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COMMENTARY

Application of Telemedicine in Diabetes Care: The Time is Now

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ABSTRACT

The utilization of telemedicine solutions to reduce outpatient clinic visits and visits to physicians' offices, thus saving financial and personal resources as well as time, has gained substantial importance in recent years. The COVID19 pandemic has made it necessary to abruptly adjust outpatient care methods in various medical settings that needlessly require consultations in person to monitor and change the disease management of patients in specific risk groups. People with diabetes represent a vulnerable population who need to be protected from avoidable outpatient clinic visits, particularly in times of influenza or other pandemic outbreaks. However, the treatment and care of patients with diabetes and its comorbidities require careful and regular monitoring and therapy adjustments by medical staff. Advanced age or cognitive impairment and insufficient access to the health care system due to low socioeconomic status can complicate the use of possible alternatives to in-person consultations in outpatient clinics or physicians' offices. Telemedicine solutions may offer suitable alternatives to standard face-to-face consultations in outpatient settings and provide sufficient access to appropriate diabetes care. Nevertheless, telemedicine methods for monitoring diabetes issues are yet to find widespread use due to numerous barriers, such as a lack of acceptance and doubt about its time- and cost-effectiveness, availability, and potential technical and regulatory issues. This article offers an overview of existing applications that provide telemedicine diabetes care. Furthermore, it discusses potential ways to restructure and revolutionize diabetes outpatient care.

Keywords: Diabetes; Telecare; Telediabetology; Telehealth

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Key Summary Points
Recent pandemic developments have made it necessary to reduce onsite visits to outpatient clinics of hospitals.
Telemedicine for diabetes patients has been shown to have a positive impact on glucose control, therapy adherence, and financial aspects.
Advances in diabetes technology and telecommunication tools have contributed to the broad availability of telemedical solutions.
There are still, however, barriers to telemedicine use in terms of acceptance, lack of knowledge, technical issues, and regulatory limitations.
This commentary summarizes a number of telemedical possibilities that should inspire physicians to facilitate and modernize diabetes care.

DIGITAL FEATURES

This article is published with digital features, including a summary slide, to facilitate understanding of the article. To view digital features for this article go to https://doi.org/10.6084/m9.figshare.13483197.

INTRODUCTION

The principle of "social distancing" is considered key to interrupting the spread of potentially fatal communicable diseases, as is the case with the current coronavirus disease 19 (COVID19) pandemic. While there has previously been a lack of acceptance and application of telehealth methods, especially in the Western world, they have been used in several medical settings to reduce the need for patients to consult physicians onsite. Telemedicine has several potential advantages. First, as mentioned before, the need for the patient to be physically present in the clinic/physician's office is diminished, which reduces the exposure of health care workers to contagious people, aerosols, and surfaces. Second, in cases where there is a large geographic distance between the patient and the clinic, telehealth saves travel time and costs. Third, medical personal can be relieved from the workloads associated with onsite visits and can perform consultations from a home office if required. This is a major advantage, as healthy hospital staff are frequently advised to isolate at home due to potential contact with infected people or because they are asymptomatically infected, and telehealth allows them to continue to engage in their intended work. Fourth, the utilization of telehealth solutions in diabetes care can enable broader access to the health system and specialist care, particularly for underserved populations and minorities.

People with diabetes, specifically those with poor glycemic control [1], have been identified as a risk cohort that needs to be particularly protected from infectious diseases such as seasonal flu and COVID19. Data provided by NHS England reveal that one-third of the COVID19 deaths in the United Kingdom are associated with diabetes, that patients with type 1 and type 2 diabetes have a 3.5-fold and twofold higher risk of dying from COVID19, respectively, and that this enhanced risk can be attributed to diabetes-related vascular comorbidities [2, 3].

