005 and she has been on CSII regimen since 2013. Her HbA1c when starting to use the Diani system was 65 mmol/mol. Besides her diabetes she is not suffering from other diseases or diabetes complications. She is preparing for pregnancy.

Daily regimen and self-management

This patient is specific in her motivation to improve her HbA1c due to her planning for pregnancy. Being a teacher at high-school, her daily program is more or less stable and regular. However, some unexpected changes in her schedule or emergencies occur occasionally. These events mostly influence her ability to eat regularly and on time. She is used to keeping on healthy food intake, but to a certain extent, she has to adapt to the menus at the school canteen during lunchtimes. She likes walking a lot and she goes for a longer walk every day, if the time allows her to do so. She is also educated in flexible dosing of insulin and tries to make changes in her insulin dosing herself based upon the collected data. From time to time, she struggles with nighttime hypoglycemia, mostly induced by evening walks.

Attitude to technology and its use

Regarding her technical abilities, she can learn how to use any device easily if she gets sufficient instructions and has the possibility to turn to technical support or a more advanced person when she gets into trouble, e.g. with Bluetooth connection or unpaired devices. She is a smartphone user, so any kind of mobile apps does not pose any obstacle for her to install and use. She does not matter how many devices she has to wear or whether they are visible to the people around her. Accuracy of blood glucose measuring devices is more important to her than design and size of the technology.

She has been on CGM system full time since November 2017. At the same time, she started to use all the other equipment within the Diani system. She also took the advantage of sharing CGM data with
her T1D friend as another motivation to achieve better blood glucose results while being observed by another person.

By wearing the activity tracker, she has been motivated to walk more and compete with friends who track their daily steps as well.

Regarding her manual registrations, she has entered her insulin doses and carbs information to the diary almost daily, but some lack of data within a day or several days with a pause of manual registrations occurs. She reviewed her historical data more frequently at the beginning, in order to identify problems that caused her blood glucose fluctuations.

Once she stabilized her glycaemia, she started to review the data more or less for a few days before the visit of her diabetologist. She always prepares for the visit and downloads the data for the doctor.

The trend indicating her blood glucose improvement and the way she collects the data can be seen in Figures 2 and 3.

![Graphical interpretation of one-month data registrations of the patient from the case study no. 2. visualized by the Diani web application. In the picture, we can observe everyday data registrations, high daily step counts and decreasing trend of average daily blood glucose.](image-url)
HbA1c outcomes

Using the technology she was equipped with and her high motivation resulted in reduction of HbA1c from 65 mmol/mol to 47 mmol/mol after 3 month.

Suggestions for optimal combination of devices

Ideal tailored system for this type of patient would certainly be an insulin pump in combination with a CGM system that would enable her to transfer data to a mobile and web applications. Since we know she experiences nighttime hypoglycemia, the flash glucose monitoring would not be profitable for her, despite the ability to use it in combination with a smartphone. Knowing her strong focus on device accuracy, the most accurate CGM device enabling to alarm and transfer data to a mobile app might be a good option for her blood glucose monitoring. Considering her motivation while sharing data, a device having such function included would represent another preference point. Regarding the type of a pump, she is not an exacting user and uses its basic settings and functions (normal boluses, temporal basal reduction, one basal profile). The most convenient option would ideally be a pump that can receive data from the CGM device, in addition to the CGM data synchronization with a smartphone. This would ensure both the ability of data sharing and assurance of data transfer to the pump in case the smartphone has weak signal or its battery level is low. If no such device is available to her, she could choose a pump that is at least comfortable to wear, easy to use, enable to export data for a doctor and has good technical support.
Case study no. 3: modern and well-educated patient with irregular daily regimen

Patient information
24 years old woman was diagnosed with T1D in 1999 and she started with CSII therapy in 2002. Since 2017 she has been connected to the CGM system fulltime. She started to use the Diani system in March 2014, starting with the HbA1c of 66 mmol/mol. She suffers from knees pain due to her patellofemoral dysplasia she was diagnosed with in 2017. Besides that she is not suffering from other diseases or diabetes complications.

