**Name of Journal:** *World Journal of Diabetes*

**Manuscript NO:** 62587

**Manuscript Type:** MINIREVIEWS

**Effect of COVID-19 on management of type 1 diabetes: Pushing the boundaries of telemedical healthcare**

Bilic Curcic I *et al*. Managing diabetes with telemedicine during COVID-19

Ines Bilic Curcic, Maja Cigrovski Berkovic, Tomislav Kizivat, Silvija Canecki Varzic, Robert Smolic, Martina Smolic

**Ines Bilic Curcic, Silvija Canecki Varzic,** Department of Endocrinology, University Hospital Osijek, Osijek 31000, Croatia

**Ines Bilic Curcic, Martina Smolic,** Department of Pharmacology, Faculty of Medicine Osijek, Osijek 31000, Croatia

**Maja Cigrovski Berkovic,** Department of Endocrinology, Diabetes, Metabolism and Clinical Pharmacology, University Hospital Dubrava, Zagreb 10000, Croatia

**Maja Cigrovski Berkovic,** Department of Kinesiological Anthropology and Methodology, Faculty of Kinesiology, University of Zagreb, Zagreb 10000, Croatia

**Tomislav Kizivat,** Clinical Institute of Nuclear Medicine and Radiation Protection, University Hospital Osijek, Osijek 31000, Croatia

**Tomislav Kizivat,** Department of Nuclear Medicine and Oncology, Faculty of Medicine Osijek, Osijek 31000, Croatia

**Silvija Canecki Varzic,** Department of Internal Medicine, Family Medicine, and History, Faculty of Medicine Osijek, Osijek 31000, Croatia

**Robert Smolic,** Department of Pathophysiology, Faculty of Medicine Osijek, Osijek 31000, Croatia

**Robert Smolic,** Department of Pathophysiology, Physiology and Immunology, Faculty of Dental Medicine and Health, Osijek 31000, Croatia

**Martina Smolic,** Department of Pharmacology and Biochemistry, Faculty of Dental Medicine and Health, Osijek 31000, Croatia

**Author contributions:** Bilic Curcic I, Smolic M, and Smolic R were responsible for theconcept and design; Bilic Curcic I, Cigrovski Berkovic M were responsible for drafting the manuscript; Kizivat T was responsible for visualizations; Smolic M, Smolic R, Kizivat T,and Canecki Varzic S were responsible for critical revision of the manuscript.

**Supported by** Ines Bilić-Ćurčić,No. ZUP2018-90.

**Corresponding author: Martina Smolic, MD, PhD, Associate Professor,** Department for Pharmacology, Faculty of Medicine Osijek, J Huttlera 4, Osijek 31000, Croatia. martina.smolic@mefos.hr

**Received:** January 13, 2021

**Revised:** April 23, 2021

**Accepted:** May 19, 2021

**Published online:** June 15, 2021

**Abstract**

The new coronavirus disease 2019 (COVID-19) pandemic posed a great burden on health care systems worldwide and is an enormous and real obstacle in providing needed health care to patients with chronic diseases such as diabetes. Parallel to COVID-19, there have been great advances in technology used for management of type 1 diabetes, primarily insulin pumps, sensors, integrated and closed loop systems, ambulatory glucose profile software, and smart phone apps providing necessary essentials for telemedicine implementation right at the beginning of the COVID-19 pandemic. The results of these remote interventions are reassuring in terms of glycemic management and hemoglobin A1c reductions. However, data on long-term outcomes and cost reductions are missing as well as proper technical infrastructure and government health policy support.

**Key Words:** Diabetes management; Telemedicine; COVID-19; Diabetes type 1

**©The** **Author(s) 2021.** Published by Baishideng Publishing Group Inc. All rights reserved.

**Citation:** Bilic Curcic I, Cigrovski Berkovic M, Kizivat T, Canecki Varzic S, Smolic R, Smolic M. Effect of COVID-19 on management of type 1 diabetes: Pushing the boundaries of telemedical healthcare. *World J Diabetes* 2021; 12(6): 780-785

**URL:** <https://www.wjgnet.com/1948-9358/full/v12/i6/780.htm>

**DOI:** https://dx.doi.org/10.4239/wjd.v12.i6.780

**Core Tip:** Mortality and morbidity rates increased during the coronavirus disease 2019 pandemic partially due to disruption in health care delivery. The implementation of telemedicine imposes itself as a logical solution given technical devices and apps already available in the management of type 1 diabetes. Presently available data are scarce but encouraging regarding glycemic control in long standing type 1 diabetes and new onset type 1 diabetes and minimizing acute complications.

