TO EXPLORE THE TREND AND IMPACT OF TELEHEALTH UTILIZATION ON DIABETES CARE IN LOUISIANA USING THE REAL-WORLD EVIDENCE

A DISSERTATION

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Yixue Shao

APPROVED: ______________________________
Charles Stoecker, PhD; date: 06/23/2022

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Lizheng Shi, PhD; date: 06/21/2022

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Elizabeth Nauman, PhD; date: 06/21/2022

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Eboni Price-Haywood, MD; date: 06/21/2022

To Explore the Trend and Impact of Telehealth Utilization on Diabetes Care in Louisiana Using the Real-world Evidence

Yixue Shao, MPH

Department of Health Policy and Management

Tulane University School of Public Health and Tropical Medicine

Chair of the Committee: Charles Stoecker, PhD

Committee Member: Lizheng Shi, PhD

Committee Member: Elizabeth Nauman, PhD

Committee Member: Eboni Price-Haywood, MD

CONTENTS

ABSTRACT

This study used Medicaid claims to perform an interrupted time series model to examine the trend of telehealth use between 2018 and 2021 and identify factors related to the uptake of telehealth during the pandemic. This study further examined the impact of telehealth during the pandemic on health care utilization in Medicaid beneficiaries with type 2 diabetes using a difference-in-difference model with propensity score weighting (DID-PSW). Telehealth use among Louisiana Medicaid beneficiaries with type 2 diabetes was low before the pandemic, soared early in the pandemic but has receded to an elevated level from the years before the pandemic. The use of telehealth services during the COVID-19 pandemic was significantly associated with Medicaid beneficiaries who were younger, female, black, with more health service utilization, and with more chronic conditions. The Medicaid beneficiaries using telehealth had 195.049 more outpatient visits (95% CI: 166.165 to 223.929, $p<0.001$) per 1,000 beneficiaries per month. After excluding those who may use telehealth for follow-up care of emergency department (ED) visits and hospitalizations, overall ED visits significantly decreased for the telehealth group versus the non-telehealth group over time by 9.456 visits (95% CI: -12.356 to -6.557, $p<0.001$) per 1,000 beneficiaries per month on average. Telehealth was also associated with decreases in ED visits and hospitalizations of major adverse cardiovascular events. Using electronic health records from the Research Action for Health Network (REACHnet) database, this study implemented a similar DID-PSW approach and found the value of HbA1c significantly decreased for the telehealth group versus the non-telehealth group over time by 0.146% on average. The telehealth group had 2.3% fewer patients with uncontrolled HbA1c (> 7%) than the comparison group over time. Telehealth use also

showed modest benefits in the control of LDL, Diastolic BP, and BMI levels. The findings provide evidence to support telehealth as an effective tool for diabetes care, especially in public health emergencies.

BACKGROUND AND SIGNIFICANCE

Telehealth

To improve the access to health care and reduce costs of care, telemedicine or telehealth, is an innovative approach that has been increasingly adopted in recent years. E-visits, telemedicine, and telehealth are often used interchangeably. Telehealth is a broad term encompassing various electronic communications and information technologies to provide healthcare services from a distance.[1]

The ability of telehealth to improve access to care has been demonstrated in the published evidence.[2-5] A study with over 300,000 patients for three years (2011-2013) found that telehealth has improved access to health care and 12% of direct-to-consumer telehealth visits replaced visits to other providers for certain patients during the study period.[6] Another study found that telehealth decreased the disparities in healthcare access among Medicaid beneficiaries and concluded that rural beneficiaries were more likely to use telehealth services compared with their urban counterparts.[5] Results from a systematic review assessing 106 telehealth interventions across various disease areas concluded that telehealth was most effective for managing care for conditions that do not primarily rely on physical examinations.[7]

Compared with in-person services, telehealth has comparable or even better performance on health outcomes. Randomized clinical trials and relevant systematic reviews have demonstrated the efficacy of telehealth in treating and monitoring patients across different disease areas.[8-10] The Agency for Healthcare Research and Quality assessed the existing literature on the efficacy of telehealth for the Medicare population. They found that telehealth can be used as an effective alternative for specialties of mental health and neurology that mostly rely on verbal interactions and not necessarily physical contact.[11] For such specialties, care provided through telehealth has showed comparable performance to care provided in person. Recently, studies based on real-world evidence have been published to support the effectiveness of telehealth.[2] In a 2017 study comparing virtual visits with in-person visits for acute, nonurgent care, virtual visits had similar follow-up outpatient visit rates (28.09%) as primary care physician visits (28.10%) and retail health clinics visits (28.59%).[12] In addition, costs of virtual visits, including medical and pharmacy costs, were less expensive than costs of in-person visits for acute, nonurgent conditions.[12] Patient survey responses from a rural pilot program indicated utilizing telehealth consultations significantly saved personal spending in travel to care.[13]

A new report in 2019 from American Telehealth Association (ATA), "2019 State of the States Report," indicated that 36 states and D.C. have parity policies to require private payers to pay for medically necessary telehealth.[14] Louisiana passed the private payer parity law in 1995, requiring private payers to cover telehealth in the same way as in-person medical services. However, the law only required coverage for telehealth services provided by physicians. Louisiana Medicaid reimbursements covered distant site healthcare providers but not providers who may be facilitating the visit at the originating site where the patient is.[15]

Although telehealth utilization was gradually increasing before the COVID-19 pandemic, it remained a small percentage of all visits because of regulations and limitations on reimbursement. Less than 1% of outpatient visits were delivered by telehealth over the two years before the pandemic.[16,17] Recent policy changes during the COVID-19 pandemic have reduced barriers to telehealth access and have promoted the use of telehealth as a way to deliver acute, chronic, primary, and specialty care.[18]

Since the beginning of the Coronavirus Disease-2019 (COVID-19) pandemic in the U.S. in January 2020, the federal government and states' governors encouraged the use of telehealth services to provide necessary care to patients while minimizing the transmission risk of SARS-CoV-2 , the virus that causes COVID-19, to healthcare personnel (HCP) and patients.[19] The Centers for Medicare & Medicaid Services (CMS) lifted the rural area and originating site requirements for reimbursement of telehealth services during the coronavirus national emergency on March 17, 2020.[20] According to this announcement, healthcare providers will be reimbursed the same amount for telehealth services as for in-person visits regardless of Medicare beneficiary's location. Two days later, the Louisiana governor issued a proclamation to encourage the use of telehealth in response to the public health emergency.[21] Louisiana Medicaid also expanded telehealth coverage and reimbursements.

Prevalence of type 2 diabetes

The rising prevalence and long-lasting impairments of diabetes mellitus bring a major public concern and a considerable impact on human life and health expenditures in the world.[22] According to the National Diabetes Statistics Report 2020, 34.2 million people have diabetes in the United States, which accounts for 10.5% of the US population.[23] Approximately 90-95% of them have type 2 diabetes. The annual expenditure on diabetes care is $327 billion, including direct medical costs and indirect costs of lost work and wages for people with diagnosed diabetes. According to Institute for Alternative Futures (IAF) Diabetes 2030 model, the prevalence of diabetes would increase by 54%, and the annual total costs would rise by 53% to more than $622 billion between 2015 and 2030.[24] Both in US and Louisiana, diabetes is among the leading causes of death. In Louisiana, the prevalence for diabetes in adults steadily increased between 2000 and 2019, from 6.1 percent to 14.1 percent.[25] Louisiana's diabetes mortality rate was the sixth-highest in the nation in 2019, with a rate 26.9 deaths per 100,000 total population.[26]

In addition to the high economic burden caused by diabetes, increasing diabetes prevalence will increase the number of chronic and acute diseases in the general population, with profound effects on quality of life and demand on healthcare services.[26] In large prospective trials, type 2 diabetes mellitus (T2DM) has been identified as a significant risk factor for cardiovascular diseases, including stroke[27,28], angina[29], heart failure[28], and myocardial infarction[28].

Diabetes can be effectively self-managed or have the disease under control. However, self-management is complex and requires ongoing support and access to care. Many Americans encounter severe barriers to accessing necessary healthcare services, including direct and indirect costs, lack of appointment times, long waiting times, insurance status, and distance from provider locations.[30]

Telehealth and diabetes

Telehealth is an innovation in care delivery that has the potential to improve healthcare access and save time for those with diabetes to engage in successful disease management at a distance and as frequently as it is needed. Over 100 clinical trials have confirmed the feasibility and effectiveness of telehealth in diabetes care, including monitoring, education programs, and digital device evaluation programs.[31-33] They additionally have shown positive effects of telehealth interventions for diabetes self-management at the primary healthcare stage. The Informatics for Diabetes Education and Telehealth (IDEATel) study is one of the few randomized trials of telehealth to have been conducted with concurrent controls, comparing telehealth case management with usual care for diabetes.[34-37] Telehealth in this study helped patients to achieve clinical management goals and significantly improved self-reported adherence.[34] In a randomized clinical trial conducted in an outpatient clinic, patients with type 2 diabetes receiving telehealth services had better laboratory results than standard in-person treatment group after six months of intervention.[38] A Care Coordination Home Telehealth program with a two-year follow-up in Veteran Affairs also found reduced avoidable healthcare services for diabetes (such as hospitalizations) and reduced care coordinator–initiated primary care clinic visits among program enrollees.[39] Another rural pilot diabetes care program indicated that telehealth has the potential to improve diabetes control, access to specialty care, and reduce health care utilization costs.[13]

RESEARCH GAPS, SIGNIFICANCE, AND INNOVATION

Louisiana has a high rate of diabetes and high expenditure on diabetes care. Moreover, Louisiana has wide disparities in race, poverty, and rurality for seeking health care. Considering the advantages of telehealth, it has the potential to be an alternative or supplemental approach for chronic care management to deal with the heavy diabetes burden and improve access to health care for diabetes in Louisiana. Therefore, it is important and urgent to explore the evidence of telehealth utilization and evaluate its effect on diabetes management in Louisiana.

Despite evidence from randomized controlled trials or studies using purposive samples suggesting that telehealth has benefits for diabetes care, the uptake of telehealth among type 2 diabetes in real-world settings is unknown. No study to date has been published and evaluated the telehealth services use and related effectiveness among patients with type 2 diabetes in Louisiana. Real-world evidence has been used to evaluate the impact of telehealth on other diseases in published studies. Previous studies evaluated telehealth utilization using various types of claims data.[12,40-42] One study published in 2018 explored telehealth use in Minnesota using all payer's claims data and found rapid growth of telehealth in Minnesota in the period 2010–2015 but low overall rates of use across the population.[42] It also found an uneven distribution of telehealth services use by rurality. A more recent study also used claims data to evaluate the effect of telemental health use on healthcare costs among commercially insured adults with mental health conditions.[41] It suggested that telehealth services can increase access to patients with mental health conditions without spending more on health care.