Daily regimen and self-management
This patient is a university student and, in addition, has a part-time job. Therefore, her daily program is very chaotic and she is often in a hurry. Since she struggles with a higher insulin resistance and complications with her knees, she tries to reduce her weight by decreasing her total daily carbs intake and incorporating different types of physical activities in her daily program. From time to time she transgresses and takes a high-carb food she loves, because she is able to anticipate the majority of her post-meal spikes using her knowledge from the CGM data. She is very well educated and able to keep her blood glucose in a tight target range, mostly thanks to her regular attendance of educational courses and CGM monitoring throughout the whole year.

Attitude to technology and its use
This patient is keen on trying new wearable technology, not only for diabetes treatment. Wearing any kind of mobile technology, even visible medical devices, is not perceived as a stigma by her. Being connected fulltime through her CGM device and having motivation to undergo educational courses, she has learnt a lot about how to make insulin adjustments based upon the arrow trends and actual glucose readings on her CGM system. Therefore, based on the trends she gives herself correction boluses or suspends the basal rate often, rather than exactly counting carbs in foods and reacting on upcoming situations too much in advance (see Figure 4).
Regarding registering data into the diary, she is able to make it properly as far as she has a good reason for doing so (for example her blood glucose is suddenly, for unknown reasons, out of her control) and has a sufficient motivation (such as being pushed by her diabetes friends).

To keep her blood glucose in a very tight target range she sets the hypo and hyperglycemia ranges close to each other. This naturally results in more frequent alarms coming out of the CGM receiver. This does not disturb her daily activities at all, however, this becomes a problem during the nights when she often does not hear the alarm, and thus, often does not wake up due to unstable glycaemia values. To ensure she will be woken up once the alarm goes off, she started to change the tones in her new receiver settings regularly once she got the version enabling that.

Although she is keen on trying a new technology and learning how to use it is not a big problem for her, she often comes up against technical issues, especially with her mobile phone. She uses many social media apps and games, listens to music and uses a navigation app when driving a car, so she always needs an extra SD card and a phone that enables her to always be “online”. Lack of signal to connected devices is also a frequent complication she faces. Another issue is the fact that she lost some devices in the past, which were too tiny or not well fixed to her body, or the devices simply died due to unknown reasons. Besides that, she is able to figure out most of the technical issues she encounters.

**HbA1c outcomes**

Using the technology she was equipped with and attending several educational courses on diabetes self-management resulted in reduction of HbA1c from 66 mmol/mol to 47 mmol/mol after 4 years, while she has been continuously keeping her HbA1c below 50 mmol/mol since the last year.
Suggestions for optimal combination of devices

Knowing all these information, this patient would certainly not be able to live without the CGM technology. Insulin pump is also the most convenient tool for her. However, as we know, losing Bluetooth signal on her phone is a frequent issue. Therefore, she might profit a lot from a pump that displays blood glucose values directly on the pump. An even better option would be a combination of displaying the data both on the pump and on the phone (similar to the previous case no. 2), since that would ensure the ability to arbitrarily change the alarm tone on her phone, in addition to receiving the one-tone alarm from the pump. In connection to her ability to do her correction boluses based upon the glucose values and trends displayed on the pump, she could profit from a device that would automatically suspend the dosing before her glucose is predicted to reach a low level. It could help her to reduce hypoglycemia incidents, especially when overdue correction boluses occur.

Case study no. 4: technically capable patient who needs constant motivation through gaming and competing

Patient information

27 years old man has T1D since 1992 and he has been on CSII regimen since 2002. Few times a year, he gets the sensor for CGM, but most of the time, he relies on SMBG only. He started using the Diani system in July 2014, starting with the HbA1c of 78 mmol/mol. Besides one laser operation he underwent due to starting manifestation of retinopathy, he is not suffering from other diseases or diabetes complications.

