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REVIEW ARTICLE

Telemedicine for the Clinical Management of Diabetes; Implications and Considerations After COVID-19 Experience

Saula Vigili de Kreutzenberg[1]

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Abstract
Telemedicine is a clinical approach that was seldom used in the day-to-day practice, if not only in certain settings, before the COVID-19 pandemic. As stated by the WHO, telemedicine is: the delivery of health care services, where distance is a critical factor, by all health care professionals using information and communication technologies (ICT) for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, …. Telemedicine has actually represented the most useful and employed tool to maintain contacts between patients and physicians during the period of physical distance imposed by the pandemic, especially during the lockdown. Diabetes in particular, a chronic disease that often needs frequent confronting between patient and health professionals has taken advantage of the telehealth approach. Nowadays, technological tools are more and more widely used for the management of diabetes. In this review results obtained by telemendicine application in type 1 and type 2 diabetic individuals during COVID-19 are revised, and future perspectives for telemedicine use to manage diabetes are discussed.

Keywords COVID-19 · Telemedicine · Continuous glucose monitoring (CGM) · Type 1 and type 2 diabetes

1 Introduction

Corona Virus Disease 2019 (COVID-19) was classified a pandemic disease on March 11, 2020 [1]. Its global spreading in such a short period of time has totally upset Health Care systems worldwide as never before, and consequently deeply upsetting normal patient care. COVID-19 infection has overwhelmed the health systems with affected patients, strongly reducing or even abolishing hospital access for patients affected by other diseases, in particular chronic diseases. This effect was due not only to the diversion of Public Health resources, but also because healthy individuals were afraid to come to the Hospital or Clinic as they may contract the infection. Follow-up visits, diagnostic exams and drug supplies that had been planned and programmed well in advance, suddenly became unattainable, and therefore the relationship between patients and physicians needed to be reinvented in order to keep under control these diseases. Definitely, this pandemic has changed the management of chronic diseases, such as diabetes mellitus, and the routine interaction between patients and physicians.

In this scenario, with a swift and abrupt acceleration, telemedicine, an instrument seldom used in particular health contexts, revealed to be a pivotal and undeniably useful tool for all chronic disease management, and not only for diabetes, in particular during the lock-down periods, which were characterized by extremely restrictive measures on free movement and profound changes in daily activity across several Countries.

Indeed, telemedicine played a central role during the COVID-19 pandemic, that till now has interested more than 412 million of cumulative cases and almost 6 million deaths around the world [2].

During the first wave of the COVID-19 pandemic, telemedicine has been strongly implemented, allowing a confront that was otherwise impossible. As an impressive example, any form of telemedicine (including telephone consultations) was considered illegal in India, until the COVID-19 pandemic [3], but suddenly it became the most important interface communication between the health system and the patients. Telemedicine was the most frequently utilized technology during the pandemic [4], and diabetes management,

✉ Saula Vigili de Kreutzenberg
saula.dekreutzenberg@unipd.it

[1] Department of Medicine-DIMED, University of Padova, Via Giustiniani, 2, 35128 Padua, Italy

as other chronic diseases, has so far relied on telemedicine to mitigate some of the disastrous consequences of COVID-19.

Telemedicine, as stated by the WHO, is "The delivery of health care services, where distance is a critical factor, by all health care professionals using information and communication technologies (ICT) for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, research and evaluation, and for the continuing education of health care providers, all in the interests of advancing the health of individuals and their communities" [5]. COVID-19 is responsible for having created an unbridgeable distance between patients and physicians, where diabetes represents one of the main targets for ICT application, aimed to medical treatment and education.

Indeed, during COVID-19 pandemic, telemedicine has been applied in several chronic non-communicable diseases, such as arterial hypertension [6], ensuring an effective management of these conditions even during the impossibility of a face-to-face relationship between patient and physician, and in heart failure [7], when continued access to in-person visits and use of intravenous diuretics was not essential to prevent decompensation. There is much evidence to demonstrate that telemedicine is a valid, safe, and satisfactory clinical option for daily management of chronic diseases, in particular cardiovascular diseases [8].

In the next sections main results obtained through the application of telemedicine for the management of diabetes during COVID-19 pandemic will be revised. This experience has highlighted and magnified the use of telemedicine as a useful, safe, effective, and unique tool, whose possibilities can go much further than the forced distance between patients and the health care system imposed by COVID-19, becoming a long-lasting irreplaceable approach for diabetes management even after the pandemic.

Some implications and considerations will also be discussed.

2 Diabetes During COVID-19

Diabetes is one of the most diffuse chronic diseases worldwide, affecting millions of people, and also one of the leading comorbidities in those who have died from COVID-19 infection [9], only second to hypertension [10, 11]. Moreover, the risk of dying in hospital with COVID-19 appears to be 3.5- to 5-fold higher in type 1 diabetes and twofold in type 2 diabetes compared to non-diabetic patients [12, 13]. The presence of diabetes, as well as of other comorbidities, significantly worsens the clinical conditions of COVID-19 infected patients, increasing the risk of adverse outcomes, including mortality [14–16]. On the other hand, having diabetes does not seem to facilitate the infection of Corona Virus [14, 16].