**INTRODUCTION**

***Diabetes and coronavirus disease 2019-aftermath to be seen***

The coronavirus disease 2019 (COVID-19) pandemic is one of the biggest challenges humanity has ever encountered with unfathomable aftermaths on all aspects of our lives including the health care system or rather the disruption of health care delivery.

Interestingly, diabetes and COVID-19 are both pandemics with distinct opposite features. The COVID-19 pandemic is a newly emerged infectious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). In the short period of time, it caused over 1850941 deaths[1] rising as a global emergency and changing the face of health care provision in a short period of time. On the other hand, diabetes is a slow pandemic, and one of the leading causes of mortality and morbidity worldwide responsible for over 42 million deaths in 2019[2].

Moreover, clinical presentation of SARS-CoV-2 infection tends to be more severe with increased mortality rates in people with type 1 and type 2 diabetes, especially those with poor glycemic regulation and accompanying comorbidities such as obesity, kidney impairment, and cardiovascular disease[3,4]. An increase in mortality rates in diabetic patients, both type 1 and type 2, has been observed in the first 3 mo of 2020 compared with the same period in the 5 years prior (from 2014 to 2019), which could be a consequence of inadequate health care as well as COVID-19[3] emphasizing an urgent need for practical solutions in remote outpatient health care.

***An emerging role of remote outpatient care in diabetes management***

If anything, the COVID-19 pandemic accelerated the implementation of telemedicine worldwide due to mandatory social distancing, and many patients’ health care providers were discovering benefits attached to remote health care[5]. Patients can receive guidance and consulting from their homes thus avoiding a potential virus threat, saving time and costs of travel and parking, which is especially convenient for children and the working population.

***Diabetes type 1 and telemedicine-a big step forward***

This form of diabetes management is particularly appropriate for type 1 patients already using available software, such as Dexcom, Care Link, or LabVIEW, able to generate ambulatory glucose profile reports, and using smart insulin pens thus allowing remote monitoring of glucose management and providing consultations based on available data *via* phone, video calls, or smart phone applications[6-8].

Indeed, the digital revolution commenced in the type 1 community starting with insulin pumps, advancing with sensors, integrated and closed loop systems, ambulatory glucose profile software, and smart phone apps procuring necessary essentials for swift and timely telemedicine implementation right at the beginning of the COVID-19 pandemic[9].

This was clearly shown in a study performed in Italy during the COVID-19 lockdown including people with type 1 diabetes using the hybrid closed loop demonstrating improved glycemic control probably due to the availability of telemedicine and more active engagement of patients in glycemic management[10].

A study conducted on type 1 diabetes patients from 89 countries encompassing 7477 survey responses showed that 30% believed their healthcare access was negatively affected, while 28% received remote care through telephone (72%) or video calls (28%). The majority of those patients considered teleconsulting useful, and hemoglobin A1c levels positively correlated with affirmative attitude towards telemedicine[11].

***Type 2 diabetes and telemedicine-limited experience in the COVID-19 era***

In the pre-COVID-19 era, virtual consultations have proven useful, effective, and accessible in type 2 diabetes management compared to face-to-face visits[12,13]. Still, outcomes in terms of glycated hemoglobin vary by studies. For instance, Cochrane meta-analysis of 21 studies comparing standard care to telemedicine in diabetic patients demonstrated inconsistent results in hemoglobin A1c improvement but a better effect on low density lipoprotein and blood pressure levels[14]. Another study showed improvement in hemoglobin A1c levels. However, strong technical support was engaged including connected devices such as continuous glucose monitoring, remote lifestyle coaching, and clinical support with a mobile app, which are not usually on disposal for type 2 diabetes patients[15].

Data on telemedicine and type 2 diabetes in the COVID-19 era are still lacking. In a recently published study including 763 type 1 and 619 type 2 diabetics, about 40% of patients stated that all of their diabetes visits were cancelled or postponed, 40% were switched to telehealth consultations, while half reported lower overall satisfaction with these visits[16].

***Managing new onset diabetes and acute complications in COVID-19 via telemedicine***

Infection with SARS-CoV-2 causes an inexplicable rise in glycemia, probably due to direct toxic effects of the virus itself and wide expression of angiotensin converting enzyme 2 on islet cells[17,18] presenting with acute hyperglycemia followed by ketosis or even ketoacidosis requiring an emergency room visit even in previously well-controlled patients[19,20].