Daily regimen and self-management

Working in an administration office, this patient has mostly regular working schedule. In his free time, he is physically very active (performing regular physical activity, such as floorball and volleyball). He is also very creative and likes gaming. He is a very competitive person when it comes to any games or sport matches.

Regarding his eating habits, he often underestimates the timing of insulin injection for meals and sometime takes boluses too late. He also loves beer and is on a bit higher carb diet, which causes frequent post-meal spikes.

He tries to check his blood glucose regularly, but there are some days with only one or no measurements.

Attitude to technology and its use

This patient is very competent technically and is able to learn, even intuitively, how to operate new mobile apps or wearables. He is also able to solve common problems with loss of connection and other minor technical complications on his own.

Considering his competitiveness, of course he is using an activity tracker all the time to set goals and compete with his friends in daily/weekly step counts.

However, it is difficult for him to register data into the diary manually. He is willing to enter more data when he gets motivation from the outside that, in addition, is often updated by some new stimulus. It can be a new tailored version of the app or another app that has a game basis, but it can also be a new device itself (a new “toy” he can play with). With respect to the long-term motivation, the best chance for him to better self-manage his disease is competing with his diabetic friends.

Figures 5 and 6 show the difference between the phase when he was not wearing the activity tracker and the period after he got the new device.

Although he uses just basic functions of his insulin pump, he has no problem to operate any kind of device and could profit from more advanced functions in case he got proper education in diabetes management.
Figure 5: Graphical interpretation of one-month data registrations of the patient from the case study no. 4, visualized by the Diani web application. In the picture, we can observe irregular data registrations and high blood glucose variability.

Figure 6: Graphical interpretation of one-month data registrations of the patient from case study no. 4 after the patient got the activity tracker. The frequency of data registrations has increased and the average blood glucose has decreased significantly compared to Figure 5.
HbA1c outcomes

Using the technology the patient was equipped with and being motivated by his friends resulted in reduction of HbA1c from 78 mmol/mol to 54 mmol/mol after 4 years.

Suggestions for optimal combination of devices

Considering all these aspects, patients like this one might try to use, for example, a mobile app that is gamesome, includes functions for setting challenges and also enables users to take advantage of coaching services through certified diabetes educator to increase the level of education in self-management issues. This patient might also be a good adept for a hybrid closed-loop system, since it could reduce the burden of frequent blood glucose control and reduce the post-meal spikes caused by his eating habits and incorrect bolusing time. (Note: regarding the hybrid closed-loop, the patient no. 3 is, on the contrary, rather unsuitable adept for this system, because she might have the tendency to interrupt the automatic action of the pump mostly when being on high glucose levels to assume control of the insulin corrections and make the action faster).

If the hybrid closed-loop system is not accessible, we could consider a pump that suspends before low. This could, in addition to other benefits, reduce hypoglycemia incidents especially during physical activity. However, if the chosen pump is susceptible to falls and hits, the silicon case should be in place to protect the device while performing competitive sports.

Case study no. 5: modest patient who likes simple tools and clearly presented information

Patient information

45 years old man was diagnosed with T1D in 2014. He has been on MDI regimen from the beginning of the onset of the disease. His HbA1c when starting to use the Diani system was 63 mmol/mol. Apart from diabetes and arterial hypertension he is not suffering from other diseases or diabetes complications.

Daily regimen and self-management

The patient has irregular working regimen due to his frequent nighttime shifts. However, he performs physical activities (walking, cycling, working out) regularly and more than twice a week. He is used to complying with fixed daily insulin dosing and tries to do proper carb counting, reading the nutrition tables on food packages.

Attitude to technology and its use

Before starting to use the Diani system, this patient has never been using any mobile or web application for diabetes self-management. Therefore, the only data he could check were the values displayed on his glucometer, which he had never reviewed before.

However, he had no problem to handle the smartphone and learn how to work with the mobile app and make data registration. He only had some minor issues when connecting the smartwatch to his phone at the very beginning, which he was able to manage himself quickly once he got the proper instructions for the device pairing process.