In any case, the most relevant challenge related to diabetes, during the pandemic has been the day-to-day handling of metabolic control. Chronic diabetes management is far from simple, implying several skills and capabilities, related not only to insulin administration and self-blood glucose monitoring, but also to a correct nutrient assumption, subcutaneous drug administration, and eventually to the use of insulin pumps, and more sophisticated continuous glucose monitoring (CGM) devices. Type 1 diabetes, in particular, necessitates a complex educational intervention, and frequent follow-up visits, to maintain good glucose control, to avoid acute hyperglycemic crisis or dangerous hypoglycemic events, and prevent chronic complications. On the other hand, type 2 diabetes affects more than 90% of all diabetic subjects, requiring a large number of Public Health resources, especially due to chronic micro- and macrovascular complications prevention and control. Therapeutical approaches of diabetes, besides the skill of insulin or other subcutaneous drug administration, often require technical learning and comprehension, and consequently the need of teaching the patients the correct application and use of devices for glucose determination, or insulin delivery systems. Therefore, diabetic patients cannot be left alone to manage their disease, and during the coronavirus pandemic this has become a real and pressing health problem. During the COVID-19 pandemic, the booking of routine clinical appointments was often interrupted or not allowed, and therefore, telemedicine has represented the lifeline, being also one of the strategic priorities supported by the WHO [17].

3 Telemedicine and Diabetes Management During COVID-19

Telemedicine and remote continuous glucose monitoring (CGM) are the two health-related technologies most diffused during the pandemic, becoming essential tools in the management of diabetes [18]. These approaches have been endorsed by several guidelines, planned and fully investigated, to culminate in the proposal of virtual diabetes clinics [3, 4, 19–21].

Before the COVID-19 diffusion, the use of telemedicine for the management of diabetes was demonstrated reliable and effective, in adult and in children, in both types of diabetes [22–28], but its application in clinical practice was limited, except in certain situations. As an example, telehealth visits were performed in rural areas of the USA, to provide diabetic patients continuous learning about their disease, access to telemedicine visits with diabetologists, dieticians, and diabetes educators. In this setting, a significant decrease in glycated hemoglobin, and a significant increase in the percentage of individuals with HbA1c at target were observed.

Moreover, a good patients' satisfaction with the use of this technology for follow-up care was observed [29].

Many studies have demonstrated flash and continuous glucose monitoring (CGM) improve glycemic control in subjects with type 1 diabetes, during COVID-19 [30–39]; fewer studies have evaluated the impact of glucose monitoring in subjects with type 2 diabetes, before an during the pandemic [40–43], however, demonstrating that CGM can improve glycemic control also in T2D patients, with a high degree of satisfaction [41]. The possibility of uploading data from continuous glucose monitors (CGM) and insulin pumps, along with telephone or tele-video consultation has been extremely useful in managing diabetes throughout all the COVID-19 pandemic [44]. But even people not using CGMs or pumps, like older type 2 diabetic patients practicing flash glucose monitoring (FGM), or nothing, have had the opportunity to contact their diabetologists through telephone calls, smartphones, or via other internet tools (freeware or mobile applications or web platforms), approaches that guaranteed the essential interrelationship between patient and physician [45].

3.1 Type 1 Diabetes

Telemedicine displays a wide range of use, especially in the management of type 1 diabetes, a disease that very often takes advantage of several technological tools, that can be supervised via web. Although a global worsening in metabolic control secondary to a dramatic reduction in access to medical services and laboratory testing was expected during COVID-19, surprisingly, most of the studies published throughout the pandemic have demonstrated significant improvements of glucose metrics either in adults [31–35, 37–39] or in children [46, 47] affected by type 1 diabetes, and telemedicine application surely contributed to these results. Remote consultations and the possibility to access frequent data on glucose trends through telemedicine have permitted to reach encouraging results in T1D population, definitely demonstrating that remote consultations and commonly shared data access can improve clinical outcomes and the patients' quality of life [48].

Among several studies published on the effective use of telemedicine in type 1 diabetes, since the rapid spread of COVID-19 began, world-wide, a Saudi Arabian study demonstrated that telemedicine visits were associated with a significant improvement of several glucose metrics in T1D individuals, compared to patients who did not adopt this kind of communication [49]. In this geographic area, access to telemedicine was strongly approved by patients, although most of them had not used telemedicine before, the transition from face-to-face visits to telemedicine appeared sustainable and smooth, due mainly to the wide availability of access to internet, and the extremely high use of smart devices [50]. Even in worse situations, as in Jordan, where insulin shortage and glucose monitoring strips rationing were suffered during the lockdown period, telemedicine was perceived by patients and their families, as an extremely useful tool for guidance and support [51].