Telemedicine is allowing a continuous and remote communication between patients and their health care provider and in terms of COVID-19-induced acute hyperglycemia offers the only solution in outpatient glycemic management. In this way, consulting a patient on timely ketone screening and suitable actions could prevent development of ketosis and diabetic ketoacidosis and relive a burden on hospitals or at least ensure apt emergency room visits[21].

Recently, two case reports were published, one adult and the other pediatric, where telemedicine was effectively applied in all aspects of type 1 diabetes management, consultation, education, and monitoring through available software to generate ambulatory glucose profiles and using a combination of e-mail, Internet *via* Zoom, and telephone calls[22].

***Future perspectives in telemedicine implementation***

The major obstacle in telemedicine implementation are technical support issues and government reimbursement policies, which differ by country. Structured background for integration and reimbursement in most countries is missing. There are two options presented, one involving private providers depending on private insurance and the other based on free applications such as WhatsApp, Skype, or Zoom that are not in accordance with health data privacy conditions and are not an integrated part of health care registries[23]. In most countries, health insurance covers the costs of technical devices in the management of type 1 diabetes, which is not the case for type 2 diabetes. Precisely for this reason telemedicine is the most widely used in long standing type 1 diabetes management but also has potential in new onset type 1 diabetes and prevention of acute complications, especially important in the COVID-19 era (Figure 1).

Downloading data from devices is a weak link in wider implementation of telemedicine because the older population is not skilled enough or do not have technical support necessary to prepare reports for consults. Unfortunately, this population in particular could benefit the most from remote consulting due to vulnerability to SARS-CoV-2 and other infections, walking disabilities, and poorer socioeconomic status. In addition, the majority of those patients do not have smart phones and do not use the internet frequently. Thus, improvements in user support services are necessary at this stage to resolve issues in service delivery[5].

The main question is could telemedicine replace face-to-face visits? One could argue that even if we have necessary data regarding glycemic management, we still could not perform a physical exam in order to evaluate cardiovascular health or polyneuropathy. It should be emphasized that telemedicine in retinopathy screening has been long recognized[24]. On the other hand, telemedicine and constant contact with patients enables physicians to act in time, to give advice regarding hypo- or hyperglycemia, adjust insulin doses, and provide proper actions in case of emergencies.

The potential in cost reductions and advancements of health care are plausible and supported by a recently published meta-analysis including 8 studies investigating a role of telemedicine in the COVID-19 pandemic confirming that telehealth care improves accessibility of health services[25]. However, there are no definite reports on long-term outcomes or cost reduction necessary for creating government health care policies as well as building technical infrastructure.

**CONCLUSION**

Nonetheless, virtual consultations and/or clinics are inevitable and essential in providing healthcare in this pandemic, securing communication between type 2 diabetes patients and health care providers necessary in supporting self-management. Based on present data, technical infrastructure is imperative in delivering high quality consultations ensuring patient satisfaction.

**REFERENCES**

1 **Worldometer.** COVID-19 coronavirus pandemic 2021. [cited 1 January 2021]. Available from: www.worldometers.info/coronavirus/

2 **International Diabetes Federation.** IDF Diabetes Atlas, 8th ed. Brussels, Belgium: 2019. [cited May 4, 2020]. Available from: www.idf.org/e-library/epidemiology-research/diabetes-at­las/134-idf-diabetes-atlas-8th-edition.html

3 **Holman N**, Knighton P, Kar P, O'Keefe J, Curley M, Weaver A, Barron E, Bakhai C, Khunti K, Wareham NJ, Sattar N, Young B, Valabhji J. Risk factors for COVID-19-related mortality in people with type 1 and type 2 diabetes in England: a population-based cohort study. *Lancet Diabetes Endocrinol* 2020; **8**: 823-833 [PMID: 32798471 DOI: 10.1016/S2213-8587(20)30271-0]

4 **Williamson EJ**, Walker AJ, Bhaskaran K, Bacon S, Bates C, Morton CE, Curtis HJ, Mehrkar A, Evans D, Inglesby P, Cockburn J, McDonald HI, MacKenna B, Tomlinson L, Douglas IJ, Rentsch CT, Mathur R, Wong AYS, Grieve R, Harrison D, Forbes H, Schultze A, Croker R, Parry J, Hester F, Harper S, Perera R, Evans SJW, Smeeth L, Goldacre B. Factors associated with COVID-19-related death using OpenSAFELY. *Nature* 2020; **584**: 430-436 [PMID: 32640463 DOI: 10.1038/s41586-020-2521-4]