The diabetes diary mobile app was the most profitable tool for him, since it was very easy to operate, the data was displayed in a well arranged way and the app was in his native language. Reviewing his data, he was motivated to achieve better results. He was very happy about the automatic transfer of data from the glucometer to his phone. Manually registered daily insulin doses and measured glycaemia were sufficient information for him to manage his diabetes in a better way. Based on the last consultation, this patient feels much better physically and mentally and his quality of life has increased appreciably. He would also be willing to pay monthly fee for the telemedicine service.
HbA1c outcomes

Using the telemedicine system, this patient has reduced his average blood glucose after 3 month of the system use (see Figure 7 vs. Figure 8) and improved HbA1c (after 3 month his HbA1c was 54 mmol/mol).

Figure 7: Graphical interpretation of one-month data registrations of the patient from case study no. 5. visualized by the Diani web application. We can observe the decreasing trend of average daily blood glucose during the first month of using the telemedicine system.

Figure 8: Graphical interpretation of one-month data registrations of the patient from case study no. 5 after 2.5 months of using the telemedicine system. We can see the data registrations are more regular compared to the Figure 7 and the average blood glucose has decreased and stabilized.
Suggestions for optimal combination of devices

As we can see, the set of devices this patient was equipped with when using the telemedicine system helped him improve his own diabetes compensation. To improve the system he has been using so far, we could suggest to him to use an insulin pen that enables automatic transfer of data to the same mobile app into which the data from his glucometer are sent. Potentially, we could discuss how acceptable it would be for him to switch to an insulin pump that would be connected to a blood glucose meter and transfer the measured data to a user-friendly mobile app. The app should also have a bolus calculator and connected food database included, in order to help him with the carbs counting.

Case study no. 6: Elderly man, who is willing to learn new things

Patient information

87 years old man was diagnosed with T1D (Type 1 Diabetes) in 1982 and is still on MDI regimen and SMBG measurement only. He suffers from diabetic peripheral polyneuropathy, due to which his hands are slightly shaking and he complains of leg pains, which he diminishes with prescribed pills. He also suffers from diabetic retinopathy, proteinuria, corrected arterial hypertension and hypercholesterolemia. His HbA1c when starting to use the Diani system was 67 mmol/mol.

Daily regimen and self-management

This patient is retired and as such has a very regular daily regimen and lots of free time he can spend on his hobbies and also the diabetes self-management. He is extremely motivated to learn new things and still has lots of energy to try or read about new methods in diabetes care. Thanks to his caring wife and thanks to his own carefulness and sense of precision he has been keeping his paper-based diabetes
records since the onset of his disease. He has read most of the diabetes books available in his native language and made notes about any unusual information that could help him to better self-manage the disease.

He also has a regular daily physical activity (everyday walk, gardening and working in his workshop). He does not check his blood glucose regularly (1.7 times per day on average, calculated from 3-month records in his glucometer measured before he started to use the telemedicine system).

**Attitude to technology and its use**

He has already tried multiple types of activity trackers in the past. The device motivates him to keep on regular physical activity (walking or gardening). He is also able to use a PC to a certain extent, i.e. surfing on the Internet, sending emails and using Skype.

Getting on the telemedicine system, the biggest problem was that he had never used a smartphone before. Therefore, he first got the phone only to learn how to switch it on and off and how to open the diabetes diary app and use it. After a month he came back to get the rest of the devices. Since he only had a cable Internet connection at home, he also got a SIM card with prepaid data with the phone. Even though he did his best, he often had problems with operating the phone, charging the devices and losing Internet connection.

Since he suffered from neuropathy, it was also difficult for him to handle the touchscreen, because his hands were shaking and he often clicked on more than one button at the same time, or on the wrong one. This led to a wrong data entry (see Figure 9) or frequent calls to the technical support when getting to a page he did not know how to get out of. Thus, he spent more time dealing with technical issues than using the system effectively.
HbA1c outcomes

The telemedicine tools were difficult to use for this patient, and thus, more burdensome than helpful. His HbA1c has increased after a 3-month period from 67 mmol/mol to 71 mmol/mol.