Danne et al. have reviewed 27 studies conducted in the period March 2020-2021, evaluating glucose control in T1D patients [36]. Several glucose monitoring devices were employed, and overall, glycemic control did not deteriorate in 25/27 cohorts but instead improved in 23/27 studies, during this period, characterized by the lock-down-indetermined impossibility to access out-patient diabetic clinics. These reassuring results are possibly attributable to the implementation of telemedicine or telemonitoring, even if the forced staying at home, and a more regular lifestyle also have contributed to improve T1D management, especially through an increased regulation of meal assumptions, more time spent sleeping and less work-place stress [33, 37, 38]. The most extensive of these studies evaluating an active telemedicine intervention was performed in the USA, and enrolled 65,067 users of real time CGM system. A comparison was made between data obtained before and during the COVID-19 pandemic, and a significant improvement was observed during the pandemic with respect to the pre-pandemic period [52].

The most frequent technological tool taken into consideration in these studies was, as already said, the continuous glucose monitoring (CGM) system. The availability of CGM devices has enabled diabetic patients and physicians to share and discuss together the remote blood glucose metrics and glucose profile downloads during this period. Data obtained from CGM have shown the significant improvement of several glycaemic indices, such as glucose time in range (TIR), time above range (TAR), time below range (TBR), and glucose variability [53, 54]. As a consequence, an amelioration of glycated haemoglobin was observed. The opportunity to monitor such parameters, and not only glycated haemoglobin, is of extreme relevance, in the daily management of diabetes, since in the long-term it associates with reduction of micro- and macrovascular complication development, in both types of diabetes [55–58].

Garofalo et al. have performed a meta-analysis of 17 European observational studies on the effect of lockdown period on glucose control, in T1D subjects on both multiple day injections (MDI) or continuous subcutaneous glucose infusion (CSII), utilizing continuous or flash glucose monitoring [59]. A slight but significant improvement was found in many glucose metrics, during the lockdown period, with both treatments, thanks to telemedicine. In another study from Finland, conducted in children patients treated with insulin pumps, an improvement of their glucose control, showing in particular, significant amelioration of TIR and mean glucose values, was demonstrated during

the lockdown, with respect to the pre-lockdown period [60]. T1D adults using the most sophisticated therapeutical approach, i.e. the hybrid closed loop system, also called artificial pancreas, were able to obtain an improvement in most glucose metrics, during COVID-19 [61], while being followed by a telemedicine strategy. Overall, this meta-analysis and these studies agree on demonstrating the relevance of telemedicine and telehealth strategies that, through remote access to sensor data allow a more correct management of T1D, even in patients treated with advanced technologies. Of course, these favorable results are ascribable, as well as to telemedicine, to a more cohesive family environment, to a better attention to the care of diabetes, and to change of lifestyle habits imposed by the lockdown.

Another important issue related to type 1 diabetes management is the new onset of the disease, that is almost always symptomatic and abrupt, affecting mostly children and young adults. It represents a very stressful condition, often inducing an important psychological involvement, and the disease can be treated only with insulin. Therefore, its management is unfeasible without learning insulin administration technique, education to self-monitoring and insulin titration. A strict and frequent information exchange between patient and diabetologist is essential in this context and during the lockdown periods telemedicine was the only possible approach able to fill the gap of distance imposed by COVID-19, both in pediatric and in adult patients [62, 63]. Although case report numbers are limited, telemedicine can be used safely and effectively for training and education of new onset T1D.

Other important aspects of T1D management are the prevention of acute diabetic ketoacidosis or hypoglycemic episodes. By delivering health care through telemedicine, these acute complications of diabetes can be successfully treated [64, 65]. A randomized controlled trial performed in Italy pre-COVID-19, utilizing a telemedicine system based on an automatic carbohydrate/insulin bolus calculator had demonstrated a significant reduction of the risk of moderate/severe hypoglycemia and improved quality of life [65]. To summarize, telemedicine application to T1D management is extremely helpful, safe and cost-effective.

3.2 Type 2 Diabetes

Similar positive results as those observed in T1D, were found in type 2 diabetes patients followed by telemedicine. T2D patients are often elderly people, having a long duration of the disease, often affected by comorbidities and are not practical with internet and technology. Nonetheless, in this population, telemedicine use had been previously demonstrated to be more effective than routine care, providing better results on glucose control. A meta-analysis of 35 randomized controlled trials, performed in the pre-COVID-19 era, showed a significant reduction in glycated hemoglobin in T2D patients treated through telemedicine intervention or via telephone, or via internet employing video-conferencing and/or informational websites or involving electronically transmitted recommendations in response to internet-based reporting by patients, in comparison to controls [66]. Wang et al. demonstrated that a group of T2D randomly assigned to a remote diabetes medical service platform showed significant lower levels of fasting and post-prandial glucose, as well as glycated hemoglobin, and triglyceride levels, after 6 months [67]. Intervention group automatically transmitted glucose data through a glucometer, receiving counselling on medicine, diet, and physical activity. Patients' adherence to the released medical instructions was also enhanced. During COVID-19 pandemic, in India, video consultation was the preferred mode of telemedicine in DM2 patients [68]. Several studies, performed in different Countries, showed that, when telemedicine was implemented, T2D subjects avoided a deterioration of HbA1c and of body weight during the lockdown period [42, 69–71]. This is an important result, since, contrary to T1D, the lockdown often deteriorated glucose metabolism and body weight gain in T2D patients [72].