Current diabetes guidelines recommend diabetologist or general practitioner consultations at least every 3 months to measure HbA1c and, if applicable, adjust the diabetes therapy and optimize the treatment of cardiovascular risk factors [4]. It should be noted that regular patient presentations and exams in the outpatient setting are required not only to optimize diabetes control but also to effectively treat related comorbidities (diabetic foot syndrome and diabetic retinopathy). However, it has been speculated that the majority of individuals with diabetes, which is a chronic and mostly incurable disease, do not necessarily need to regularly present themselves physically at outpatient clinics or doctors' offices, especially when

alternative services that can guide disease management are available.

Telediabetology is dedicated to supporting and guiding diabetes management digitally, and aims to reduce onsite visits. Tchero et al. published a meta-analysis in 2019 that focused on the clinical effectiveness of telemedicine in diabetes. They showed significant HbA1c reductions in the group that was supported by telehealth care. Intriguingly, people with type 2 diabetes, specifically the elderly, benefited most [5]. Specific disease management programs incorporating telemedical solutions that are contractually provided by health insurance companies have been introduced (e.g., in Germany). More than 2,000 diabetic patients with diabetes were supplied with diabetes telehealth care as part of their contracts with cost bearers, and the results regarding HbA1c reductions and user/patient acceptance were promising [6].

However, there are a variety of barriers to the acceptance of telemedicine in diabetes, including a lack of technical knowledge and specific training, missing standards, doubt about its efficacy and success rate, and altered practitioner/patient interactions, all of which negatively impact the acceptance of telemedicine by practitioners [7]. Additionally, regulatory issues such as a lack of funding or reimbursement have been blamed for the limited uptake of telemedicine in diabetes care.

Thus, carefully considered structures, experienced personnel, and appropriate technical support must be provided to ensure that telediabetology is feasible. This article aims to summarize available telediabetology-related technology that can facilitate and potentially revolutionize outpatient diabetes care. The possibilities of telediabetology are summarized in Fig. 1.

This article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by any of the authors.

AVAILABLE TELEDIABETOLOGY SOLUTIONS

Telephone/Video Calls for Telediabetology

Increasing patient contact, by including more frequent telephone calls, has been shown to improve patient motivation, therapy adherence, and metabolic control [8]. Due to the widespread availability and usage of (mobile) phones, such interventions to monitor treatment goals can be established easily and flexibly. For example, phone calls can be scheduled as an adjunct following an outpatient clinic visit. A therapy management plan diary incorporating dates of telephone visits can be handed out during the onsite visit, and clinical recommendations such as the frequency of self-monitoring of blood glucose values (SMBG),

