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Review

The impact of telemedicine on patient self-management processes and clinical outcomes for patients with Types I or II Diabetes Mellitus in the United States: A scoping review

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ABSTRACT

Objective: The objective of this scoping review was to identify peer-reviewed medical literature on the use of telemedicine in patients with Types I or II DM in the United States, assess its impact on self-management processes and clinical outcomes of care, and to delineate research gaps.

Methods: We utilized a structured scoping review protocol to conduct this research. We searched the published medical literature utilizing two databases, PubMed and CINHALL, and we included all original research articles published prior to July 20th, 2018. Using a 4-step systematic approach, we identified, reviewed, extracted and summarized data from all relevant studies.

Results: We identified 47 articles overall. Telemedicine impact was reported as positive in articles addressing the following components of patient self-management: adherence to blood glucose monitoring, day-to-day decision-making related to self-care, and adherence with medications. The most commonly reported clinical outcome was HbA1c level. Few or no studies evaluated impact on long term clinical outcomes such as blindness, amputation, cardiovascular events, development of chronic kidney disease, or mortality.

Discussion: This scoping review provides important information about studies conducted in the United States evaluating the impact of telemedicine on patient self-management and on clinical outcomes in patients with DM.

Conclusions: Results suggest that telemedicine has a positive impact on self-management processes and on HbA1c levels. However, future evaluative reviews are necessary to confirm and quantitate the impact of telemedicine on self-management processes and primary studies are necessary to evaluate its impact on long term clinical outcomes.

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1. Introduction

Diabetes Mellitus (DM) is a chronic metabolic condition that affects 30.3 million people in the United States [1,2]. There are two major types of diabetes mellitus, type 1 and type 2. In type 1 DM, there is an absolute deficiency of insulin, and in type 2 DM, there is

a combination of resistance to insulin and inadequate insulin secretion [2]. The lack of insulin, insulin resistance, or a combination of the two results in a hyperglycemic state that, over an extended period of time, causes damage and dysfunction to multiple organs, such as the eyes, kidneys, nerves, heart, and blood vessels [2]. Diabetes mellitus is also the seventh ranked cause of death and the number one cause of kidney failure, blindness, and nontraumatic amputations in the United States [3]. These complications cause diabetic patients to have many more examinations, procedures, and clinical visits than a patient without DM.

Due to the number of required examinations, new tools are being developed and tested to better engage patients in their own care and to improve quality of care and clinical outcomes.

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Telemedicine, which is described as the remote exchange of medical information and/or services between patients and clinicians through electronic information communication technologies, is one of these new tools [4–6]. In example studies, telemedicine was used to transmit weekly blood glucose data from patients to clinicians and to facilitate follow-up [7,8]. It has also been used to provide education, support, and cell phone text messages to improve self-management of diabetes [9–11].

The goals of this paper are to identify peer-reviewed medical literature on the use of telemedicine in patients with Type I or II DM in the United States, assess its impact on self-management processes and clinical outcomes of care, and to delineate research gaps.

2. Methods

2.1. Overview

We used the scoping review methodology of Arksey and O'Malley and we conducted an expansive literature review [12]. This method was employed because it provides a clear and rapid review of relevant information. We considered conducting a systematic review, which is similar to a scoping review. However, a scoping review was chosen due to its ability to examine large quantities of information in an emerging field. The scoping review methodology is efficient at identifying gaps in areas of research and determining opportunities for future research. Based on Arksey and O'Malley's guidelines, we carried out the following phases: 1. Identifying the research question, 2. Identifying relevant studies, 3. Selecting the studies, 4. Extracting and charting the data, and 5. Reviewing and summarizing the results.

2.2. Phase 1: Identifying the research question

The research question was created by establishing a link between the patient population; the intervention; and self-management processes and clinical outcomes. Diabetic patients were chosen due to the prevalence of the disease and its high rate of complications [13,14]. Telemedicine was chosen as the intervention due to its increasing use in the medical field and its widespread availability to persons living in the United States [15]. We hypothesized that by utilizing telemedicine, patients with DM may improve self-management and achieve improved clinical outcomes.