Another important task performed by telemedicine is the prevention of disruptions in medical prescriptions. Patel et al addressed this issue in a cohort of American adults with type 2 diabetes, finding comparable medication fill rates in 2020 versus 2019, thanks to the use of mail-order pharmacies and pharmacy delivery service, that could ensure that patients receive their medications [73].

Finally, among chronic diabetes complications, retinopathy, the most common one, can be effectively managed through telemedicine. The development of devices for remote evaluation of retinal digital photos, that can also be taken without inducing mydriasis, thus simplifying image acquisition, has shown a very high diagnostic accuracy of telemedicine based on digital imaging technique [74]. COVID-19 pandemic stressed the importance of a telemedicine approach to the screening, diagnosis, and follow-up of diabetic retinopathy [75]. To summarize, telemedicine application to T2D management confirms its undeniable advantages.

4 Implications and Considerations After COVID-19 Experience

Maintenance of euglycemia is the back-bone of the treatment of diabetes mellitus. Nowadays technological advancement allows the measurements of several metrics related to glucose metabolism, beyond glycated haemoglobin, favoring a more accurate control of glucose metabolism and its consequences. During COVID-19 pandemic, telemedicine has become a common practice, providing a great and unique opportunity to effectively manage patients with diabetes,

when face-to-face consultation and outpatient clinic access were denied, especially during the lockdown periods.

One of the outcomes and lessons learned from this pandemic is that the use of telemedicine in diabetes, when feasible, can successfully fill the gap of physical distance, allowing an interface between patient and physician, ensuring patient education to dietary and physical activity plans, to drug auto-administration, to glucose value interpretation and correction, and possibly to availability of medications and glucose testing. Moreover and, of extreme importance, patients were highly satisfied. Telemedicine can take advantage of different intervention modalities, such as real-time video/audio communication, asynchronous communication, and combined communication (real-time and asynchronous) and all these types generally showed improvements in clinical diabetes management, and were appreciated by a wide spectrum of patients. Therefore, favorable results obtained by the use of telemedicine, during the pandemic, strongly suggest a wider use and a key role for telemedicine in the future.

5 Limitations to the Use of Telemedicine and Future Perspectives

Comprehensive International Consensus documents and practical guidelines dedicated to COVID-19 infection management through telemedicine, in people with diabetes, have been proposed by experts from different Countries, and published in 2020 [76, 77]. These documents highlight telemedicine as one of the most attractive options to manage the disease, during the pandemic. However, some potential limitations to use of telemedicine have to be acknowledged. Unfortunately, telemedicine is not always available, especially in underdeveloped Countries, where efficient internet connection, appropriate equipment and technical knowledge are lacking, representing the main objective limitations.

Moreover, several practical and ethical issues still represent a limit to telemedicine use, that have to be resolved before a more diffuse application of this modality of health care: telemedicine technologies require adequate patients and healthcare professional training, accurate data management, and privacy, security protection, reimbursement policy application, and governance guidelines [78–81]. As clearly specified by March et al., in their Editorial, a correct approach to diabetes care through telemedicine, should be a multidisciplinary approach [82]. Practitioners and health care professionals have to become aware of technological, ethical, and legal concerns, such as privacy and data ownership. Moreover, they should be practical on the advancement of this methodology, as well as to involve the patients.

Unfortunately, telemedicine cannot be within everyone's reach, and this is another important consideration to be looked upon: possible availability of telemedicine for all the diabetic individuals, all over the world. The adoption of telemedicine for T1D care was very rapid across the United States [43], and in Europe, but in other Countries or in particular settings, the lack of access to the technology and the unequal coverage of video visits and telephone visits in particular realities may further exacerbate health disparities in diabetes care [81–83].

Finally, it must also be kept in mind that telemedicine not always represents the optimal choice, neither for patients, nor for physicians. Special situations, in particular acute conditions, require face-to-face consultation or immediate hospitalization, and cannot be confronted by telemedicine. Some patients would prefer to physically meet up with their physicians, and not to communicate on a screen. Several psychological aspects linked to telemedicine, must therefore be considered. Cultural or emotional barriers could refuse a telemedicine approach; moreover, a proper physical examination of the patient is of course impossible, if not in presence.

In addition, data till now available are still limited and further research is needed to give telemedicine a well-defined place in the day-to-day management of diabetes.

Notwithstanding possible limitations, the over all experience that the pandemic has allowed to be made on the application of telemedicine in diabetes management has been positive and surely laid the groundwork to expand its use in the future. Telemedicine could become a practical and time-sparing option, for patients, care-givers and physicians, especially when confrontation is needed to discuss glucose prophiles and therapy adjustments, and physical proximity is not necessary. Its application could be expanded, to several specific situations, such as patient education, and advice on physical activity and diet etc., and in the end not only considered in situations such as stated by the WHO definition. Potentialities of telemedicine are really remarkable, and an intelligent and careful application of this innovative approach could improve the management of diabetes, and reduce fearsome clinical outcomes of this chronic disease.