This study aims to assess the effect of telehealth use on multiple health outcomes among the diabetes population in Louisiana based on real-world evidence. The findings from this study will have the potential to inform policymakers, healthcare providers, and payers regarding telehealth adoption and expansion, especially for those states who share similar characteristics with Louisiana. Additionally, findings from this study may change patients' behavior toward seeking health care. This study uses longitudinal data before and during the COVID-19 pandemic, which provides opportunities to examine telehealth utilization over time and the effect of rapid telehealth adoption on various outcomes. This study also provides evidence for future studies to examine barriers and facilitators of adopting telehealth, and to extend analyses in this study to explore other conditions and services related to telehealth.

THEORETICAL FRAMEWORK

Although studies have been published to construct the conceptual framework for the implementation, adoption, and evaluation of telehealth from an organization's perspective or to study the diagnosis efficacy of telehealth, few studies have proposed a specific conceptual framework for telehealth services use from the patient's perspective.[43,44] In a recently published study, Zhao et al adopted Andersen's Behavioral model to explore factors related to telehealth utilization among patients.[41] Andersen's model has been used in various studies of health services, which considers the perceived health status, evaluated health status, and consumer satisfaction as outcomes.[45-47] Grigsby et al reviewed frameworks for the evaluation of telehealth from the perspective of health services research.[48] A multidisciplinary group of 21 experts proposed a systematic, policy-relevant framework to integrate regulatory, operational, and clinical factors and guide future investments in telehealth research and practice, but some important environmental factors are not considered in this framework, such as rurality and poverty.[49] Some outcomes of telehealth are mentioned in these frameworks but not in Andersen's model. The above frameworks provide guidelines to examine factors related to patients' decisions on using telehealth and how to evaluate the effect of telehealth compared with usual in-person care. Therefore, the following conceptual framework is based on these frameworks and literature review, covering potential measurable variables. Analyses in this dissertation have followed the integrated and comprehensive framework.

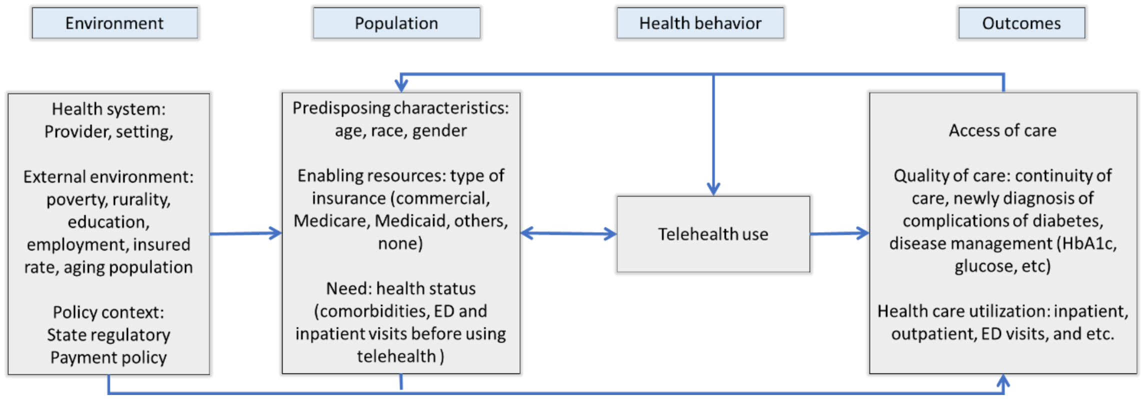


Figure1. Conceptual Framework

As mentioned in Andersen's model, the external environment is acknowledged as an important input for understanding the use of health services including physical, political, and economic factors. The policy content is also mentioned in the Telehealth Research and Policy Framework as a major component.[49] Considering telehealth as a health service, the internal environment of a healthcare setting is also an important factor that will influence the patient's decision to adopt telehealth, such as the number of providers offering telehealth services, and the setting differences.

Another component influencing the patient's decision is related to population characteristics including predisposition, enabling resources, and the need for care. Predisposing characteristics consist of demographic characteristics, social structure, and health beliefs. We only considered demographic characteristics (e.g. age, sex, race) in the model because of the limitation of data sources. We considered the type of insurance as the major enabling resource. Different insurance types may have different policies and coverages for telehealth. To estimate the need for care, We used the individual's comorbidities, numbers of ED visits, and inpatient visits before adopting telehealth.

From an evidence-based study, telehealth triggered about 6% more office visits but with mixed results on phone visits and patient health. These additional visits come at the sacrifice of new patients that physicians accepted 15% fewer new patients each month following e-visit adoption.[2] With the successful adoption of telehealth, people will have better access to health care without considering time and distance and will have better diabetes chronic care management. Preventable emergency department visits and hospitalization can then be avoided because of better access to primary care. Therefore, related costs would be reduced.

This integrated framework allows me to examine factors related to the patient behavior, alternating in-person usual care with telehealth care, and then evaluate the effect of telehealth use on the healthcare utilization and health outcomes compared with traditional in-person visits. Therefore, three main research aims were listed below.

1. To explore the trend of telehealth use and identify factors associated with telehealth use during the pandemic among Louisiana Medicaid beneficiaries with diabetes

2. To evaluate the effect of telehealth use on healthcare utilization among Louisiana Medicaid beneficiaries with diabetes

3. To evaluate the effect of telehealth use on health outcomes among diabetes using REACHnet EHR data

AIM 1: TO EXPLORE THE TREND OF TELEHEALTH USE AND IDENTIFY FACTORS ASSOCIATED WITH TELEHEALTH USE DURING THE PANDEMIC AMONG LOUISIANA MEDICAID BENEFICIARIES WITH DIABETES.

Introduction

The federal government and states' governors encouraged the use of telehealth services since the beginning of the COVID-19 pandemic in the United States to provide necessary care to patients while minimizing the transmission risk of SARS-CoV-2 , the virus that causes COVID-19, to healthcare personnel and patients.[19] The Centers for Medicare and Medicaid Services (CMS) lifted the rural area and originating site requirements for reimbursement of telehealth services during the coronavirus national emergency effective on March 6th, 2020.[20] Pursuant to this announcement, healthcare providers would be reimbursed the same amount for telehealth services as for in-person visits regardless of a Medicare beneficiary's location. The Louisiana governor issued a proclamation later to encourage the use of telehealth in response to the public health emergency.[21] Louisiana Medicaid program also has expanded coverage and reimbursement on telehealth services.

Although telehealth utilization was increasing before the COVID-19 pandemic, it remained a small percentage of all visits because of regulations and limitations on reimbursement. A recent study examined the trends of telehealth use before the pandemic for evaluation and management services among Louisiana Medicaid beneficiaries. They found that telehealth use in Louisiana Medicaid was low but growing before the pandemic with narrowing disparities by race and geography but emerging disparities by age from January 2018 through February 2020.[50]

Recent policy changes during the COVID-19 pandemic have reduced barriers to telehealth access and have promoted the use of telehealth as a way to deliver acute, chronic, primary, and specialty care.[18] Prior studies have found a rapid increase in telehealth use across the united states since the beginning of the pandemic.[51-54] More than a 20-fold increase in the incidence of telehealth utilization was observed in four months since March 2020 across all the 50 U.S. states.[51] The telehealth rate decreased later with the COVID-19 cases declined in late 2020 but still stabilized at a relatively high level of outpatient visits. The Centers for Disease Control and Prevention (CDC) estimated that the overall average percentage of weekly telehealth visits decreased 25%, from 35.8% at the end of June 2020 to 26.9% in early November 2020.[55] National survey data from the Census Bureau showed one in four respondents (23.1%) reported use of telehealth services in the previous four weeks overall between April and October 2021.[56] Factors related to telehealth use during the pandemic have been examined from at the local level or national level.[57,58]

Telehealth has the potential to serve as an alternative to improve healthcare access and timesaving for those with diabetes to engage in successful disease management at a distance and as frequently as it is needed, especially for the vulnerable population. However, sparse evidence has examined the trend of telehealth use and factors related to telehealth use among Medicaid beneficiaries with type 2 diabetes. Louisiana has a high incidence of type 2 diabetes and provides a unique setting for understanding telehealth use in diabetes care. Therefore, we conducted the present study to assess the trend of telehealth use before and during the COVID-19 pandemic and identify the factors related to the uptake of telehealth during the pandemic among Louisiana Medicaid beneficiaries with type 2 diabetes.

Method

Study design and data source

This study used a retrospective quasi-experimental, interrupted time series design to examine the trend of telehealth use among Louisiana Medicaid beneficiaries with type 2 diabetes using Medicaid claims data from January 2018 to August 2021. The sample was restricted to those continuously enrolled in Louisiana Medicaid over the sample period to avoid issues with compositional changes resulting from increased enrollment due to COVID-19 and excluded the dual-eligible as we lack access to Medicare claims. Among these patients, We further examined the one-year (March 2019 to February 2020) patient-level characteristics associated with the uptake of telehealth during the COVID-19 pandemic. The 2019 zip code-level American Community Survey (ACS) was linked to Medicaid claims based on residential 5-digit zip codes to acquire the zip code-level environmental characteristics.

Sample selection

Telehealth services were selected based on the claim's modifiers (eg. GT, GQ, 95), and/or place of service code (02) in Louisiana Medicaid claims.

Patients with type 2 diabetes were selected according to their diagnoses and medication history due to the absence of lab results in the Medicaid claims data. Therefore, a refined SUPREME-DM diabetes definition was used to select the type 2 diabetes cohort in claims data[59]:

(1) 1 or more of the International Classification of Disease, Tenth Revision, Clinical Modification (ICD-10-CM) codes (E11.xx) for type 2 diabetes mellitus associated with inpatient encounters.

(2) 2 or more ICD codes associated with outpatient encounters on different days within 2 years.

(3) combination of ICD codes and antidiabetic medications with outpatient encounters on different days within 2 years.

Measurements

We examined changes in telehealth use by race, ethnicity, geography, and age. Race/ethnicity included Black, White, Hispanic, and others (e.g., Asian). The geography was categorized into rural and urban according to the county of residence as defined by the National Center for Health Statistics.[60] The age groups consisted of 18-39, 40-54, and 55-64. We also checked the change of provider types for delivering telehealth services before and during the COVID-19 pandemic. The provider type was selected based on the provider type code which designates the classification of a provider per the state plan (i.e., dentist, pharmacy). The monthly share of outpatient claims delivered by telehealth was calculated by monthly telehealth services divided by monthly outpatient claims and multiplied the ratio by 100 for each separate race/ethnicity, geography, and age category.