5 **Wake DJ**, Gibb FW, Kar P, Kennon B, Klonoff DC, Rayman G, Rutter MK, Sainsbury C, Semple RK. ENDOCRINOLOGY IN THE TIME OF COVID-19: Remodelling diabetes services and emerging innovation. *Eur J Endocrinol* 2020; **183**: G67-G77 [PMID: 32508313 DOI: 10.1530/EJE-20-0377]

6 **Battelino T**, Danne T, Bergenstal RM, Amiel SA, Beck R, Biester T, Bosi E, Buckingham BA, Cefalu WT, Close KL, Cobelli C, Dassau E, DeVries JH, Donaghue KC, Dovc K, Doyle FJ 3rd, Garg S, Grunberger G, Heller S, Heinemann L, Hirsch IB, Hovorka R, Jia W, Kordonouri O, Kovatchev B, Kowalski A, Laffel L, Levine B, Mayorov A, Mathieu C, Murphy HR, Nimri R, Nørgaard K, Parkin CG, Renard E, Rodbard D, Saboo B, Schatz D, Stoner K, Urakami T, Weinzimer SA, Phillip M. Clinical Targets for Continuous Glucose Monitoring Data Interpretation: Recommendations From the International Consensus on Time in Range. *Diabetes Care* 2019; **42**: 1593-1603 [PMID: 31177185 DOI: 10.2337/dci19-0028]

7 **Sangave NA**, Aungst TD, Patel DK. Smart Connected Insulin Pens, Caps, and Attachments: A Review of the Future of Diabetes Technology. *Diabetes Spectr* 2019; **32**: 378-384 [PMID: 31798296 DOI: 10.2337/ds18-0069]

8 **Iyengar K**, Upadhyaya GK, Vaishya R, Jain V. COVID-19 and applications of smartphone technology in the current pandemic. *Diabetes Metab Syndr* 2020; **14**: 733-737 [PMID: 32497963 DOI: 10.1016/j.dsx.2020.05.033]

9 **Danne T**, Limbert C. COVID-19, type 1 diabetes, and technology: why paediatric patients are leading the way. *Lancet Diabetes Endo* 2020; **8**: 465-467 [DOI: 10.1016/S2213-8587(20)30155-8]

10 **Longo M**, Caruso P, Petrizzo M, Castaldo F, Sarnataro A, Gicchino M, Bellastella G, Esposito K, Maiorino MI. 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. *Diabetes Res Clin Pract* 2020; **169**: 108440 [PMID: 32926958 DOI: 10.1016/j.diabres.2020.108440]

11 **Scott SN**, Fontana FY, Züger T, Laimer M, Stettler C. Use and perception of telemedicine in people with type 1 diabetes during the COVID-19 pandemic-Results of a global survey. *Endocrinol Diabetes Metab* 2021; **4**: e00180 [PMID: 33532617 DOI: 10.1002/edm2.180]

12 **Armstrong N**, Hearnshaw H, Powell J, Dale J. Stakeholder perspectives on the development of a virtual clinic for diabetes care: qualitative study. *J Med Internet Res* 2007; **9**: e23 [PMID: 17942385 DOI: 10.2196/jmir.9.3.e23]

13 **Greenhalgh T**, Vijayaraghavan S, Wherton J, Shaw S, Byrne E, Campbell-Richards D, Bhattacharya S, Hanson P, Ramoutar S, Gutteridge C, Hodkinson I, Collard A, Morris J. Virtual online consultations: advantages and limitations (VOCAL) study. *BMJ Open* 2016; **6**: e009388 [PMID: 26826147 DOI: 10.1136/bmjopen-2015-009388]

14 **Flodgren G**, Rachas A, Farmer AJ, Inzitari M, Shepperd S. Interactive telemedicine: effects on professional practice and health care outcomes. *Cochrane Database Syst Rev* 2015: CD002098 [PMID: 26343551 DOI: 10.1002/14651858.CD002098.pub2]

15 **Dixon RF**, Zisser H, Layne JE, Barleen NA, Miller DP, Moloney DP, Majithia AR, Gabbay RA, Riff J. A Virtual Type 2 Diabetes Clinic Using Continuous Glucose Monitoring and Endocrinology Visits. *J Diabetes Sci Technol* 2020; **14**: 908-911 [PMID: 31762302 DOI: 10.1177/1932296819888662]