6 Conclusions

In conclusion, the great majority of studies performed in diabetic individuals during COVID-19 confirms the feasibility, sustainability, and effectiveness of telemedicine application during a pandemic. These encouraging results suggest that telemedicine use could find an important place in the

management of diabetes also in the future, obviously and hopefully beyond a pandemic condition. Lastly, an important issue not to be left out, related to telemedicine application is its favorable cost-effective ratio, demonstrated also before COVID-19 era [84, 85]. Telemedicine could also help in reducing racial, ethnic, social disparities often present in health management.

Definitively, the telemedicine experience ensuing COVID-19 pandemic paved the way to new valid possibilities for patients and physicians to successfully manage diabetes mellitus, such as other chronic diseases.

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Declarations

Conflict of interest The author declares no conflicts of interest

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References

1. WHO. Director-General's opening remarks at the media briefing on COVID-19, 2020. https://www.who.int/dg/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-oncovid-19-11-march-2020. Accessed 2 Feb 2022.
2. WHO Coronavirus Disease (COVID-19) dashboard. World Health Organization. https://covid19.who.int/. Accessed 2 Feb 2022.
3. Phillip M, Bergenstal RM, Close KL, et al. The digital/virtual diabetes clinic: the future is now—recommendations from an international panel on diabetes digital technologies introduction. Diabetes Technol Ther. 2021;23:146–54.
4. Abd-Alrazaq A, Hassan A, Abuelezz I, et al. Overview of technologies implemented during the first wave of the COVID-19 pandemic: scoping review. J Med Internet Res. 2021;23(9): e29136.
5. WHO. A health telematics policy in support of WHO's Health-For-All strategy for global health development: report of the WHO group consultation on health telematics, 11–16 December, Geneva, 1997. Geneva: World Health Organization; 1998.
6. Citoni B, Figliuzzi I, Presta V, Volpe M, Toggi G. Home blood pressure and telemedicine: a modern approach for managing hypertension during and after COVID-19 pandemic. High Blood Press Cardiovasc Prev. 2022;29(1):1–14.
7. Bader F, Manla Y, Atallah B, Starling RC. Heart failure and COVID-19. Heart Fail Rev. 2021;26(1):1–10.
8. Ruzzenenti G, Maloberti A, Giani V, et al. Covid and cardiovascular diseases: direct and indirect damages and future perspective. High Blood Press Cardiovasc Prev. 2021;28(5):439–45.
9. Shenoy A, Ismaily M, Bajaj M. Diabetes and COVID-19: a global health challenge. BMJ Open Diab Res Care. 2020;8(1): e001450.
10. Zhou F, Yu Y, Du R, et al. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. Lancet. 2020;395(10229):1054–62.
11. Istituto Superiore di Sanità. Coronavirus. https://www.epicentro.iss.it/coronavirus/sars-cov-2-decessi-italia#4. Accessed 2 Feb 2022.
12. Istituto Superiore di Sanita. Report of characteristics of patients who died positive for COVID-19 in Italy. 2020 (in Italian). https://www.epicentro.iss.it/coronavirus/bollettino/Report-COVID-2019_17_marzo-v2.pdf. Accessed 2 Feb 2022.
13. Mantovani A, Byrne CD, Zheng M-H, Targher G. Diabetes as a risk factor for greater COVID-19 severity and in-hospital death: a meta-analysis of observational studies. Nutr Metab Cardiovasc Dis. 2020;30:1236–48.
14. Fadini GP, Morieri ML, Longato E, Avogaro A. Prevalence and impact of diabetes among people infected with SARS-CoV-2. J Endocrinol Investig. 2020;43(6):867–9.
15. Wu J, Zhang J, Sun X, et al. Influence of diabetes mellitus on the severity and fatality of SARS-CoV-2 (COVID-19) infection. Diabetes Obes Metab. 2020;22(10):1907–14.
16. Wu ZH, Tang Y, Cheng Q. Diabetes increases the mortality of patients with COVID-19: a meta-analysis. Acta Diabetol. 2021;58(2):139–44.
17. World Health Organization. Operational Considerations for Case Management of COVID-19 in Health Facility and Community. 2020. https://www.who.int/publications/i/item/10665-331492. Accessed 17 Feb 2022.
18. Pranata R, Henrina J, Raffaello WM, et al. Diabetes and COVID-19: The past, the present, and the future. Metab Clin Exp. 2021;121: 154814.
19. Kiran T, Moonen G, Bhattacharyya OK, et al. Managing type 2 diabetes in primary care during COVID-19. Can Fam Physician. 2020;66:745–7.
20. Sarveswaran G, Rangamani S, Ghosh A, et al. Management of diabetes mellitus through teleconsultation during COVID-19 and similar scenarios—Guidelines from Indian Council of Medical Research (ICMR) expert group. Diabetes Metab Syndr. 2021;15: 102242.
21. Quinn LM, Davies MJ, Hadjiconstantinou M. Virtual consultations and the role of technology during the COVID-19 pandemic for people with type 2 diabetes: the UK perspective. J Med Internet Res. 2020;22(8): e21609.
22. Lee WC, Balu S, Cobden D, et al. Medication adherence and the associated health-economic impact among patients with type 2 diabetes mellitus converting to insulin pen therapy: an analysis of third-party managed care claims data. Clin Ther. 2006;28:1712–25.
23. Charpentier G, Benhamou PY, Dardari D, et al. The Diabeo software enabling individualized insulin dose adjustments combined with telemedicine support improves HbA1c in poorly controlled type 1 diabetic patients: a 6- month, randomized, open-label, parallel-group, multicenter trial (TeleDiab 1 Study). Diabetes Care. 2011;34:533–9.
24. Bertuzzi F, Stefani I, Rivolta B, et al. Teleconsultation in type 1 diabetes mellitus (TELEDIABE). Acta Diabetol. 2018;55:185–92.