To identify factors associated with the uptake of telehealth during the pandemic, we included the age in March 2020, gender, race/ethnicity, healthcare utilization and comorbidities during 12 months before March 2020, and zip-code level computer, internet, and telephone use rate. Healthcare utilization consisted of any ED visits, any hospitalization, monthly outpatient visits, and the number of HbA1c tests during the baseline. The ED visits and hospitalizations were identified according to the Healthcare Effectiveness Data and Information Set (HEDIS) measures. The outpatient visits included visits delivered in outpatient hospitals and clinics.

Statistical analysis

The ITS model was used to estimate the monthly share of outpatient claims delivered by telehealth as the dependent variable.

$$Y_t = \beta_0 + \beta_1 T_t + \beta_2 P_t + \beta_3 P_t T_t + \varepsilon_t$$

Y_t is measured monthly telehealth use, T_t represents months since the start of the study period (January 2018), P_t is an indicator of telehealth expansion (since March 2020), $P_t T_t$ is an interaction that represents months since telehealth expansion and $\varepsilon_t$is the error term. A statistically significant effect estimate for β_2 (intercept) would indicate an immediate policy effect on outcome; while a statistically significant β_3 (change in slope from pre- to post-periods, and the main parameter of interest) suggests an effect of expanded telehealth over time. All analyses will be performed using Stata 15.1.

Results

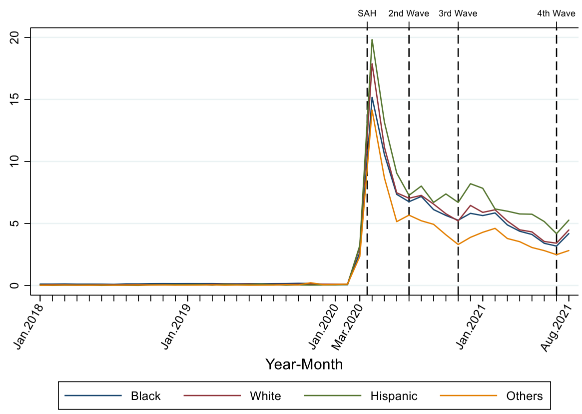
The trend of telehealth use

The study included 51,817 Medicaid beneficiaries with T2DM who were continuously enrolled from January 2018 through August 2021. Figure 2A depicts the share of outpatient visits delivered by telehealth from January 2018 through August 2021 by race/ethnicity. While Louisiana Medicaid covered some telehealth services before the pandemic, utilization of these services was relatively low, accounting for less than 1% of outpatient visits. Telehealth use increased substantially during the first wave of COVID-19 infections in April 2020 for all races, ethnicity, age groups, and geographic groups. At its pandemic peak, telehealth represented over 15% of outpatient claims in April 2020 after state governors issued a Stay-at-Home Order on March 22. As in-person care resumed, telehealth began to represent a smaller share of outpatient care (about 7%). The second wave of COVID infection started in June 2020 and telehealth use among outpatient claims had a small spike in July 2020 when COVID-19 infection in Louisiana reached the peak of the second wave. Similar rebounds in telehealth use were found in during the third wave starting in November 2020 and the fourth wave starting in July 2021.

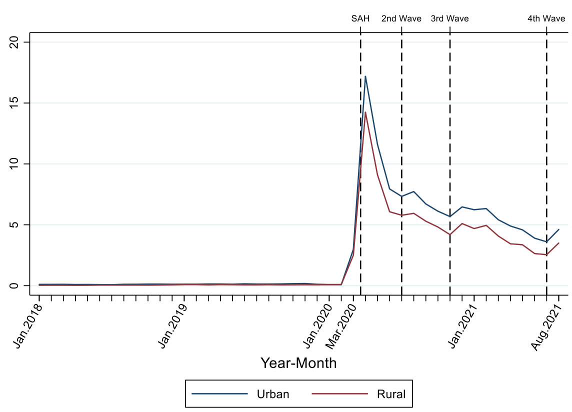
Figure 2B plots telehealth use for Louisiana Medicaid beneficiaries with T2DM living in rural and urban counties. On average, rural beneficiaries had 5.13% of outpatient claims delivered by telehealth compared with urban beneficiaries' rate of 6.63% during the pandemic, from March 2020 to August 2021. While one goal of telehealth is to improve healthcare access in rural areas, beneficiaries in the urban counties had a greater proportion of outpatient claims delivered by telehealth during the pandemic. The gap remained consistent and was about 2% in the share of outpatient claims delivered by telehealth between rural and urban counties.

For age groups, the share of outpatient visits delivered by telehealth among beneficiaries aged between 55 and 64 years was lower than that among younger groups (18-39 and 40-54) (Figure 2C). The group aged between 40 and 54 years shared a similar trend to the youngest group, aged between 18 and 39 years, in the share of outpatient visits delivered by telehealth before the peak in April 2020.

A. Race/Ethnicity



B. Geography



C. Age

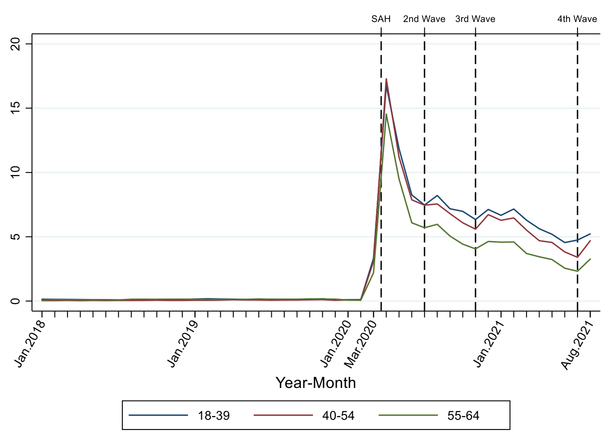


Figure 2. Monthly Shares of Outpatient Visits Delivered by Telehealth by Race/Ethnicity, Geography, and Age.

Estimates in Table 1 from our corresponding ITS models confirm the graphical evidence indicating telehealth use increased substantially during the first wave of COVID-19 infections in April 2020 for all groups. White beneficiaries exhibited higher rates of telehealth use than Black or Hispanic beneficiaries in the pre-COVID-19 period. The share of outpatient visits delivered by telehealth during April 2020 substantially increased across all groups (column 2). Black beneficiaries experienced the largest share of outpatient claims delivered by telehealth with an average of 0.131% (95% CI, 0.120% to 0.141%) per month in the pre-COVID-19 period. Hispanic beneficiaries experienced the largest share of outpatient claims delivered by telehealth of 10.7% (95% CI, 6.365% to 15.036%) in April 2020. Hispanic patients had the largest relative increase among the three main racial/ethnic groups in the share of outpatient claims delivered by telehealth with an average of 0.048% (95% CI, 0.037% to 0.058%) per month in the pre-COVID-19 period moving to 10.7% (95% CI, 6.365% to 15.036%) in April 2020, about 223-fold increase over baseline rates. Relative increases were smaller for Black and White beneficiaries.

Beneficiaries living in the urban counties always had higher share of outpatient claims delivered by telehealth than beneficiaries living in the rural area, an average of 0.121% (95% CI, 0.112% to 0.131%) versus 0.063% (95% CI, 0.054% to 0.071%) per month in the pre-COVID-19 period and 9.578% (95% CI, 5.966% to 13.190%) versus 7.732% (95% CI, 4.768% to 10.696%) in April 2020. But beneficiaries living in the rural counties had the larger relative increase than beneficiaries living in the urban in the share of outpatient claims delivered by telehealth, about 123-fold increase versus 79-fold increase over baseline rates.

For age groups, young Beneficiaries, aged 18-39, were always with higher outpatient telehealth use rate before and after the outbreak of COVID pandemic than the other two age group (40-54 and 55-64). However, the group of aged 40-54 had the largest relative change from an average of 0.066% (95% CI, 0.057% to 0.074%) per month in the pre-COVID-19 period to 9.607% (95% CI, 6.073% to 13.142%) in April 2020, about 146-fold increase over the baseline.

Table 1. ITS Estimates of Changes in Share of Outpatient Visits Delivered by Telehealth

	1	2	3
Group	Baseline Average (1/2018-2/2020)	Mar. 2020	Mar. 2020 to Aug. 2021 Trend
Race and Ethnicity			
Black	0.131	8.689	-0.332
	[0.120,0.141]	[5.501,11.876]	[-0.599,-0.064]
White	0.074	9.499	-0.38
	[0.064,0.084]	[5.769,13.230]	[-0.690,-0.070]
Hispanic	0.048	10.700	-0.382
	[0.037,0.058]	[6.365,15.036]	[-0.738,-0.025]
Other	0.048	7.219	-0.308
	[0.031,0.064]	[4.171,10.266]	[-0.559,-0.058]
Geography			
Rural	0.063	7.732	-0.32
	[0.054,0.071]	[4.768,10.696]	[-0.567,-0.073]
Urban	0.121	9.578	-0.364
	[0.112,0.131]	[5.966,13.190]	[-0.666,-0.063]
Age			
18-39	0.131	9.72	-0.317
	[0.121,0.140]	[6.273,13.167]	[-0.605,-0.030]
40-54	0.066	9.607	-0.366
	[0.057,0.074]	[6.073,13.142]	[-0.661,-0.071]
55-64	0.125	7.693	-0.336
	[0.113,0.137]	[4.513,10.873]	[-0.601,-0.070]

Notes: Regression estimates are from an interrupted time series (ITS) specification that includes a monthly time trend, an indicator for March 2020 and the interaction between the trend term and March 2020 indicators. Column (1) reports mean monthly telemedicine shares in outpatient visits from January 2018 through February 2020. Column (2) reports the coefficient estimate for the March 2020 indicator from the ITS model. Column (3) reports the sum of the monthly time trend and the coefficient estimate of the interaction between the trend term and the March 2020 indicator. Data for each regression model are comprised of 44 month-year level observations. Cumby-Huizinga tests for autocorrelation led to the inclusion of a maximum lag of order 1.

We also checked the provider type delivering the telehealth before and during the pandemic. Before the pandemic, from January 2018 to February 2020, over 80% of telehealth services were delivered by physicians and nurse practitioners. Followed provider types are others (6.0%) and mental health clinics (5.1%). About 6% of telehealth services were delivered by licensed clinical social workers (2.0%), licensed professional counselors (1.6%), phycologists (1.7%), and Federally Qualified Health Center (FQHC) (0.7%). With the telehealth expansion since March 2020, some telehealth services started to be delivered by non-licensed behavioral health staff (24.6%) and hospitals (1.4%). Increases were found in other categories, including nurse practitioner, licensed professional counselor, licensed clinical social worker, FQHC, physician assistant, and behavioral health rehabilitation. Increases in other provider types resulted in a decrease in the percent of telehealth services delivered by physicians from 61.7% to 27.3%. Only 0.1% of telehealth services were delivered by mental health clinics during the pandemic.