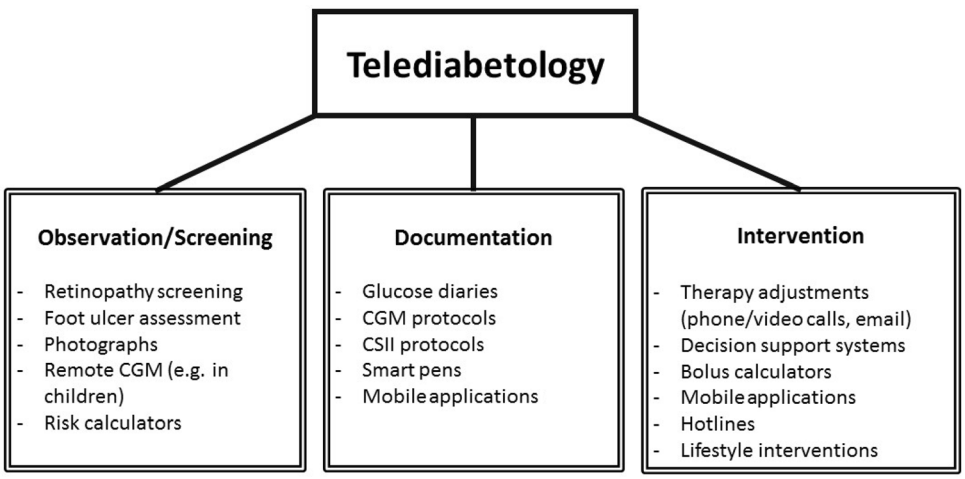

Fig. 1 The possibilities of telediabetology

recommendations for insulin therapy, and physical activity or dietary advice can be given to evaluate the effectiveness and adherence of these measures during later telephone visits. Moreover, to build a personal bridge and allay potential fears of contact with a foreigner, it makes sense to introduce the patient to the person who will be calling them. Thus, the phone contact frequency can be adapted to the patient's requirements or prespecified program schedules. In this context, web-based psychoeducational interventions have helped adults with both type 1 and type 2 diabetes to cope with depression and emotional distress [9]. In the pediatric setting, the use of frequent video consultations as an adjunct to regular care was found to lower the burden of disease and improve treatment satisfaction in patients with limited evidence of improved glycemic control [10, 11], and has shown promising levels of acceptance among diabetes professionals [12].

Additionally, a hotline number can be offered that allows the patient to proactively contact the treating center in the event of emergencies or device problems, or for other diabetes-related inquiries. Video calls might also be suitable for face-to-face appointments with selected patients who need to see the face of the healthcare professional to build up trust and confidence in those guiding their daily therapy. Similarly, the healthcare professional can better assess the mood and motivation of the patient during a video call. A further advantage of video calls is the chance to properly inspect glucose data documented in a conventional paper diary.

Lastly, virtual training sessions via telephone or video calls have been introduced in clinical practice, enabling remote training on specific diabetes-related aspects such as handling technical devices, dietary advice, or behavioral recommendations.

Advanced Telediabetology Methods Based on New Technologies

Mobile Applications

As paper-based diabetes diaries are often incomplete and potentially incorrect (due to a lack of readability, missing information, or misinterpretation), mobile applications that can overcome some of these issues have been developed. In 2017, more than 1,500 diabetes-related mobile applications were available in app stores, making diabetes-related apps the most common type of disease-related apps [13]. The majority of mobile applications used for diabetes management are designed for various platforms, providers, and devices. They integrate some basal/bolus insulin documentation tools (which may include a bolus calculator), give information on carbohydrate counting, and provide automated feedback on users' glucose patterns. Regardless of the limitations of the studies conducted, these mobile tools have positively affected outcomes, improving HbA1c levels, reducing the frequency of hypoglycemic events, and increasing quality of life in type 1 and type 2 diabetes patients, for example [8, 13]. Health data gained from mobile applications can usually also be converted to transferable data, which can be shared with healthcare providers with the user's consent (commonly via the acceptance of email-based invitation links).

Continuous/Intermittently Scanned Continuous Glucose Monitoring Systems

Nowadays, due to their improved accuracy and acceptance as well as relatively liberal reimbursement criteria in many countries, most people with diabetes and complex insulin therapies can make use of continuous glucose monitoring (CGM) systems. These systems report real-time glucose values gained from sensors that measure glucose in the interstitial fluid. Through the real-time transfer of glucose values to a reader or smartphone (when using CGM) or by deriving glucose data from scans (intermittently scanned glucose monitoring), the frequency of capillary glucose measurements can be substantially reduced. The use of these systems has also significantly improved glycemic control, treatment adherence, and quality of life [14–16]. Recently, a consensus endorsed by the American Diabetes Association and Advanced Technologies and Treatments for Diabetes (ATTD) defined new strategies for assessing glycemic control in diabetic individuals who use such systems [17, 18]. The usual

approach to assessing glycemic control is for the patient to regularly (generally every 3 months) meet their treating physician, who will then gauge glycemic control based on HbA1c results and paper-based diaries. However, with the increasing use of CGM systems, glycemic control can be evaluated remotely via CGM reports—which include data on time spent in different target ranges, the glucose management indicator (GMI, a substitute for HbA1c), and the percentage of the sensor used in a given time—without the need to perform a HbA1c test. CGM system recorders can also be used to document insulin injections, meal intake, or other events such as sports or illness.