25. Tchero H, Kangambega P, Briatte C, et al. Clinical effectiveness of telemedicine in diabetes mellitus: a metaanalysis of 42 randomized controlled trials. Telemed J E Health. 2019;25:569–83.
26. Wang X, Shu W, Du J, et al. Mobile health in the management of type 1 diabetes: a systematic review and metaanalysis. BMC Endocr Disord. 2019;19:21.
27. De Guzman KR, Snoswell CL, Taylor ML, et al. A systematic review of pediatric telediabetes service models 2020. Diabetes Technol Ther. 2020. https://doi.org/10.1089/dia.2019.0489.
28. Salehi S, Olyaeemanesh A, Mobinizadeh M, et al. Assessment of remote patient monitoring (RPM) systems for patients with type 2 diabetes: a systematic review and metaanalysis. J Diabetes Metab Disord. 2020;19:115–27.
29. Maxwell LG, McFarland MS, Baker JW, Cassidy RF. Evaluation of the impact of a pharmacist-led telehealth clinic on diabetes-related goals of therapy in a veteran population. Pharmacotherapy. 2016;36:348–56.
30. Brener A, Mazor-Aronovitch K, Rachmiel M, et al. Lessons learned from the continuous glucose monitoring metrics in pediatric patients with type 1 diabetes under COVID-19 lockdown. Acta Diabetol. 2020;57:1511–7.
31. Fernandez E, Cortazar A, Bellido V. Impact of COVID-19 lockdown on glycemic control in patients with type 1 diabetes. Diab Res Clin Pract. 2020;160: 108348.
32. Maddaloni E, Coraggio L, Pieralice S, et al. Effects of COVID-19 lockdown on glucose control: continuous glucose monitoring data from people with diabetes on intensive insulin therapy. Diabetes Care. 2020;43(8):e86–7.
33. Capaldo B, Annuzzi G, Creanza A, et al. Blood glucose control during lockdown for COVID-19: CGM metrics in italian adults with type 1 diabetes. Diabetes Care. 2020;43(8):e88–9.
34. Mesa A, Vinals C, Pueyo I, et al. The impact of strict COVID-19 lockdown in Spain on glycemic profiles in patients with type 1 diabetes prone to hypoglycemia using standalone continuous glucose monitoring. Diabetes Res Clin Pract. 2020;167: 108354.
35. Potier L, Hansel B, Larger E, et al. Stay-at-home orders during the COVID-19 pandemic, an opportunity to improve glucose control through behavioral changes in type 1 diabetes. Diabetes Care. 2020;44(3):839–43.
36. Danne T, Limbert C, Puig Domingo M, et al. Telemonitoring, telemedicine and time in range during the pandemic: paradigm change for diabetes risk management in the post-COVID future. Diabetes Ther. 2021;12(9):2289–310.
37. Bonora BM, Boscari F, Avogaro A. Glycaemic control among people with type 1 diabetes during lockdown for the SARS-CoV-2 outbreak in Italy. Diabetes Ther. 2020;11(6):1369–79.
38. Aragona M, Rodia C, Bertolotto A, et al. Type 1 diabetes and COVID-19: the '"Lockdown effect."' Diabetes Res Clin Pract. 2020;170: 108468.
39. Boscari F, Ferretto S, Uliana A, et al. Efficacy of telemedicine for persons with type 1 diabetes during COVID19 lockdown. Nutr Diabetes. 2021;11(1):1.
40. Sacre WJ, Holmes-Truscott E, Salim A, et al. Impact of the COVID-19 pandemic and lockdown restrictions on psychosocial and behavioural outcomes among Australian adults with type 2 diabetes: findings from the PREDICT cohort study. Diabet Med. 2021;38: e14611.
41. Beck RW, Riddlesworth TD, Ruedy K, et al. Continuous glucose monitoring versus usual care in patients with type 2 diabetes receiving multiple daily insulin injections: a randomized trial. Ann Intern Med. 2017;167:365–74.
42. Tourkmani AM, ALHarbi TJ, Bin Rsheedet AM, et al. The impact of telemedicine on patients with uncontrolled type 2 diabetes mellitus during the COVID-19 pandemic in Saudi Arabia: findings and implications. J Telemed Telecare. 2021;1357633X20985763.