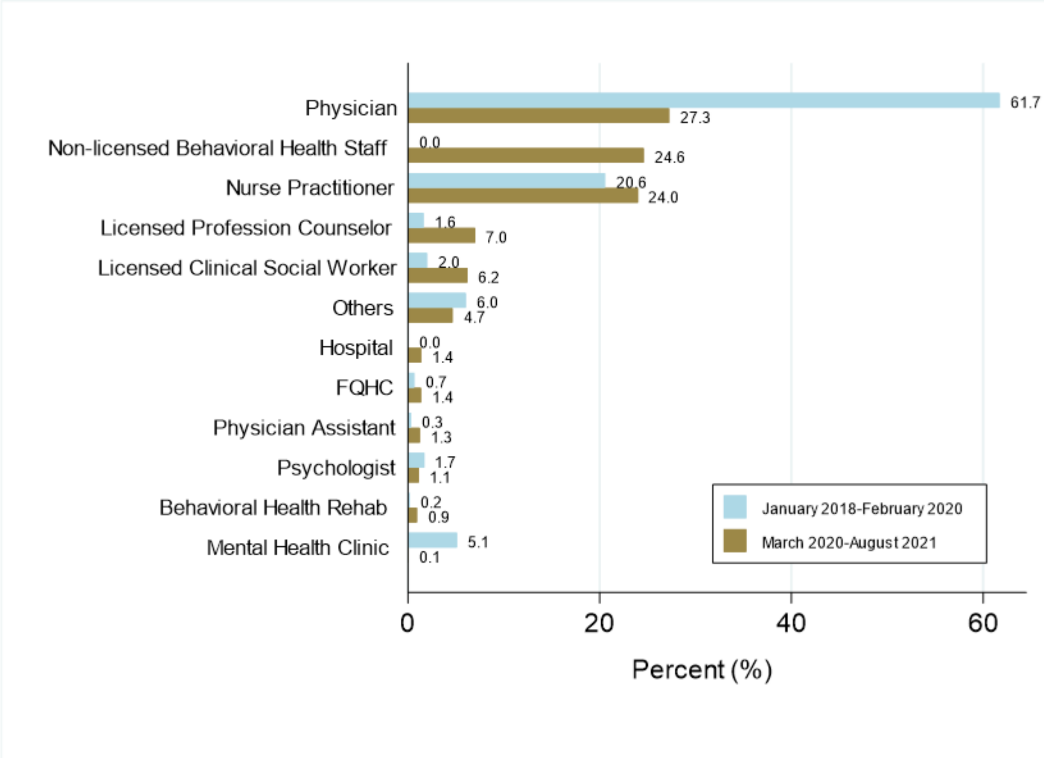


Figure 3. Change of Provider Types in Telehealth Services Before and During COVID-19 Pandemic

Factors associated with telehealth use during the COVID-19 pandemic

To evaluate the factors associated with telehealth use among type 2 diabetes patients during the COVID-19 pandemic, this study included 49,111 Medicaid beneficiaries with type 2 diabetes after linking with the 2019 zip-code level American Community Survey on residential zip code. Among these patients, 27,616 patients used any telehealth services during the pandemic. Table 2 lists the results of logistic regression on the update uptake of telehealth and lists one-year baseline factors (March 2019 to February 2020). The use of telehealth services was significantly associated with beneficiaries who were younger, female, black, with more monthly outpatient visits, more HbA1c tests, and with some certain chronic conditions (e.g. asthma, hypertension, arthritis, depression, hyperlipidemia) because those AORs are over 1.

Table 2. Factors Associated with The Telehealth Uptake During The COVID-19 Pandemic

	Coefficient	AOR [95% CI]		P-value
Age				
18-39	0.009	1.009	[0.951,1.070]	(0.777)
40-54	reference	1	-	-
55-64	-0.135***	0.874***	[0.831,0.919]	<0.001
Female	0.307***	1.359***	[1.298,1.423]	<0.001
Race				
White	reference	1	-	-
Black	0.065*	1.067*	[1.000,1.139]	(0.050)
Hispanic	-0.050	0.952	[0.858,1.056]	(0.348)
Other	-0.243***	0.784***	[0.714,0.861]	<0.001
Rural	-0.178**	0.837**	[0.747,0.937]	(0.002)
Any ED visits	0.004	1.004	[0.959,1.052]	(0.863)
Any IP visits	-0.359***	0.699***	[0.653,0.748]	<0.001
Outpatient visits	0.034***	1.035***	[1.032,1.037]	<0.001
Number of HbA1c tests	0.167***	1.182***	[1.143,1.221]	<0.001
Chronic Conditions				
Asthma	0.175***	1.191***	[1.113,1.274]	<0.001
Stroke	-0.062	0.940	[0.851,1.038]	(0.220)
Hypertension	0.261***	1.298***	[1.235,1.364]	<0.001
Arthritis	0.137***	1.147***	[1.084,1.213]	<0.001
Atrial Fibrillation	-0.003	0.997	[0.873,1.140]	(0.971)
Cancer	0.110	1.117	[0.983,1.269]	(0.091)
Chronic Obstructive Pulmonary Disease	-0.017	0.983	[0.916,1.055]	(0.642)
Chronic Kidney Disease	-0.012	0.988	[0.914,1.067]	(0.758)
Depression	0.553***	1.739***	[1.648,1.835]	<0.001
Heart Failure	-0.074	0.929	[0.854,1.010]	(0.086)
Hyperlipidemia	0.089**	1.093**	[1.034,1.156]	(0.002)
Coronary Heart Disease	-0.031	0.969	[0.899,1.046]	(0.423)
CCI score	0.015	1.015	[0.999,1.031]	(0.071)
Zip code level Characteristics				
Computer rate	-0.006	0.994	[0.978,1.011]	(0.490)
Internet rate	0.012	1.012	[1.000,1.024]	(0.057)
Telephone rate	0.014	1.014	[0.988,1.041]	(0.288)
Telehealth users	27,616			
Total	49,111			

Notes: AOR: adjusted odds ratio. CI: confidence interval. CCI: Charlson Comorbidity Index. ED: emergency department. IP: inpatient.

Beneficiaries aged between 55 and 64 years were less likely to use telehealth during the pandemic compare with the group aged between 40 and 54 years (AOR=0.874, 95% CI: 0.831 to 0.919], p<0.001). Female beneficiaries were 1.359 (95% CI: 1.298 to 1.423) times more likely to use telehealth services than male beneficiaries. Black beneficiaries were 1.067 (95% CI: 1.000 to 1.139) times more likely to use telehealth services than White beneficiaries, while beneficiaries in the racial group of others were 0.784 (95% CI: 0.714 to 0.861) times less likely to use telehealth services than White beneficiaries. Beneficiaries who had any inpatient visits during the year before the pandemic were less likely to use telehealth services (AOR=0.699, 95% CI: 0.653 to 0.748, p<0.001). For every visit increase per month in outpatient visits and one test of HbA1c increase at the baseline, the odds of receiving telehealth services increased by 1.035 times (95% CI: 1.032 to 1.037) and 1.182 times (95% CI: 1.143 to 1.221), respectively. The use of telehealth services was significantly associated with patients who had depression relative to those without asthma (ARO=1.739, 95% CI:1.648 to 1.835, p<0.001). The uptake of telehealth had similar associations with asthma, hypertension, arthritis, and hyperlipidemia.

Discussion

Using the state-wide Medicaid claims data, we found that telehealth use among Louisiana Medicaid beneficiaries with type 2 diabetes was low before the pandemic and spiked in April 2020. While the share of outpatient visits delivered by telehealth declined later, it was still elevated from the pre-pandemic era. Telehealth use was varied across different racial/ethnic groups, rurality, and age groups. We also found changes in provider types delivering telehealth services before and during the pandemic. The use of telehealth services during the COVID-19 pandemic was significantly associated with Medicaid beneficiaries who were younger, female, black, with more health service utilization, and with more chronic conditions during the one year before March 2020. The present study is the first to examine the trend and assess disparities among Medicaid beneficiaries with type 2 diabetes in Louisiana by different comparison groups before and during the COVID-19 pandemic.

We found a similar trend of telehealth use among Louisiana Medicaid beneficiaries with type 2 diabetes visits as the findings in the prior work.[51,56,58,61] The share of outpatient visits delivered by telehealth was less than 1% before the pandemic and had a surge in April 2020 followed by a decline across all groups. Telehealth is often discussed as a potential way to improve access to care for older adults and residents in rural areas, who may be less mobile or with less access to health care. However, older beneficiaries have had lower retention of telehealth since the pandemic peak than younger beneficiaries in Louisiana Medicaid in the present study. Beneficiaries with type 2 diabetes in urban areas used more telehealth services over outpatient services than patients in rural areas both before and after the onset of the COVID-19 pandemic. Lower telehealth use by rural beneficiaries may be due to limitations in broadband access and challenges with Internet availability and affordability.[62] This is supported by our analysis showing lower rates overall among beneficiaries living in the rural area.

The types of providers delivering telehealth have changed with the expansion of telehealth services in Louisiana. Among overall telehealth services used by Louisiana Medicaid beneficiaries with type 2 diabetes, providers related to behavioral health got the largest increase. Similar findings on telehealth services in the realm of behavioral health care are in line with a Medicare study.[63] Among the older population, the study showed the largest increase in telehealth visits to behavioral health specialists in 2020. The need for behavioral health could be related to several factors such as stress, loneliness, unemployment, and economic uncertainty during the pandemic, especially for patients with chronic conditions.[64] Behavioral health services could also be well suited to telehealth as physical exams or in-person diagnostic tests may be less frequently required. Patients with both chronic disease and behavioral disorders therefore may gain more benefits from telehealth.

Consistent with previous studies documenting factors related to telehealth use during the pandemic, the present study also found similar factors related to telehealth use during the pandemic among Louisiana Medicaid beneficiaries with type 2 diabetes. For example, patients using telehealth tend to be younger, female, and black, living in urban counties.[58,62,65] Unlike previous studies, we additionally identified type 2 diabetes patients with more health care utilization (e.g. outpatient visits) during the year before the pandemic were more likely to use telehealth during the pandemic.