We defined patients with DM as individuals with a confirmed diagnosis of Type I or Type II Diabetes Mellitus. Additionally, we included patients who were listed as unspecified type of diabetes. Pre-diabetes and gestational diabetes were not included due to the transient nature of their disease.

We defined telemedicine as the application of remote telecommunication technology that was used to treat, counsel, screen or remind patients of their monitoring and treatment. Examples of telemedicine include text messaging, telephone communication, videoconferencing, and the use of mobile applications.

We assessed every article for 30 unique self-management processes or clinical outcomes that are used to assess patients with DM. Some examples of clinical outcomes are HbA1c level and medication adherence.

2.3. Phase 2: Identifying relevant studies

In order to answer our research question, we searched the PubMed and CINAHL databases using the terms “diabetes mellitus” and “telemedicine”. This allowed us to identify additional relevant MESH terms. The list of MESH terms that we used in our literature search included:

“videoconferencing”; “remote consultation”; “distance counseling”; “telemedicine; telemed*”; “telehealth”; “e-health”; “diabetes mellitus”; “diabetes mellitus type 2”; “diabetes mellitus type 1”; “outcome assessment (health care)”.

Initially, we included all studies published prior to April 15, 2016. The search included only English language articles due to resources constraints. We excluded all letters, editorials, news articles, reviews and updates that were not conducted in the United States. We utilized the web service, RefWorks, to manage the identified articles and references. Subsequently, we updated the original article search to include additional studies published between April 15, 2016 and July 20, 2018. July 20th was chosen because it was the most recent date the database was accessed. A total of 35 additional articles were identified. Of these, five satisfied the inclusion and exclusion criteria and were included for data extraction.

2.4. Phase 3: Selecting the studies

Our methodology for this phase to narrow our search to the most relevant articles is listed in separate subheadings below.

2.4.1. Initial articles identified

We first identified 629 articles using our MESH terms. From there, four members of the team (TMB, AB, JR, and AD) assessed each article by reviewing its title. We removed all articles that did not measure self-management or clinical outcomes in patients with DM. After completing this step, we narrowed our search to 340 articles.

2.4.2. Application of inclusion and exclusion criteria

The same four team members reviewed the titles and abstracts of each of the 340 articles and applied inclusion and exclusion criteria (Table 1). Included articles met all inclusion criteria and had no exclusions. This step identified 45 articles as satisfying inclusion and exclusion criteria.

2.4.3. Cited searching

We then chose 10 high impact articles from our selected 45 articles to complete a cited search. We defined a “high impact” article as one that was referenced multiple times in the original 45 articles. We reviewed the references of the 10 articles to identify any additional articles that were missed in the initial search. This step identified six articles; four of these were duplicates and two were novel articles. The two identified as novel were included for extraction and review. This brought our final article count to 47.

Table 1
Article selection criteria.

Inclusion Criteria	Exclusion Criteria
Diabetes Mellitus, type I or II ... and Telemedicine	Duplicate article ... or Gestational diabetes ... or Pre-diabetes ... or Non-USA articles ... or Non-English language articles ... or Letters ... or Editorials ... or Newsletters ... or Reviews ... or Updates ... or No patient data or patients included in study ... or Non-peer reviewed