On the one hand, users can assess their current glycemic control and adjust their therapy if needed. On the other hand, CGM reports can be quickly delivered to the treating physician (via email or directly via the platform with the user's permission) and then discussed during a telephone call between healthcare professionals and the person with diabetes. Insulin pumps and CGM systems from the same manufacturer (e.g., Medtronic) or systems from different manufacturers that communicate with each other (e.g., Tandem and Dexcom) allow combined documentation of insulin delivery and glucose values. This is also possible when using specific software solutions, such as Diasend. Using these tools, CGM data, insulin doses, and food intake can easily be visualized and discussed between users with diabetes and healthcare professionals.

Remote CGM has also been implemented in pediatric diabetes management. The opportunity for real-time glucose monitoring has been shown to have a beneficial impact on the parents' or caregivers' sentiments regarding their child's sleep quality, glucose control, individual freedom, and confidence. This is especially relevant when children are not close at hand (during the night or during daycare/school/-camps), and is supported by the fact that, aside from in the domestic setting, caregivers and educators are often inexperienced and insecure about assuming the responsibility for diabetes control in pediatric patients [19].

Remote CGM might also be applicable in appropriate hospital settings such as isolation rooms where hygienic standards prevent frequent regular glucose measurements. The efficacy and safety of managing glucose control via remote CGM in the hospital setting have been demonstrated via case reports, but they undoubtedly need further attention [20]. To date, CGM systems are not intended for use in the hospital setting by manufacturers.

Smart Pens

Smart pens have been specifically developed for pediatric care, cognitively impaired patients, and those with insufficient therapy adherence. These devices automatically record the amount and timing of insulin application and wirelessly transmit the information to mobile apps that interact with them. Smart pens provide a more reliable and transparent picture of dosing behaviors, which can help the user to keep track of previously administered insulin doses and administration times [21]. Collected data can also be transferred to digital glucose diaries and delivered to health care professionals, thus supporting diabetes telecare. In study settings, potential benefits for glycemic control and insulin dosing behavior were demonstrated [22]; however, in reality, smart pens are still only rarely used in clinical practice due to their costs, lack of coverage by insurance companies, and availability issues.

Decision Support Systems for Insulin Therapy

Considering that insulin therapy is often complicated and tricky to adjust and manage in outpatient settings, standardized decision support systems for home care may be useful for overcoming some of these barriers. Specifically, in vulnerable populations such as older adults who require domiciliary nursing care or those who live in nursing homes, such systems may facilitate the attainment of adequate glycemic control. This approach may avoid the need for diabetes-related unscheduled patient presentations to practitioners, emergency rooms, or hospitalizations. One of these systems, incorporating a basal algorithm and a basal plus insulin algorithm, was tested within a proof-of-concept study on patients with type 2 diabetes who were receiving domiciliary nursing care

under routine conditions [23]. Preliminary results showed that admissions to the hospital due to hypo- or hyperglycemic derailment is substantially reduced while glycemic control is improved by using this system. Furthermore, user acceptance (where users included the nursing staff and affected patients and their relatives) was high [24]. Also, in people with type 1 diabetes, remote insulin dose adjustments provided by an electronic algorithm-based decision support system were investigated and found to produce results that were noninferior to physicians' recommendations in terms of time in target and safety (e.g., hypoglycemia and ketoacidosis) [25]. Note that, due to safety issues, no system that allows the proactive remote control of insulin therapy has been launched; therefore, such systems need to be tested further in a broader population.

Diabetes Screening

It is thought that almost half of all diabetes cases worldwide are unrecognized. The majority of these cases are assumed to occur in low- or middle-income countries [26]. Screening to identify asymptomatic individuals who are likely to be affected by diabetes is recommended for those > 45 years of age or those with a positive family history, those who are overweight/obese, or those from specific ethnic groups [27]. A simple online tool to estimate the risk of developing diabetes was launched during the COVID19 pandemic by Diabetes.uk. This online service requires user-based input of specific risk factors for the development of diabetes and uses this input to estimate the individual's diabetes risk. If the tool calculates an increased risk, fast access to the NHS Diabetes Prevention Program is guaranteed and can easily be arranged by a hotline call. Additionally, instructions for achieving a healthy lifestyle and appropriate cooking recipes can immediately be gathered from the website. During the first 3 months after going live, almost 300,000 people had used the tool. Of those, 5,000 self-referred to a practitioner for laboratory screening for diabetes due to positive prescreening results [28].