Though this is the first study to assess telehealth use among Medicaid beneficiaries with type 2 diabetes in Louisiana, there are some noteworthy limitations. The present study only used single-state Medicaid claims data and may not be representative of the population with other diseases or other insurance coverage. A more diverse population with other insurance types and/or other health conditions would be better to address the generalizability of these findings. Second, we used an interrupted time-series approach to assess the impact of COVID-19 on changes in the share of outpatient visits delivered by telehealth. Identification in the ITS model relies on trend breaks in outcome measures, which could be driven by other confounders unrelated to the pandemic.[66] Third, we only focused on the general volume of outpatient care services without linking the services with any specific health services. We only examined the general telehealth services and were unable to separate audio and video telehealth visits. Fourth, although we linked Medicaid claims to the ACS data to get zip code level environmental characteristics, this study did not include all factors related to telehealth due to data limitations, such as individual factors of socioeconomic and education status, access to technology equipment, etc. Provider-level factors may also have contributed to our findings, such as infrastructure, equipment, and training provided to the providers to support telehealth, and quality in delivering telehealth services during the COVID-19. Qualitative studies in the future on patient and provider experience may provide more information to comprehensively evaluate disparities in telehealth utilization among type 2 diabetes.

Among Louisiana Medicaid beneficiaries with type 2 diabetes in our study, we found disparities in race/ethnicity, age, and rurality in the uptake of telehealth during the COVID-19 pandemic. Telehealth use for outpatient visits remained elevated after a surge in April 2020, compared to the level of use in previous years. Future studies need to be conducted to assess the quality of care delivered by telehealth and healthcare spending to better understand the value of telehealth on diabetes care and inform policymaking on whether to continue the coverage of more telehealth services beyond the pandemic.

AIM 2: TO EVALUATE THE EFFECT OF TELEHEALTH USE ON HEALTHCARE UTILIZATION AMONG LOUISIANA MEDICAID BENEFICIARIES WITH DIABETES.

Introduction

The coronavirus disease 2019 (COVID-19) spread rapidly worldwide with the first confirmed case reported in the United States in January 2020 and has created challenges for providing health care for patients with diabetes through disclosure and discouragement of in-person care. Both private and public payers have expanded reimbursement for telehealth encouraged by federal and state regulations to provide health care during the pandemic.

The Louisiana governor proclaimed to encourage the use of telehealth during the coronavirus emergency in response to the public health emergency.[21] Louisiana Medicaid program also expanded telehealth coverage and reimbursements. As a result, some providers were better positioned to manage the shift to telehealth. The Louisiana State Board of Medical Examiners has issued temporary permits to out-of-state professionals in addition to an existing telehealth registration process that does not require full state licensure.[67] Telehealth is a valuable approach to providing care to diabetes patients in such an environment because routine care is needed for diabetes management.

The feasibility and effectiveness of telehealth in diabetes care have been confirmed by previous clinical trials and designed programs.[31] However, real-world evidence relating to the impact of telehealth on people with diabetes was impeded by the low uptake of telehealth before the pandemic. The emerging literature has empirically demonstrated the surge in healthcare delivery of telehealth and the rapid shift in telehealth adoption among both patients and providers during the pandemic.[68-71] A recent report indicates that thirty percent of all visits at outpatient practices were provided through telehealth at the start of the pandemic.[72] Total weekly outpatient visits in Louisiana fell by about 22.6 percent between May 20 and June 16.[73] Over the same period, telehealth visits accounted for approximately 16 percent of total outpatient visits in Louisiana.[16] Inadequate access to outpatient clinics during the pandemic may delay diabetes care, which in turn, can aggravate the health conditions and eventually lead to a higher rate of future ED visits or hospitalization.[74] It is also concerned about the quality of care of the rapid adoption of telehealth during the pandemic.[75] Considering the high prevalence of diabetes in Louisiana,[25] the rapid increase of telehealth use presented an unprecedented opportunity for patients through the proliferation of telehealth. Therefore, we conducted the present study to evaluate the impact of telehealth use during the pandemic on primary care visits, ED visits, and hospitalizations among Louisiana Medicaid beneficiaries with type 2 diabetes.

Methods

Study design and data source

The propensity score weighted difference-in-difference analysis was used to estimate the comparative effect of telehealth use on healthcare utilization among patients with type 2 diabetes using the Medicaid claims data from March 2019 to August 2021. This model can be used to mitigate the selection bias and control observed factors related to telehealth use. The sample was restricted to those continuously enrolled in Louisiana Medicaid over the study period to avoid issues with compositional changes resulting from increased enrollment due to COVID-19 and excluded the dual-eligible as we lack access to Medicare claims. The 2019 zip code-level American Community Survey (ACS) was linked to

Medicaid claims based on residential 5-digit zip codes to acquire the zip code-level environmental characteristics.

Sample selection

Patients with type 2 diabetes were selected according to their diagnoses and medication history due to the absence of lab results in the Medicaid claims data. Therefore, a refined SUPREME-DM diabetes definition was used to select the type 2 diabetes cohort:

(1) 1 or more of the International Classification of Disease, Tenth Revision, Clinical Modification (ICD-10-CM) codes (E11.xx) for type 2 diabetes associated with inpatient encounters.

(2) 2 or more ICD codes associated with outpatient encounters on different days within 2 years.

(3) combination of any ICD codes and antidiabetic medications with outpatient encounters on different days within 2 years.

We further excluded patients with type 1 diabetes or gestational diabetes using ICD 10 codes.

Outcome measures

For healthcare utilization, we measured the visit frequency of heath care services, such as visits for outpatient visits, inpatient visits, and ED visits. The visit frequency was presented as an average number of visits for each type per month and it was calculated separately before and after the index date during the COVID-19 pandemic. ED visits and inpatient visits were identified according to the Healthcare Effectiveness Data and

Information Set (HEDIS) measures. The outpatient visits included in-person visits with claim types of outpatient hospitals, clinics, and physician services. The secondary outcomes included ED visits and hospital stays related to major adverse cardiovascular events (MACE) and ambulatory care sensitive conditions (ACSC) because they could be preventable by improved access to primary care.

Independent variables

The comparison groups were defined based on telehealth use during COVID-19 (since March 2020) (yes/no). Telehealth users (treatment group) were selected among beneficiaries with any claims of telehealth since March 2020. Telehealth services were identified based on procedure codes appended with modifiers (eg. GT, GQ, 95), and/or place of service code (02) in Louisiana Medicaid claims. All other Medicaid beneficiaries were assigned as non-telehealth users (control group).

For other control variables, we included age, gender, race/ethnicity, monthly health utilization during 12 months before the index date, comorbidities, and computer, internet, and telephone use rate at the zip code level. Monthly Healthcare utilization consisted of ED visits, hospital stays, outpatient visits, and the number of HbA1c tests during the baseline period.

Statistical analysis

The difference-in-difference model with propensity score weighting strategy was used to capture the effect of telehealth services during the pandemic on healthcare utilization. We defined the treatment group as beneficiaries with at least one record of telehealth since March 2020, and the dates of the first telehealth encountered were coded as the initiation dates (index dates). We then assigned index dates randomly for non-telehealth beneficiaries (control group) based on the distribution of initiation dates in the treated population. The baseline period was 12 months before the index date and the selected cohort also needs to have at least 6 follow-up months after the index date to make sure enough evaluation period. For example, patients who had their first telehealth service after February 2021 were not included in this study because follow-up months were less than 6 months. The time indicator was a dichotomous variable, 0 for the pre-period (12 months before the index date) and 1 for the post-period (>=6 months after the index date). We used the propensity score weighting method to obtain a successful balance between treatment and control groups. To succeed in balancing, we first used group-based trajectory modeling to categorize individuals into latent groups with similar patterns of outpatient visits over 12 months before the initiation dates. The 12 monthly indicators of outpatient visits before treatment were introduced and modeled using the zero-inflated Poisson model for the group-specific models with time units defined by months. Once the best group-based trajectory model has been chosen, measures of group membership were then incorporated as control variables in propensity score weighting protocols and regression models.[76] We used the Bayesian information criterion (BIC) to select the optimal number of trajectory groups. Additionally, each trajectory group should have more than 5 percent of the population contributing to it.[77] Detailed explanations of using group-based trajectory models can be found in prior work of other studies.[78-80] We then estimated the propensity scores of getting the telehealth during the pandemic using a probit regression model, controlling for the covariates of baseline characteristics and binary indicators of each trajectory group. Beneficiaries using telehealth were assigned a weight of 1 and non-telehealth beneficiaries were assigned weights that weighting by odds (propensity score weight=propensity scores/ (1-propensity scores)). These weights were used in the subsequent outcome modeling. The outcomes were estimated using weighted linear regression and implemented the estimator by controlling the same set of variables used in estimating the propensity scores except for those outcome variables. We used the weighted linear regression on all outcomes. The treatment sample may change with different treatment definitions and different outcome assessments; therefore, we repeated our matching process and regenerated propensity scores for non-telehealth beneficiaries to approximate the corresponding counterfactuals. For every weighting, the standardized mean difference was checked between treatment and control before and after weighting to ensure successful weighting as defined as standardized mean differences within 10% for all baseline characteristics.

The DID model is listed as follows.

$$Y_{it} = \alpha + \beta * Effect_{it} + Post_t + Telehealth_i + X + \delta + \partial_t + \varepsilon_{it}\ ,\ w_i$$

The variable, $Effect_{it}$, is an interaction between the time indicator ($Post_t$: 0 for pre and 1 for post) and the indicator of telehealth users ($Telehealth_i$: 0 for non-telehealth users and 1 for telehealth users). β is the coefficient of interest and captures the change in outcomes in the pre- and post-period between Medicaid beneficiaries with and without telehealth use. The model also zip code level fixed effect (δ) and time fixed effect (∂_t) of index to control unobservable individual differences and secular trends, respectively. X is a set of factors used in the propensity score weighting model, with the exception of the baseline outcome variables, used as control variables in our regressions to help control for additional variation that may remain after matching.[81] Weights, w_i , are calculated based on propensity scores; w_i=1 for treated units and w_i= propensity scores /(1- propensity scores) for untreated units. The standard error will be clustered at the zip code level to account for common variances in these observations.

Subgroup analysis

We identified multiple sub-groups of beneficiaries to determine how the impact of telehealth uptake during the COVID-19 differed by local environmental characteristics related to telehealth. These characteristics included zip-code computer use rate, internet rate, and telephone rate. The sample was divided into two sub-groups based on the 50th percentile of each characteristic. Telehealth is used as an approach to improve the health care access of rural residents. We, therefore, examined whether telehealth impacted differently across the rural status of the county where beneficiaries lived. Other sub-group analyses were performed in different age groups (>=50 versus <50) and racial groups (Black versus non-Black).

Sensitivity analysis

With the lack of healthcare access due to the pandemic, patients with critically poor health could receive telehealth services for follow-up care after they had inpatient stays or emergency department visits. Therefore, we further performed the analysis after excluding those who had ED visits or hospitalizations within 30 days before the telehealth visit.