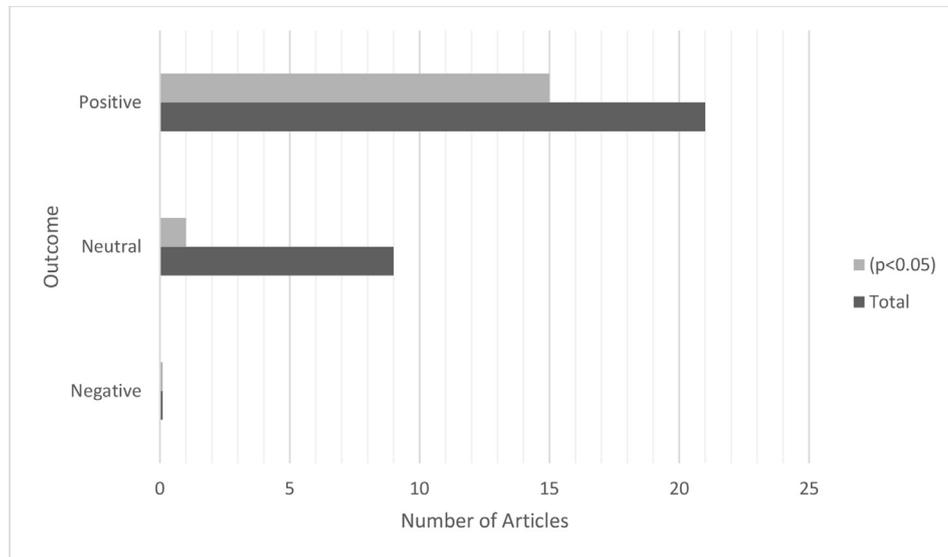


Fig. 1. HbA1c Outcomes.

2.5. Phase 4: Extracting and charting the data

In addition to capturing diabetes subtype, we captured important patient characteristics such as demographics and comorbidities. We also captured sample size of each study, the duration of the intervention, the care setting (i.e. primary care vs. Speciality), whether the population represented a traditionally underserved group, and how the data were collected.

We assessed all articles for 30 unique self-management processes and clinical outcomes that are commonly used to assess the health status of patients with diabetes (Appendix 1). We captured statistical significance when it was reported in the primary articles, i.e. if an article listed a p-value for a process or outcome, we noted if it was less than or greater than 0.05. We utilized a standardized data extraction tool to extract the data from all 47 articles. Ten percent of the 47 articles were extracted by the senior member of the team (TPM) to validate the accuracy of the extractions.

2.6. Phase 5: Reviewing and summarizing the results

After extracting the data from the 47 articles and completing a validation check, the data were entered into an Excel spreadsheet for analysis.

3. Results

3.1. Major reported outcomes

The most commonly reported clinical outcome that was evaluated in the 47 articles was an intermediate outcome, HbA1c level (Fig. 1). A total of 30 articles reported on HbA1c levels, and 15 of the 21 articles that reported a positive HbA1c outcome (a reduction in HbA1c value) were reported as statistically significant (71%).

The most commonly reported self-management process was day-to-day decision making related to self-care (Fig. 2). This was defined as patient decisions that influenced their health and

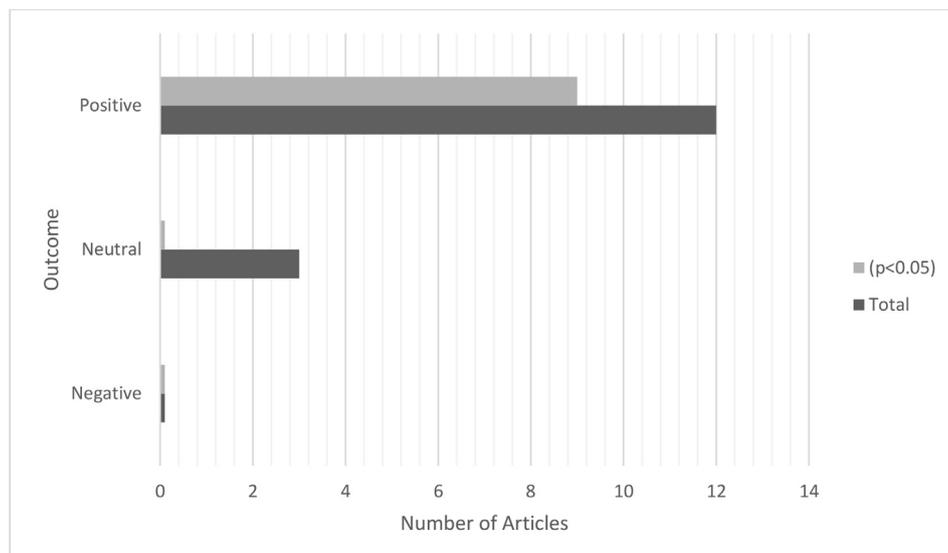


Fig. 2. Day-to-day decision making related to self-care.

maintenance of their diabetic disease. A total of 12 articles reported on this self-management process and nine of the 12 articles that demonstrated positive outcomes were reported as statistically significant (75%).