Suggestion for optimal combination of devices

In summary, besides the activity tracker that is simple to use even for an elderly person, the rest of the system is not a suitable solution for such a patient. However, being able to monitor his blood glucose data from a distance, it occurred many times that he did not check his blood glucose through the whole day, or did so only in situations when he was not feeling well. Therefore, we could at least convince him to measure blood glucose more often. However, this is a financial issue for him, since he is unwilling to pay for additional amount of glucose strips that is not covered by his medical insurance. Another possible help could be occasional phone call checkups made by some diabetes educator to increase his adherence to regularly checking of his blood glucose, or connection to a remote assistance service that would track and control the patient via a smart device (SIM card and GSM module-based) and react in case of emergency.
Discussion

It is obvious, not only based on the case studies presented here, that there is no ‘one size fits all’ diabetes self-management tool, which would fully satisfy the needs of each particular patient.

To be able to give proper advice about the type of device that would fit a given patient the most, specific information about the person is required. Such information includes, in particular, patient’s personality, his/her technical skills, daily regimen, the attitude to his/her diabetes, obstacles in diabetes management, preferences in data visualization and devices’ functionalities, willingness to learn new things, and also motivational means that could help him or her use any system effectively and on a long-term basis.

From the case series, we could learn that a physically very active patient, who tends to hide the disease in public, could only profit from a technology that would not represent an obstacle when performing physical activity and would not be visible from the outside. On the contrary, there are patients who do not have any problems wearing any kind of devices and of any size, as far as the system is reliable and sufficiently accurate.

While some patients would profit from automatic functions of the most advanced pumps that suspend the insulin delivery, or work in hybrid mode, enabling them to reduce their hypoglycemia incidents and correcting their “mistakes” in bolusing, there are other patients for whom this system could be rather burdensome. These are patients who need to have their dosing under control, do not trust the system and do not have the will to wait until the system corrects their blood glucose spikes.

Technical abilities, educational level and age can also play a dominant role in technology acceptance and its use. Obviously, there are certain limits indicating that a given patient would not be able to operate some systems, even if proper education and technical support was provided.

Motivational tool embedded into technology is more related to a patient’s personality. It can be, for example, the ability to share data with other patients/users or compete with friends who constantly push a patient to achieve good results, a function that is gamesome, or even just the ability to review data from the given device that proves the patient that he or she is doing well or achieves exceptional results.

Also, it is a very effective method both to observe how patients handle given technology in the present and after they get a new one, and to check the data they collect regularly, in order to learn more about their daily regimen, self-management, and potential changes in data entry and frequency of data registration over the long term.

Conclusion

We believe this article can provide relevant guidance on how to help particular patients to choose the best technology that is likely to fit them the most, based on specific patient information we are able to obtain.

Except for the input information we get about a patient, it is obvious that there is a substantial need for proper education of both patients who are to use the systems, and clinicians or educators who should be aware of and continuously updated on the technology a given patient can choose from.

Moreover, with the rapid development of new and more advanced technology, educators specialized in technical-related areas of diabetes management are needed to help with such customization and technical support of patients.

Acknowledgements

This article was supported by the Charles University Grant Agency (CU GA, project no. 362217).
Conflict of interest
The authors have no conflict of interest to declare.

Authors’ Contributions
Authors AH, MV and JM were involved in technical education and support, patients’ interviews, data collection and its monitoring. JB contributed to the patients’ interviews and clinical supervision. All authors contributed to the data analysis and its interpretation and editing of the manuscript.

Multimedia Appendix 1
Diani web application screenshots.

References


**Abbreviations**

CGM: Continuous glucose monitoring

GSM: Global system for mobile communication

MDI: Multiple daily injection

PA: Physical activity
SD card: Secure digital card
SIM: subscriber identity module
SMBG: Self-measured blood glucose
T1D: Type 1 Diabetes