Telehealth was not particularly expanded for diabetes care during the pandemic. A proportion of patients used only telehealth services just for non-diabetes care, such as mental health, which could bias the findings in this study. We then repeated our main analysis only including patients who used telehealth services for any diabetes care in the treatment group.

All data analyses were performed using SAS version 9.4 and Stata version 15.1 (StataCorp). Mean values were reported with standard deviations and regression coefficients were reported with 95% CIs. Statistical significance was set at $P < 0.05$, and all tests were two-tailed.

Results

Baseline characteristics

This study identified 56,759 continuously Medicaid enrollees with diagnosed type 2 diabetes. 2,286 patients were then excluded because they were late telehealth users and with a follow-up period of fewer than 6 months. We further excluded 3,984 beneficiaries because they had no outpatient visits during the 12-month baseline. To get zip code level characteristics, a sample of 49,034 beneficiaries was linked with the 2019 zip code level ACS data. After propensity score weighting, we finally included 27,340 telehealth beneficiaries in the treatment group and 21,652 non-telehealth beneficiaries in the control group. According to the BIC and the proportion of beneficiaries, a three-group trajectory model was identified and best suited for the analytic sample (Figure S4). Beneficiaries in each group shared a similar trend of outpatient visits during 12 months at baseline.

As shown in Table 3, all baseline characteristics were successfully balanced within 10% or 0.01 of a standardized mean difference after weighting by propensity scores. In the weighted sample, the mean age was about 47 years old and nearly half of them were Black. Hypertension, hyperlipidemia, and depression were the three most common chronic conditions in this sample, about 78%, 60%, and 38%, respectively. The weighting procedures were repeated for each sample of subgroup analyses or sensitivity analyses.

They were all successfully weighted characteristics for the treatment group and control group.

Table 3. Baseline Characteristics Before and After Propensity Score Weighting.

	Unweighted			Weighted		
Variables	Telehealth	In-person	SMD	Telehealth	In-person	SMD
Age at first TH (years)	47.268	46.360	-0.078	47.268	47.461	0.017
Female	0.722	0.643	-0.171	0.722	0.714	-0.017
Race/ethnicity						
White	0.383	0.362	-0.043	0.383	0.383	0.000
Black	0.513	0.500	-0.025	0.513	0.512	-0.002
Hispanic	0.040	0.044	0.024	0.040	0.040	0.003
Other	0.310	0.357	0.099	0.310	0.314	0.008
Chronic conditions						
Asthma	0.148	0.094	-0.165	0.148	0.131	-0.048
Stroke	0.071	0.050	-0.088	0.071	0.074	0.014
Hypertension	0.773	0.692	-0.185	0.773	0.780	0.018
Arthritis	0.285	0.193	-0.215	0.285	0.288	0.009
Atrial Fibrillation	0.029	0.020	-0.062	0.029	0.031	0.013
Cancer	0.031	0.019	-0.076	0.031	0.031	-0.001
COPD	0.164	0.120	-0.126	0.164	0.164	0.001
Chronic Kidney Disease	0.120	0.088	-0.106	0.120	0.124	0.011
Depression	0.377	0.190	-0.425	0.377	0.377	-0.001
Heart Failure	0.084	0.064	-0.076	0.084	0.085	0.004
Hyperlipidemia	0.583	0.499	-0.169	0.583	0.590	0.015
Coronary Heart Disease	0.133	0.100	-0.103	0.133	0.132	-0.004
Monthly HCRU						
OP	1.339	0.842	-0.534	1.339	1.362	0.021
Inpatient	0.017	0.012	-0.123	0.017	0.018	0.017
ACSC related	0.003	0.002	-0.038	0.003	0.003	0.023
MACE related	0.001	0.001	-0.032	0.001	0.001	-0.007
ED	0.129	0.100	-0.201	0.129	0.126	-0.017
ACSC related	0.034	0.027	-0.075	0.034	0.040	0.034
MACE related	0.002	0.001	-0.048	0.002	0.002	-0.003
HbA1c tests	0.072	0.050	-0.227	0.072	0.073	0.014
Environmental factors (%)						
Computer rate	83.549	82.893	-0.082	83.549	83.494	-0.007
Internet rate	72.651	71.607	-0.095	72.651	72.541	-0.010
Telephone rate	97.647	97.527	-0.070	97.647	97.627	-0.012
Trajectory group						
Trajectory group 1	0.341	0.623	0.589	0.341	0.338	-0.006
Trajectory group 2	0.521	0.334	-0.386	0.521	0.523	0.004

Trajectory group 3	0.138	0.043	-0.336	0.138	0.139	0.003
N	27,340	21,652		27,340	21,652	

Notes: TH: telehealth. SMD: standard mean difference. COPD: chronic obstructive pulmonary disease. HCRU: healthcare utilization. OP: outpatient. IP: inpatient. ACSC: ambulatory care sensitive conditions. MACE: major adverse cardiovascular events. ED: emergency department.

Healthcare utilization

Beneficiaries using telehealth during the COVID-pandemic had more healthcare utilization on average compared with the beneficiaries who only had in-person care (Table 4). The in-person outpatient visits significantly increased for the telehealth group versus the non-telehealth group over time by 195.049 visits (95% CI: 166.169 to 223.929, p<0.001) per 1,000 beneficiaries per month on average. The differences in the rate of growth between telehealth users and their comparisons for inpatient and ED visits were 3.816 (95% CI: 2.539 to 5.093, p<0.001) and 10.499 (95% CI: 7.287 to 13.712, p<0.001) visits per 1,000 beneficiaries per month, respectively. The HbA1c test significantly used increased for the telehealth group compared with the comparison group over time by 14.153 tests (95% CI: 11.431 to 16.875, p<0.001) per 1,000 beneficiaries per month on average.

Table 4. The Impact of Telehealth on Health Utilization (Per 1,000 Beneficiaries Per Month)

	DID estimates
OP visits	195.049*** [166.169,223.929] <0.001
IP visits	3.816*** [2.539,5.093] <0.001
ACSC related	0.497 [-0.156,1.149] 0.135
MACE related	-0.113 [-0.426,0.200] 0.480
	10.499***

ED visits	[7.287,13.712] <0.001
ACSC related	5.749 [-0.039,11.537] 0.052
MACE related	-0.028 [-0.513,0.456] 0.909
HbA1c tests	14.153*** [11.431,16.875] <0.001
N treatment	27,340
N control	21,652

Notes: DID: difference-in-difference. OP: outpatient (in-person). IP: inpatient. ACSC: ambulatory care sensitive conditions. MACE: major adverse cardiovascular events. ED: emergency department. Estimates are listed and followed by 95% CI and p-value: * p<.05, ** p<.01, *** p<.001. Baseline characteristics, time fixed effect, and zip code fixed effects were controlled in regressions. Standard errors were clustered at the zip code level.

To further check the impact of telehealth on ED visits and inpatient visits, we checked the decomposed measurements including the visits related to ACSC and MACE. While the ACSC and MACE could be preventable by improved access to primary care, no significant impacts of telehealth on these outcomes were found for both ED visits and inpatient visits over time (Table 4).

Sensitivity analysis

We identified 6,461 beneficiaries who had any ED visits or inpatient visits in 30 days before receiving telehealth visits. We excluded these patients and re-performed propensity score weighting and analyses. Table 5 showed that outpatient visits significantly increased for the telehealth group versus the non-telehealth group over time by 133.171 visits (95% CI: 109.562 to 156.780, p<0.001) per 1,000 beneficiaries per month on average. While we found no significant differences in the rate of growth between telehealth users and their comparisons for overall inpatient visits on average, inpatient visits related to MACE were slightly decreased by telehealth over time by 0.383 visits (95% CI: -0.639 to -0.126, p=0.004) per 1,000 beneficiaries per month. ED visits significantly decreased for the telehealth group versus the non-telehealth group over time by 9.456 visits (95% CI: -12.356 to -6.557, p<0.001) per 1,000 beneficiaries per month on average. MACE-related ED visits were also dropped by 0.490 visits (95% CI: -0.862 to -0.119, p=0.010) per 1,000 beneficiaries per month. The estimate on HbA1c tests was similar to that shown in Table 4 with a significant increase over time by 14.121 tests (95% CI: 11.554 to 16.689, p<0.001) per 1,000 beneficiaries per month on average, comparing telehealth users and non-telehealth users.

Table 5. The Impact of Telehealth on Health Utilization After Excluding Who Had Any ED visits Or Hospitalizations in 30 Days Before a Telehealth Visit (Per 1,000 Beneficiaries Per Month)

	DID estimates
OP visits	133.171*** [109.562,156.780] <0.001
IP visits	-0.860 [-1.900,0.180] 0.105
ACSC related	-0.254 [-0.730,0.223] 0.296
MACE related	-0.383** [-0.639,-0.126] 0.004
ED visits	-9.456*** [-12.356,-6.557] <0.001
ACSC related	-1.178 [-4.050,1.693] 0.421
MACE related	-0.490** [-0.862,-0.119] 0.010
HbA1c tests	14.121*** [11.554,16.689]

	<0.001
N treatment	20,866
N control	21,652

Notes: DID: difference-in-difference. OP: outpatient (in-person). IP: inpatient. ACSC: ambulatory care sensitive conditions. MACE: major adverse cardiovascular events. ED: emergency department. Estimates are listed and followed by 95% CI and p-value: * p<.05, ** p<.01, *** p<.001. Baseline characteristics, time fixed effect, and zip code fixed effects were controlled in regressions. Standard errors were clustered at the zip code level.

After excluding patients who only used telehealth services for non-diabetes care, we rebalanced and reanalyzed the sample. We found similar results to the primary results. Beneficiaries using telehealth during the COVID-pandemic had more healthcare utilization on average compared with the beneficiaries who only had in-person care, including in-person outpatient visits, ED visits, inpatient visits, and HbA1c tests (Table S1.).

Subgroup analysis

The associations between telehealth and outpatient visits, ED visits, inpatient visits, and HbA1c tests in Table 6 were similar to those in Table 4 and Table 5 across all sub-groups of local environmental characteristics. The impact of telehealth on outpatient visits, ED visits, and inpatient visits was similar between rural and urban counties where beneficiaries lived (Table 7). The DID estimates of telehealth effect on HbA1c tests in both samples are larger among beneficiaries living in urban areas than those living in rural areas (Table 7). While the HbA1c test significantly increased for the telehealth group compared with the comparison group in rural areas by 6.038 tests (95% CI: 2.331 to 9.745, p=0.001) per 1,000 beneficiaries per month on average, the estimate of this impact was 18.663 tests (95% CI: 15.206 to 22.121, p<0.001) per 1,000 beneficiaries per month on average in urban areas. We found that the DID estimates were similar between the Black group and non-Black group for outpatient visits and HbA1c tests in both samples. Telehealth was associated with a modest decrease of 1.715 visits (95% CI: -3.321 to -0.110, p=0.036) in overall inpatient visits in the age group of at least 50 years old after excluding patients who had any ED visits or hospitalizations before a telehealth service. Other associations were also similar between the two age groups.