3.2. Additional reported self-management processes and clinical outcomes

There were several additional self-management processes that were studied and were found to have mainly positive results. Fourteen articles reported on self-monitoring of blood glucose levels and 12 (85%) demonstrated a positive impact. Of these 12 articles, we found that 58% were statistically significant (7/12). We also found articles reporting that telemedicine had a positive impact on adherence to diet and exercise advice 70% (7/10) and adherence to medications, 67% (10/15). Only 2 articles were reported to be statistically significant for diet and exercise, and 5 articles were reported to be statistically significant for adherence to medications.

Three articles reported on diabetic eye exams, with 2 showing improvement, and one showing no change. None of the 3 articles reported statistical significance. Articles on diabetic foot exams demonstrated similar results. Only 4 articles reported on diabetic foot exams, with 2 showing improvement and 2 showing no change. Patient lipid panels showed an improvement in 7 studies, with 5 demonstrating statistical significance. Fasting plasma glucose levels had 2 articles demonstrating improvement with statistical significance. Depression symptoms were shown to improve in 2 articles, with 4 reporting unchanged symptoms. The 2 articles demonstrating an improvement were statistically significant. Ischemic heart disease demonstrated an improvement in 1 article that was statistically significant. Peripheral vascular disease, neuropathy, diabetic retinopathy, creatinine, and microalbumin levels were only reported in 1 study each with an unchanged outcome. They did not report statistical significance.

Articles reporting on patients' quality of life were shown to improve in 57% (4/7) of articles, with all except one neutral outcome reporting statistical significance. Patient functional status and hospital admissions for Diabetic KetoAcidosis (DKA) or HyperOsmolar NonKetosis (HONK) were reported in 2 studies each, with 66% (2/3) demonstrating a positive outcome. Only one of the positive outcome articles was statistically significant. Hospital readmissions were shown to improve in 75% (3/4) of articles, with 2 of the positive outcomes being statistically significant. Hospital readmission included DKA or HONK. Finally, emergency department use showed improvement (decreased) in 60% (3/5) of articles, with only one positive outcome demonstrating statistical significance.

There were no articles that evaluated the impact of telemedicine on prevention of other long-term adverse outcomes, such as cerebral vascular disease, amputations, dialysis treatment, and mortality. From the 47 articles only 3 reported an adverse event related to the use of telemedicine in diabetic patients. These were: hospitalization due to hypoglycemia, self limited rash due to wearable device, and one patient who suffered from diabetic neuropathy, stage IV renal insufficiency, and congestive heart failure who passed away 7 months into a study. A complete list of outcomes and processes and their respective number of articles and statistically significant results can be found in [appendix 2](#).

4. Discussion

Telemedicine is an emerging approach which utilizes technology to enhance the care and clinical outcomes of patients with many diseases including diabetes mellitus. We hypothesized that

the use of telemedicine in patients with DM would improve patient self-management processes and clinical outcomes of care. We found that telemedicine had an overall positive impact on self-management processes and clinical outcomes. The 2 main outcomes that telemedicine had a positive outcome on were HbA1c level and day-to-day decision-making related to self-care. We also found positive outcomes in other areas, such as blood glucose levels, adherence to diet and exercise, and adherence to medication.

Results of this scoping review found that Hemoglobin A1c level was the most commonly evaluated clinical outcome studied. HbA1c is the gold standard for monitoring blood glucose levels in patients with diabetes mellitus [16]. This is due to the ease of measurement and use for clinicians and because it is a single number that both patients and clinicians are able to interpret, allowing a determination of how well patients' DM is controlled [17]. Overall, our review found a positive impact on HbA1c levels in patients using telemedicine. One study stated that having a "high touch" mobile application and asynchronous communication was the main benefit in improving HbA1c [18]. Providers also reported high satisfaction with the use of telemedicine. They state it enhances their ability to monitor and treat patients' diabetes [18,19]. Receiving reminders on self-management and testing and should improve patients' ability to manage their disease and keep their blood glucose levels well controlled [20]. With the continued use and expansion of electronic medical records, patients will be able to upload their HbA1c directly into their medical record, which will provide clinicians additional data to manage and treat their patients' diabetes.