Lifestyle Modification

The keystone of glycemic control in people with prediabetes and overt type 2 diabetes remains dietary adaption and intensification of physical activity to reduce body weight [29]. Several telemedical programs have been conducted, including diabetes prevention programs and randomized controlled trials. The methods used included regular phone and video calls, virtual education sessions, remote exercise and dietary coaching, as well as virtual physical exercise sessions. A recent meta-analysis including 17 studies lasting between 3 and 12 months that employed telemedical lifestyle modification measures revealed modest reductions in HbA1c (− 0.3%) and weight (− 0.6 kg), and it was suggested that automated mobile transmission or a real-time feedback modality strengthened the efficacy of these interventions [30].

Telediabetology in Diabetic Foot Care

Video/Telephone Consultations

As well as being useful for evaluating diabetes therapy and for glucose management, telediabetology may also be appropriate for visually assessing potential diabetes-related complications. Video calls could be suitable for evaluating issues that are apparent visually on presentation, such as diabetic foot syndrome, skin issues caused by insulin injections or CGM systems, and technical problems relating to insulin delivery systems or glucose sensors.

In particular, the monitoring of diabetic foot ulcers via online consultations has shown a similar efficacy in terms of healing tendency or foot-related adverse events (such as amputations) to frequent, regular onsite visits, as demonstrated by two randomized controlled trials [31, 32]. However, in the study conducted by Rasmussen et al., mortality was higher in the telemedicine group. The authors could not explain this finding, but it may be linked to covariates (smoking status, comorbidities, etc.) that were not assessed in detail in their study [32]. Additionally, there was no significant cost reduction for the group receiving telemedicine care [33]. In subsequent studies, specific factors that were critical to effective diabetic foot

telecare were identified: technology and training, user-friendliness, people in charge who facilitate the intervention, the need for support from leaders, as well as appropriate communication at the structural level [34, 35].

Screening Devices for Self-Monitoring of Ulcer Recurrence or Progression

Self-performed patient foot temperature assessments based on various methods of measuring foot temperature changes substantially influence diabetic foot ulcer recurrence, as shown in three well-designed randomized controlled trials [36–38]. The regular application of various temperature-sensing methods (infrared thermography, liquid–crystal thermography, thermistor-based temperature sensors) at various points on the foot enables early detection of potential (re)ulcerations that require urgent examination at a clinical center while also eliminating unnecessary patient presentations at the physician's office. However, in a study performed by Skafjeld et al., temperature self-monitoring was not superior to commonly recommended visual foot inspections performed daily [38]. Also, systems for determining tissue oxygenation with hyperspectral imaging have been developed. Nevertheless, these devices have mainly been tested in clinical settings, and insufficiently defined endpoints are the main reason why they have not found widespread application [35]. Similarly, photographic imaging tools that primarily check for changes in ulcer size have thus far been overlooked in terms of their potential commercial application to telemedical monitoring of diabetic foot problems; future research into such tools is still required [35].

In summary, patients with diabetic foot syndrome require clinical attention, education, and motivation to self-monitor. Further research into whether telecare methods can be feasibly, cost-effectively, and safely applied to this vulnerable cohort of patients is needed.

Telediabetology in Diabetic Retinopathy

Recently, the American Telemedicine Association published a practice guideline for ocular telehealth for diabetic retinopathy (DRP) that aimed to assist providers in offering safe and effective medical care when employing telehealth services, implying that telehealth for the screening and monitoring of diabetic eye disease has been widely introduced into routine clinical care [39]. Ophthalmology, which is highly visual and image intensive, is optimally suited for telemedicine and telescreening [40]. In particular, in developing countries, where access to health care systems is limited and large proportions of the population live in rural areas, inexpensive, easily applicable, and reliable tools and staff who are trained to conduct eye investigations are needed.