Table 6. The DID estimates of Telehealth on Health Utilization by Environmental Characteristics (Per 1,000 Beneficiaries Per Month)

	Telephone		Computer		Internet	
	>=50%	<50%	>=50%	<50%	>=50%	<50%
Full sample						
OP	216.677***	171.152***	220.703***	173.951***	212.844***	176.242***
	[173.912,259.441]	[130.882,211.422]	[173.034,268.373]	[141.300,206.603]	[171.446,254.241]	[137.006,215.478]
	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
IP	3.904***	3.854***	4.091***	3.696***	3.650***	3.770***
	[2.167,5.641]	[1.997,5.710]	[2.077,6.106]	[1.950,5.441]	[1.767,5.532]	[2.032,5.508]
	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
ED	10.396***	10.685***	10.094***	11.588***	11.368***	9.529***
	[5.681,15.110]	[6.261,15.110]	[5.493,14.696]	[7.049,16.126]	[6.864,15.873]	[5.045,14.012]
	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
HbA1c tests	13.100***	15.157***	14.768***	13.822***	14.608***	13.306***
	[9.350,16.849]	[11.345,18.970]	[11.426,18.110]	[9.186,18.458]	[11.185,18.031]	[8.990,17.622]
	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Excluding who had any ED or hospitalization in 30 days before a telehealth visit						
OP	148.382***	116.213***	144.477***	119.942***	144.922***	123.125***
	[113.611,183.154]	[83.325,149.100]	[107.324,181.630]	[92.447,147.438]	[110.679,179.165]	[90.772,155.478]
	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
IP	-0.817	-0.800	-0.587	-1.168	-0.754	-1.151
	[-2.218,0.584]	[-2.357,0.758]	[-2.185,1.012]	[-2.576,0.240]	[-2.280,0.771]	[-2.603,0.300]
	0.253	0.313	0.471	0.104	0.332	0.12
ED	-10.082***	-8.556***	-9.431***	-8.879***	-8.262***	-10.479***
	[-14.330,-5.833]	[-12.508,-4.604]	[-13.689,-5.173]	[-12.878,-4.881]	[-12.410,-4.114]	[-14.562,-6.395]
	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
HbA1c tests	12.983***	15.028***	15.150***	13.178***	14.772***	12.990***
	[9.447,16.520]	[11.416,18.639]	[12.135,18.165]	[8.858,17.498]	[11.588,17.956]	[8.884,17.096]
	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Notes: DID: difference-in-difference. OP: outpatient visits. IP: inpatient. ACSC: ambulatory care sensitive conditions. MACE: major adverse cardiovascular events. ED: emergency department. Estimates are listed and followed by 95% CI and p-value: * p<.05, ** p<.01, *** p<.001. Baseline characteristics, time fixed effect, and zip code fixed effects were controlled in regressions. Standard errors were clustered at the zip code level.

Table 7. The DID estimates of Telehealth on Health Utilization by Rurality, Race, and Age (Per 1,000 Beneficiaries Per Month)

	Urban	Rural	Non-Black	Black	Age<50	Age>=50
Full sample						
OP	194.887***	196.671***	207.848***	181.998***	185.003***	200.044***
	[157.080,232.694]	[150.842,242.501]	[164.450,251.245]	[140.886,223.109]	[143.040,226.966]	[159.053,241.036]
	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
IP	3.968***	3.271***	4.468***	3.371***	3.620***	3.641***
	[2.329,5.608]	[1.355,5.188]	[2.457,6.478]	[1.417,5.325]	[1.910,5.329]	[1.756,5.526]
	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
ED	10.655***	10.790***	14.013***	7.594***	9.544***	11.372***
	[6.928,14.381]	[4.903,16.676]	[8.973,19.053]	[3.265,11.922]	[4.638,14.450]	[7.217,15.527]
	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
HbA1c tests	18.663***	6.038**	13.711***	14.845***	14.507***	13.711***
	[15.206,22.121]	[2.331,9.745]	[10.076,17.347]	[11.588,18.102]	[11.121,17.894]	[9.885,17.537]
	<0.001	0.001	<0.001	<0.001	<0.001	<0.001
Excluding who had any ED or hospitalization in 30 days before a telehealth visit						
OP	122.943***	145.777***	148.468***	114.589***	118.246***	143.349***
	[93.155,152.731]	[107.227,184.327]	[113.854,183.083]	[80.880,148.297]	[84.839,151.653]	[109.072,177.626]
	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
IP	-1.272	-0.009	-0.06	-1.439	-0.141	-1.715*
	[-2.581,0.037]	[-1.621,1.603]	[-1.697,1.576]	[-2.970,0.091]	[-1.386,1.105]	[-3.321,-0.110]
	0.057	0.992	0.942	0.065	0.825	0.036
ED	-10.056***	-7.518**	-5.575**	-12.799***	-11.185***	-7.787***
	[-13.402,-6.710]	[-13.005,-2.031]	[-9.616,-1.535]	[-16.943,-8.656]	[-15.293,-7.077]	[-11.546,-4.028]
	<0.001	0.007	0.007	<0.001	<0.001	<0.001
HbA1c tests	18.505***	5.771**	14.003***	14.278***	14.264***	13.822***
	[15.304,21.707]	[2.016,9.527]	[10.625,17.381]	[11.034,17.522]	[11.096,17.431]	[10.358,17.286]
	<0.001	0.003	<0.001	<0.001	<0.001	<0.001

Notes: DID: difference-in-difference. OP: outpatient visits. IP: inpatient. ACSC: ambulatory care sensitive conditions. MACE: major adverse cardiovascular events. ED: emergency department. Estimates are listed and followed by 95% CI and p-value: * p<.05, ** p<.01, *** p<.001. Baseline characteristics, time fixed effect, and zip code fixed effects were controlled in regressions. Standard errors were clustered at the zip code level.

Discussion

Using state-wide Medicaid claims, we found type 2 diabetes patients with any telehealth services during the pandemic had more outpatient visits and HbA1c tests over time compared with those who only had in-person care. After we removed those who had telehealth for follow-up care after ED visits or inpatient stays, we also found beneficiaries with any telehealth during the pandemic had slight few hospitalization visits related to the MACE over time compared with those with in-person care only. The ED visits were also significantly dropped by telehealth over time. This paper contributes to the discussion regarding the impact of telehealth use during the pandemic versus traditional care on health utilization among type 2 diabetes, including primary care, HbA1c tests, emergency care, and hospital inpatient care.

Our findings of increases in outpatient visits in the group with telehealth may be consistent with prior work. A study also found an increase in outpatient visits after receiving telehealth.[82] They found a significant increase (5.36%) in the proportion of established patients with OP visits during the pandemic for the overall sample compared to the pre-pandemic. However, it is a pre-post study and no control group was included in the study. Its findings may not be comparable to our findings. During the pandemic, limited healthcare services were provided. Telehealth is a promising approach to maintaining contact between patients and physicians, which could promote more in-person outpatient visits for needed care or examinations than those non-telehealth users.

The DID estimates in the present study showed that both ED visits and hospitalizations increased on average over time among those who used any telehealth compared to in-person care only during the pandemic. Our findings on ED visits and hospitalizations are inconsistent with prior work while in different diseases.[83,84] A care coordination home-telehealth program found patients receiving telehealth services were less likely to be admitted for inpatient care.[85] However, temporary disruptions in routine healthcare services during the pandemic may cause differences in these associations.[82] The

CDC found that 40% of adults reported delaying or avoiding urgent or emergency medical care because of concerns related to COVID-19.[86] Patients seeking telehealth may have more opportunities to gain timely emergency and inpatient care. Other reasons may include the limited quality of telehealth services or timely follow-up care after emergency care and hospitalization captured by telehealth. Outpatient care converted rapidly to virtual care over a short time, which may raise a concern about the quality of delivering care remotely.[87] However, we are unable to directly examine the quality of telehealth services with this rapid adoption and implementation of telehealth during this era. Instead, we removed sicker patients who had ED visits and hospitalizations within 30 days before a telehealth visit. Findings of significant decreases in ED and non-significant estimates in hospitalization further demonstrated sicker patients were more likely to use telehealth services. Telehealth has been served as an alternative to provide care after emergency department visits and hospitalization during the pandemic. A very recent study has demonstrated its effectiveness in delivering follow-up care after hospitalization.[88] It is notable for diabetes care that MACE-related ED visits and hospitalization also have decreased by telehealth in this analysis sample, while this decrease is modest. More analyses should be conducted to further demonstrate these associations in the future.

Our study also assessed the DID estimates on healthcare utilization across different subgroups. As we expected, most DID estimates are slightly larger in areas with relatively higher use of telephone, computer, and broadband internet. We found significant estimates on outpatient visits, ED visits, and hospitalizations across all subgroups by rurality, race, and age. These findings indicate that the uptake of telehealth during the pandemic has induced timely health services across different subgroups for type 2 diabetes patients with

Medicaid coverage. Disparities in the impact of telehealth may need to be further evaluated in future work across these comparison groups.

Several limitations are notable in this study. First, the telehealth visits were not randomly assigned during the pandemic. While we used the propensity score weighting method to control observed factors related to telehealth use, unobserved heterogeneity between the treatment and control groups may introduce bias to our estimates. Therefore, we used the difference-in-difference model with propensity score weighting in this study which is a useful technique when randomization of treatment is not possible. However, some unobserved factors may still bias the estimates in this study, such as patient and provider preference, performance of providers in delivering telehealth, and available health care settings around patients' addresses during the pandemic. For example, the quality of care delivered by telehealth may not be guaranteed because of the rapid adoption of telehealth by both providers and patients, which may increase the utilization of ED visits and hospitalizations. Diabetes management is complex and is highly related to diabetes duration, disease severity, diet and nutrition, and other unobservable factors not captured by the current data. However, we have further demonstrated that telehealth use during the pandemic was not associated with more ED visits or hospitalizations by removing those who used telehealth services for follow-up care after an ED visit and/or hospitalization. Patient motivation is another important unobserved factor that could bias our findings. Patients who received telehealth could be sicker or care more about their health, which could result in the increases in healthcare utilization found in this study. While we used the propensity score weighting to balance the different characteristics between telehealth users and non-telehealth users, our model still cannot fully capture and control the patient motivation. Second, we did not use a fixed follow-up time in this study. However, the volume of health care utilization may be related to the time of follow-up time. Instead, we calculated the monthly health care utilization as the outcome. Third, the sample was comprised of Medicaid beneficiaries with type 2 diabetes in Louisiana and may not extend to the low-income population or other diseases in other states not in the south where social and institutional factors may meaningfully differ. Fourth, we evaluated the impact of telehealth services delivered by either audio or video, not for a specific type of telehealth service. The findings of the impact of telehealth on utilization may vary by type of telehealth. However, we are unable to evaluate the impact of telehealth on health utilization separately for audio-based and video-based telehealth in the present study. In this context, during the COVID-19 pandemic, telehealth has been introduced successfully to deliver care, especially among patients living with type 2 diabetes. Using telehealth during this public health emergency may help to promote timely care for emergency care and will be an effective complement to in-person care. Future studies need to be conducted to assess healthcare spending to better understand the value of telehealth in diabetes care.