The most frequently reported self-management process was day-to-day decision making related to self-care, which was a measure of how active and engaged patients were with their own diabetes care (i.e. were they thinking about their blood sugar levels daily when they eat). Results of our scoping review found that there was a positive impact on this measure. This may result from improved provider access and reminders that telemedicine provides to a patient [21]. Having a device, such as a cell phone at a patient's fingertips to provide reminders, education, and access to their health care provider should engage the patient and lead to better clinical outcomes. Additionally, a study reported that patient's receiving an automated phone call on a weekly basis had an 84% completion rate, which shows that patient's are receptive to telemedicine [22].

Additionally, we found that using telemedicine helped patients with monitoring their blood glucose levels. Most patients should have a home blood glucose monitor that they can use to test their blood glucose levels daily and should assist them in using these devices. The American Diabetes Association recommends patients should use technology-based methods for their diabetes control. Telemedicine also showed a positive impact on medication adherence and diet and exercise. Reminders and ease of access that telemedicine provides could be the reasons why this result was observed. With telemedicine, patients can be more connected to their physician and their own healthcare. Patient's are receptive to using telemedicine in their home and enjoy using it [22]. Telemedicine has shown to improve patient's education on carbohydrate quantity in food choices, which will help control their blood glucose levels. Patients are able to use an electronic medical record to engage with their clinician on feedback of their glucose levels, which has shown to improve their blood glucose levels [23].

With regard to physical examination findings, there were only 3 articles addressing diabetic eye exams and 4 articles addressing foot exams. Each type of exam had 2 studies that showed an improvement, but there was no reported statistical significance.

Interestingly, lipid panels demonstrated an improvement in 7

articles with 5 being statistically significant. It has been shown that diabetic patients have altered HDL levels due to oxidative stress and glycation from excess glucose in their bloodstream [24]. By using telemedicine, this can help control their blood glucose levels, which in turn will improve their lipid panel studies. Improvement in their lipid panel studies can cause a decrease in other chronic complications that patients with DM face [24].

Peripheral vascular disease, neuropathy, diabetic retinopathy, creatinine, and microalbumin levels were only reported in 1 study each and were shown to be unchanged with no negative or positive outcome. These outcomes can be difficult to study in a patient population that is using telemedicine because a skilled healthcare professional is required to identify and diagnose peripheral vascular disease, neuropathy and diabetic retinopathy. A patient cannot identify these ailments on their own and then report it back through their electronic device, which makes studying them difficult. Future studies would need to identify the impact that telemedicine has on these outcomes.

There were only a few articles that reported on patient outcomes. ED usage, hospital admissions and readmissions all demonstrated positive outcomes (declines) in the few articles they were reported in. This is interesting because a major reason for telemedicine usage is to prevent patients from entering the hospital. Additional studies need to be conducted on these outcomes to identify whether telemedicine is impacting diabetic hospital usage.

A scoping review has some limitations. It does not assess the methodologic strength of the articles that are reviewed. We were able to capture statistical significance if it was reported in the article, but we did not conduct an evaluation of study designs or summarize quantitative results in a meta-analysis. We also limited our scope to articles that were published within the United States and we excluded any non-English articles. We also did not capture how the telemedicine intervention was implemented or any barriers that patients faced while using telemedicine. Finally, we did not distinguish between the types of telemedicine used (e.g. text messaging vs. Use of a web portal). We only captured whether a positive, neutral, or negative outcome occurred.

This scoping review was conducted to identify the impact that telemedicine was having on clinical outcomes and self-management processes in patients with diabetes. This article is intended to identify areas where research is lacking. Multiple studies have been completed on HbA1c levels and day-to-day decision making related to self-care but relatively few studies have been completed in other areas, such as a diabetic eye and foot exams. Finally, we found no research that focused on the impact of telemedicine on long term complications of diabetes mellitus such as development of cerebral, cardiac, or peripheral vascular disease, amputations, chronic kidney disease or mortality. More research needs to be conducted in these areas so that we may truly understand the benefits of telemedicine.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.dsx.2019.02.014>.

Conflicts of interest

No conflicts of interest to report.

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