43. Lee PA, Greenfield G, Pappas Y. The impact of telehealth remote patient monitoring on glycemic control in type 2 diabetes: a systematic review and meta-analysis of systematic reviews of randomised controlled trials. BMC Health Serv Res. 2018;18(1):495.
44. Norgaard K. Telemedicine consultations and diabetes technology during COVID-19. J Diabetes Sci Technol 2020. 1932296820929378.
45. Kanc K, Komel J, Kos M, et al. H(ome)bA1c testing and telemedicine: High satisfaction of people with a diabetes. Diabetes Res Clin Pract. 2020;166: 108285.
46. Rachmiel M, Lebenthal Y, Mazor-Aronovitch K, et al. Glycaemic control in the paediatric and young adult population with type 1 diabetes following a single telehealth visit—what have we learned from the COVID-19 lockdown? Acta Diabetol. 2021;58(6):697–705.
47. Braune K, Boss K, Schmidt-Herzel J, et al. Shaping workflows in digital and remote diabetes care during the COVID-19 pandemic via a service design: prospective, longitudinal, open-label feasibility trial. JMIR Mhealth Uhealth. 2021;9(4): e24374.
48. Norgaard K. Telemedicine consultations and diabetes technology during COVID-19. J Diabetes Sci Technol. 2020;1932296820929378.
49. Alharthi SK, Alyusuf EY, Alguwaihes AM, et al. The impact of a prolonged lockdownand use of telemedicine on glycemic control in people with type 1 diabetes during the COVID-19 outbreak in Saudi Arabia. Diabetes Res Clin Pract. 2021;173: 108682.
50. Al-Sofiani ME, Alyusuf EY, Alharthi S, et al. Rapid implementation of a diabetes telemedicine clinic during the coronavirus disease 2019 outbreak: our protocol, experience, and satisfaction reports in Saudi Arabia. J Diabetes Sci Technol. 2021;15:329–38.
51. Odeh R, Gharaibeh L, Daher A, et al. Caring for a child with type 1 diabetes during COVID-19 lockdown in a developing country: challenges and parents' perspectives on the use of telemedicine. Diabetes Res Clin Pract. 2020;168: 108393.
52. van der Linden J, Welsh JB, Hirsch IB, Garg SK. Realtime continuous glucose monitoring during the coronavirus disease 2019 pandemic and its impact on time in range. Diabetes Technol Ther. 2021;23:S1–7.
53. Battelino T, Danne T, Bergenstal RM, et al. Clinical targets for continuous glucose monitoring data interpretation: recommendations from the international consensus on time in range. Diabetes Care. 2019;42(8):1593–603.
54. Garg S, Norman GJ. Impact of COVID-19 on health economics and technology of diabetes care: use cases of real-time continuous glucose monitoring to transform health care during a global pandemic. Diabetes Technol Ther. 2021;23(S1):S15–20.
55. Beck RW, Bergenstal RM, Riddlesworth TD, et al. Validation of time in range as an outcome measure for diabetes clinical trials. Diabetes Care. 2019;42(3):400–5.
56. Selvin E, Marinopoulos S, Berkenblit G, et al. Meta-analysis: glycosylated hemoglobin and cardiovascular disease in diabetes mellitus. Ann Intern Med. 2004;141(6):421–31.
57. Stratton IM, Adler AI, Neil HAW, et al. Association of glycaemia with macrovascular and microvascular complications of type 2 diabetes (UKPDS 35): prospective observational study. BMJ. 2000;321(7258):405–12.
58. Cavero-Redondo I, Peleteiro B, Alvarez-Bueno C, et al. Glycated haemoglobin A1c as a risk factor of cardiovascular outcomes and all-cause mortality in diabetic and non-diabetic populations: a systematic review and meta-analysis. BMJ Open. 2017;7(7):e015949.
59. Garofolo M, Aragona M, Rodia C, et al. Glycaemic control during the lockdown for COVID-19 in adults with type 1 diabetes: a meta-analysis of observational studies. Diab Res Clin Pract. 2021;180: 109066.