16 **Fisher L**, Polonsky W, Asuni A, Jolly Y, Hessler D. The early impact of the COVID-19 pandemic on adults with type 1 or type 2 diabetes: A national cohort study. *J Diabetes Complications* 2020; **34**: 107748 [PMID: 33059981 DOI: 10.1016/j.jdiacomp.2020.107748]

17 **Bindom SM**, Lazartigues E. The sweeter side of ACE2: physiological evidence for a role in diabetes. *Mol Cell Endocrinol* 2009; **302**: 193-202 [PMID: 18948167 DOI: 10.1016/j.mce.2008.09.020]

18 **Yang JK**, Lin SS, Ji XJ, Guo LM. Binding of SARS coronavirus to its receptor damages islets and causes acute diabetes. *Acta Diabetol* 2010; **47**: 193-199 [PMID: 19333547 DOI: 10.1007/s00592-009-0109-4]

19 **Li J**, Wang X, Chen J, Zuo X, Zhang H, Deng A. COVID-19 infection may cause ketosis and ketoacidosis. *Diabetes Obes Metab* 2020; **22**: 1935-1941 [PMID: 32314455 DOI: 10.1111/dom.14057]

20 **Kim NY**, Ha E, Moon JS, Lee YH, Choi EY. Acute Hyperglycemic Crises with Coronavirus Disease-19: Case Reports. *Diabetes Metab J* 2020; **44**: 349-353 [PMID: 32347027 DOI: 10.4093/dmj.2020.0091]

21 **Cassar MR**, Borg D, Camilleri L, Schembri A, Anastasi EA, Buhagiar K, Callus C, Grech M. A novel use of telemedicine during the COVID-19 pandemic. *Int J Infect Dis* 2021; **103**: 182-187 [PMID: 33246041 DOI: 10.1016/j.ijid.2020.11.170]

22 **Garg SK**, Rodbard D, Hirsch IB, Forlenza GP. Managing New-Onset Type 1 Diabetes During the COVID-19 Pandemic: Challenges and Opportunities. *Diabetes Technol Ther* 2020; **22**: 431-439 [PMID: 32302499 DOI: 10.1089/dia.2020.0161]

23 **Ohannessian R**, Duong TA, Odone A. Global Telemedicine Implementation and Integration Within Health Systems to Fight the COVID-19 Pandemic: A Call to Action. *JMIR Public Health Surveill* 2020; **6**: e18810 [PMID: 32238336 DOI: 10.2196/18810]

24 **Zimmer-Galler IE**, Kimura AE, Gupta S. Diabetic retinopathy screening and the use of telemedicine. *Curr Opin Ophthalmol* 2015; **26**: 167-172 [PMID: 25759962 DOI: 10.1097/ICU.0000000000000142]

25 **Monaghesh E**, Hajizadeh A. The role of telehealth during COVID-19 outbreak: a systematic review based on current evidence. *BMC Public Health* 2020; **20**: 1193 [PMID: 32738884 DOI: 10.1186/s12889-020-09301-4]

**Footnotes**

**Conflict-of-interest statement:** There is no conflict of interest associated with the senior author or other coauthors.

**Open-Access:** This article is an open-access article that was selected by an in-house editor and fully peer-reviewed by external reviewers. It is distributed in accordance with the Creative Commons Attribution NonCommercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: http://creativecommons.org/Licenses/by-nc/4.0/

**Manuscript source:** Invited manuscript

**Peer-review started:** January 13, 2021

**First decision:** April 20, 2021

**Article in press:** May 19, 2021

**Specialty type:** Endocrinology and metabolism

**Country/Territory of origin:** Croatia

**Peer-review report’s scientific quality classification**

Grade A (Excellent): 0

Grade B (Very good): B

Grade C (Good): C

Grade D (Fair): 0

Grade E (Poor): 0

**P-Reviewer:** Bansal A, Liu YC **S-Editor:** Zhang L **L-Editor:** Filipodia **P-Editor:** Ma YJ

**Figure Legends**

****

**Figure 1 Essential requirements for successful implementation of telemedicine in the management of type 1 diabetes.** CGM: Continuous glucose monitoring; FGM: Flash glucose monitoring.



Published by **Baishideng Publishing Group Inc**

7041 Koll Center Parkway, Suite 160, Pleasanton, CA 94566, USA

**Telephone:** +1-925-3991568

**E-mail:** bpgoffice@wjgnet.com

**Help Desk:** https://www.f6publishing.com/helpdesk

https://www.wjgnet.com



**© 2021 Baishideng Publishing Group Inc. All rights reserved.**