Screening for Diabetic Retinopathy

Impairments in vision are usually asymptomatic early in the development of DRP, soon after the diagnosis of diabetes of any kind. Therefore, regular screening for diabetic retinopathy is recommended given that eye interventions (e.g., photocoagulation) have the greatest therapeutic benefit when they are performed during the early stages of DRP [41–43]. A wide variety of simple retinal cameras that can be used by trained non-ophthalmologist personnel have been developed. These systems have mainly been introduced into clinical practice in countries with limited financial resources and/or with limited access to the usual DRP screening programs. The systems should help countries to identify people who require a consultation with an ophthalmologist. For example, data gained from a feasibility study performed on more than 1,600 diabetic individuals living in rural and underserved regions of North Carolina demonstrated that access to DRP screenings could be substantially increased from 25% to more than 40% of all diabetic individuals. Furthermore, the authors concluded that those with suspicious results were more rapidly and selectively referred to an ophthalmologist [44].

DISCUSSION

Diabetes is a significant public health concern worldwide, and is estimated to have become the

seventh leading cause of death in the USA [45]. It is well known that a large proportion of those with diabetes do not achieve their individual glycemic goals. In many cases, this can be attributed to low adherence to therapy or a lack of awareness of the consequences of uncontrolled diabetes (comorbidities and mortality) [46].

Considering the increasing number of people with diabetes worldwide and the large proportion of those people who do not have access to specialist care, we need to establish time-saving, cost-effective, user-friendly, and practicable options and alternatives for providing optimal diabetes care. Thus, we should aim to implement appropriate diabetes care for those who have limited access to the health care system, particularly those who struggle to perform regular onsite visits, such as (1) people who live in rural areas where long distances must be traveled to reach a clinic, (2) people who are socially disadvantaged and cannot be properly integrated into the usual health care supply, and (3) those who are physically or cognitively unable to visit health institutions regularly. On the other hand, in the case where a patient presents regularly at an outpatient clinic, alternative options may be preferable to face-to-face visits.

In this context, during the COVID19 pandemic, health care providers have been instructed by hospital management to reduce the number of onsite visits in order to mitigate the potential for exposure to the virus. Specifically, people living with diabetes are at considerably higher risk for community-acquired and nosocomial infections. Therefore, they should be protected from having to needlessly visit medical institutions, but they should still receive adequate care.

Patient care using telemedical solutions has been introduced into various medical disciplines and may offer a practicable alternative to onsite visits. Progressive advances in digitalization and diabetes technology have increased the applicability of telediabetology as an adjunct to or replacement for regular onsite presentations. However, there are several barriers and pitfalls that explain why it is scarcely employed in diabetes care. These barriers were summarized for patients with type 2 diabetes in a systematic review by Alvarado et al. They distinguish between barriers that are patient-based (low education, technology illiteracy, lack of in-person contact with the healthcare provider, low individual belief inefficacy), technological access-based (unavailability or expense of the required technology, no internet access), or design-based (lack of customization to patient preferences and needs, lack of transparency, accuracy, and reliability, lack of timing of online visits, and intensive workload for healthcare providers). In addition, increasing concerns about data protection and the need to consent to data insight complicate the use of telemedical solutions. Several suggestions of ways to eliminate or reduce these barriers have been tentatively discussed and summarized in a conceptual model that integrates patient engagement, accessibility, the compatibility and usability of technical devices, technology cost reduction, provider productivity, and quality of care [47]. Successfully overcoming these barriers requires motivation, acceptance, encouragement of the use of health care providers, political and structural adjustments, collaborations with companies working in diabetes technology, and—most notably—patient awareness of the need to adopt diabetes care in an outpatient setting. Lastly, additional scientific evidence gained from randomized controlled trials is needed to obtain strong evidence of the efficacy and acceptance of telediabetology.

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Compliance with Ethics Guidelines. This article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by any of the authors.

Data Availability. Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

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