60. Hakonen E, Varimo T, Tuomaala A-K, et al. The effect of COVID-19 lockdown on the glycemic control of children with type 1 diabetes. BMC Pediatr. 2022;22:48.
61. Longo M, Caruso P, Petrizzo M, et al. Glycemic control in people with type 1 diabetes using a hybrid closed loop system and followed by telemedicine during the COVID-19 pandemic in Italy. Diab Res Clin Pract. 2020;169: 108440.
62. Garg SK, Rodbard D, Hirsch IB, Forlenza GP. Managing new onset type 1 diabetes during the COVID-19 pandemic: challenges and opportunities. Diab Technol Ther. 2020;22(6):431–9.
63. d'Annunzio G, Maffeis C, Cherubini V, Rabbone I, Scaramuzza A, Schiaffini R, Minuto N, Piccolo G, Maghnie M. Caring for children and adolescents with type 1 diabetes mellitus: Italian Society for Pediatric Endocrinology and Diabetology (ISPED) statements during COVID-19 pandemia. Diabetes Res Clin Pract. 2020;168: 108372.
64. Peters AL, Garg SK. The silver lining to COVID-19: avoiding diabetic ketoacidosis admissions with telehealth. Diabetes Technol Ther. 2020;22(6):449–53.
65. Rossi MC, Nicolucci A, Lucisano G, et al. Impact of the "Diabetes Interactive Diary" telemedicine system on metabolic control, risk of hypoglycemia, and quality of life: a randomized clinical trial in type 1 diabetes. Diabetes Technol Ther. 2013;15(8):670–9.
66. Zhai YK, Zhu WJ, Cai YL, et al. Clinical- and cost-effectiveness of telemedicine in type 2 diabetes mellitus: a systematic review and meta-analysis. Bull Sch Med Md. 2014;93(28): e312.
67. Wang G, Zhang Z, Feng Y, Sun L, Xiao X, Wang G, Gao Y, Wang H, Zhang H, Deng Y, Sun C. Telemedicine in the management of type 2 diabetes mellitus. Am J Med Sci. 2017;353(1):1–5.
68. Ghosh A, Arora B, Gupta R, et al. Effects of nationwide lockdown during COVID-19 epidemic on lifestyle and other medical issues of patients with type 2 diabetes in north India. Diabetes Metab Syndr. 2020;14:917–20.
69. AlMutairi MF, Tourkmani AM, Alrasheedy AA, et al. Cost-effectiveness of telemedicine care for patients with uncontrolled type 2 diabetes mellitus during the COVID-19 pandemic in Saudi Arabia. Ther Adv Chronic Dis. 2021;12:1–11.
70. Scoccimarro D, Giove G, Silverii A, et al. Effects of home confinement during COVID-19 outbreak on glycemic control in patients with type 2 diabetes receiving telemedicine support. Acta Diabetol. 2021;59(2):281–4.
71. Luzi L, Carruba M, Crialesi R, et al. Telemedicine and urban diabetes during COVID-19 pandemic in Milano, Italy during lock-down: epidemiological and sociodemographic picture. Acta Diabetol. 2021;58:919–27.
72. Eberle C, Stichling S. Impact of COVID-19 lockdown on glycemic control in patients with type 1 and type 2 diabetes mellitus: a systematic review. Diabetol Metab Syndr. 2021;13:95.
73. Patel SY, McCoy RG, Barnett ML, et al. Diabetes care and glycemic control during the COVID-19 pandemic in the United States. JAMA. 2021;181(10):1412–4.
74. Shi L, Wu H, Dong J, et al. Telemedicine for detecting diabetic retinopathy: a systematic review and meta-analysis. Br J Ophthalmol. 2015;99:823–31.
75. Galiero R, Pafundi PC, Nevola R, et al. The importance of telemedicine during COVID-19 pandemic: a focus on diabetic retinopathy. J Diabetes Res. 2020;2020:9036847.
76. Caballero AE, Ceriello A, Misra A, et al. COVID-19 in people living with diabetes: an international consensus. J Diabetes Complicat. 2020;34: 107671.
77. Ghosh A, Gupta R, Misra A. Telemedicine for diabetes care in India during COVID19 pandemic and national lockdown period: guidelines for physicians. Diabet Metab Syndr. 2020;14:273–6.
78. Giani E, Dovc K, Dos Santos TJ, et al. Telemedicine and COVID-19 pandemic: The perfect storm to mark a change in diabetes care. Results from a world-wide cross-sectional web-based survey. Pediatr Diabetes. 2021;22:1115–9.
79. Iyengar K, Upadhyaya GK, Vaishya R, et al. COVID-19 and applications of smartphone technology in the current pandemic. Diabet Metab Syndr. 2020;14:733–7.
80. Dash S, Aarthy R, Mohan V. Telemedicine during COVID-19 in India—a new policy and its challenges. J Public Health Policy. 2021;42:501–9.
81. Iyengar K, Jain VK, Vaishya R. Pitfalls in telemedicine consultations in the era of COVID 19 and how to avoid them. Diabetes Metab Syndr. 2020;14(5):797–9.
82. March CA, Flint A, DeArment D, et al. Paediatric diabetes care during the COVID-19 pandemic: lessons learned in scaling up telemedicine services. Endocrinol Diab Metab. 2021;4:e00202.
83. Garcia-Villasante E, Baca-Carrasco V, Gutierrez-Ortiz C, et al. Diabetes care during COVID 19: experience in telemedicine from a developing country. Diabet Metab Syndr. 2020;14:1519.
84. Schechter CB, Cohen HW, Shmukler C, et al. Intervention costs and cost-effectiveness of a successful telephonic intervention to promote diabetes control. Diabetes Care. 2012;35:2156–60.
85. Klonoff DC. Diabetes and telemedicine: is the technology sound effective, cost-effective, and practical? Diabetes Care. 2003;26(5):1626–8.