AIM 3: TO EVALUATE THE EFFECT OF TELEHEALTH USE ON HEALTH OUTCOMES AMONG DIABETES USING REACHNET EHR DATA.

Introduction

Diabetes mellitus, especially type 2 diabetes, is a leading public health concern in the United States with an estimated total cost of $327 billion in 2018.[89] Approximately 10% of the US population have type 2 diabetes.[23] Patients and clinicians frequently face various challenges in managing type 2 diabetes, such as poor glycemic control, the presence of comorbidities, and complications.[90,91] Diabetes management usually requires consistent collaboration between patients and providers. The COVID-19 pandemic has brought huge challenges to diabetes care due to inadequate health care services available during the pandemic. Policies and strategies of telehealth have been launched and promoted since the onset of the pandemic to provide health care, especially for patients with chronic conditions, such as diabetes. Living with diabetes during the COVID-19 pandemic may worsen health status due to many factors, including lifestyle changes, more sedentary behaviors, inaccessibility to healthy foods, lack of family support, and mental health deterioration.[92] The COVID-19 pandemic has also transformed the health care system from face-to-face consultations to telehealth.[93]

In recent years before the pandemic, telehealth has been facilitated to serve as an alternative to improve healthcare access and timesaving for those with diabetes to engage in successful disease management at a distance and as frequently as is needed. The Informatics for Diabetes Education and Telehealth (IDEATel) study is one of the few randomized trials of telehealth to have been conducted with concurrent controls, comparing telehealth case management with usual diabetes care.[34-37] Telehealth in one study achieved clinical management goals and significantly improved self-reported adherence.[35] In a randomized clinical trial conducted in an outpatient clinic, patients with type 2 diabetes receiving telehealth services had better laboratory results than standard in-person treatment group after six months of intervention.[38] Another rural pilot diabetes care program indicated that telehealth has the potential to improve diabetes control.[13] The combination of telehealth strategies with usual care was also associated with improved glycemic control in diabetic patients.[94-96]

While some studies have been conducted in other countries and evaluated the glycemic control followed the telehealth during the pandemic,[97,98] telehealth use rate was low before the pandemic and real-world evidence is limited in examining the impact of telehealth on people with diabetes in the U.S. The utilization of telehealth has incredibly increased since March 2020 and remained at an elevated level compared with the telehealth use before the pandemic.[70,71,99] Telehealth visits accounted for approximately 16 percent of total outpatient visits in Louisiana between May 20 and June 16.[16,73] High prevalence of diabetes in Louisiana and the rapid increase of telehealth use presented an unprecedented opportunity for us to evaluate the impact of telehealth on diabetes care during the pandemic compared with traditional in-person care. There was a concern that health care among patients with type 2 diabetes would deteriorate during the pandemic. Therefore, this study aims to use electronic health records and evaluate the impact of telehealth use during the pandemic on clinical outcomes including glycemic control among patients with type 2 diabetes.

Methods

Study design and data source

To compare health outcomes among telehealth users with traditional care users, a difference-in-difference model with propensity score weighting was implemented in this study to mitigate the selection bias and control observed factors related to telehealth use . This study used the EHR data between March 2019 and February 2021 from the Research Action for Health Network (REACHnet) database. The EHR data were from three Louisiana health systems in the REACHnet, a PCORnet® Clinical Research Network, and standardized to the PCORnet Common Data Model.[100] The 2019 zip code-level American Community Survey (ACS) was linked to EHR data based on residential 5-digit zip codes to acquire zip code-level environmental characteristics.

Sample selection

The type 2 diabetes cohort was selected using the diabetes definition of Surveillance Prevention, and Management of Diabetes Mellitus (SUPREME-DM), which provides detailed guidelines to select diabetes patients when using EHR data and has been widely used in previous studies.[59,101] The definition is as follows:

(1) 1 or more of the International Classification of Disease, Tenth Revision, Clinical Modification (ICD-10-CM) codes (E11.xx) for type 2 diabetes mellitus associated with inpatient encounters.

(2) 2 or more ICD codes associated with outpatient encounters on different days within 2 years.

(3) combination of 2 or more of the following associated with out-patient encounters on different days within 2 years:

1. ICD codes
2. fasting glucose level ≥126 mg/dL
3. 2-hour glucose level ≥200 mg/dL
4. random glucose ≥200 mg/dL
5. hemoglobin A1c (HbA1c) ≥6.5%
6. prescription for an antidiabetic medication

Considering patients may use multiple health systems, we refined the diabetes cohort after the crosswalk of these systems to avoid duplication of individuals. REACHnet provides a crosswalk of unique global patient IDs that match across the three data-contributing health systems so that their records may be linked for analysis. All eligible patients are adults over 35 years old in this dataset.

Outcome measures

This study examined relevant biomarkers for diabetes management including BMI, HbA1c, LDL, and blood pressure (BP). The primary outcome is glycemic control (HbA1c) and secondary outcomes include BMI, LDL, and BP. All outcomes were measured as average values during the baseline and follow-up.

Independent variables

The comparison groups were defined based on telehealth use during COVID-19 (since March 2020) (yes/no). Telehealth visits are identified by the encounter type ("TH"), an existing variable in PCORnet Common Data Model.

Control variables measured during the baseline included age at first telehealth use, sex (male/female), race (Black, White, Hispanic, and other), insurance type at first telehealth use (commercial, Medicare, Medicaid, self/pay, and others), presented chronic diseases, health services utilization, selected diabetic biomarkers, medications, and several zip code-level variables from the 2019 American Community Survey. A full list of baseline characteristics is shown in Table 1.

Statistical analysis

The difference-in-difference model with propensity score weighting strategy was used to capture the effect of telehealth services during the pandemic on clinical outcomes. With the type 2 diabetes cohort, two groups were assigned, the telehealth users as the treatment group and the non-telehealth users as the control group. The date of receiving the first telehealth services after March 2020 was assigned as the index date for treated observations. Each patient in the control group was randomly assigned an “index date” to have a similar distribution of initiation dates as in the treatment group. Patients included in the analysis had at least one record in both baseline and follow-up periods. The baseline period is 12 months before the index date. The follow-up period for each patient is at least 6 months after the index date. The time indicator was a dichotomous variable, 0 for the pre-period (12 months before the index date) and 1 for the post-period (>=6 months after the index date).

We used the propensity score weighting method to obtain a successful balance between treatment and control groups. To have a success in balancing, we first used group-based trajectory modeling to categorize individuals into latent groups with similar patterns of outpatient visits over 12 months before the initiation dates. The 12 monthly indicators of outpatient visits before treatment being introduced were modeled using the zero-inflated Poisson model for the group-specific models with time defined by months. Once the best group-based trajectory model has been chosen, measures of group membership were then incorporated as control variables in propensity score weighting protocols and regression models.[76] We used the Bayesian information criterion (BIC) to select the optimal number of trajectory groups. Additionally, each trajectory group should have more than 5% of the population contributing to it.[77] Detailed explanations of using group-based trajectory models can be found in prior work of other studies.[78-80] We then estimated the propensity scores of getting the telehealth during the pandemic using a probit regression model, controlling for the covariates of baseline characteristics and binary indicators of each trajectory group. Beneficiaries using telehealth were assigned a weight of 1 and non-telehealth beneficiaries were assigned weights that weighting by odds (propensity score weight=propensity scores/ (1-propensity scores)). These weights were used in the subsequent outcome modeling. The outcomes were estimated using weighted linear regression and implemented the estimator by controlling the same set of variables used in estimating the propensity scores except for those outcome variables. We used the weighted linear regression for all.

The DID model is listed as follows.

$$Y_{it} = \alpha + \beta * Effect_{it} + Post_t + Telehealth_i + X + \delta + \partial_t + \varepsilon_{it} \text{ , } w_i$$

The variable, $Effect_{it}$, is an interaction between the time indicator ($Post_t$: 0 for pre and 1 for post) and the indicator of telehealth users ($Telehealth_i$: 0 for non-telehealth users and 1 for telehealth users). β is the coefficient of interest and captures the change in outcomes in the pre- and post-period between patients with and without telehealth use. The model also zip code level fixed effect (δ) and time fixed effect (∂_t) of the index to control unobservable individual differences and secular trends, respectively. X is a set of factors used in the propensity score weighting model, with the exception of the baseline outcome variables, used as control variables in our regressions to help control for additional variation that may remain after matching.[81] Weights, w_i , are calculated based on propensity scores; w_i=1 for treated units and w_i= propensity scores /(1- propensity scores) for untreated units. The standard error will be clustered at the zip code level to account for common variances in these observations.

Sensitivity analysis

To capture the effect of telehealth frequency, treatment was alternatively defined as two more telehealth visits or three more telehealth visits, compared with those who just had one telehealth visit. The treatment sample changed with different treatment definitions and different outcome assessments; therefore, we repeated our matching process and regenerated propensity scores for non-telehealth beneficiaries to approximate the corresponding counterfactuals. For every weighting, the standardized mean difference was checked between treatment and control before and after weighting to ensure successful weighting as defined as standardized mean differences within 10% for all baseline characteristics.

All data analyses were performed using SAS version 9.4 and Stata version 15.1 (StataCorp). Mean values were reported with standard deviations and regression coefficients were reported with 95% CIs. Statistical significance was set at $P < 0.05$, and all tests were two-tailed.

Results

Baseline characteristics

We identified 28,578 diabetes patients with baseline and follow-up HbA1c test results. Among these patients, 10,979 patients had at least one telehealth visit and 17,599 only had in-person care during the pandemic. The baseline characteristics of this sample are shown in Table 8. Three trajectory groups were selected in group-based trajectory modeling (Figure S5). Patients in each group shared a similar trend of outpatient visits during 12 months during baseline. In the weighted sample, the mean age was about 65 years old and most of them aged over 60 years. Over 50% of patients had Medicare as their primary payer during the baseline. About 60% of patients were female and about 46% were Black in the treatment group. Patients in the telehealth group were more likely to have chronic conditions and used more health services during the one-year baseline than those in the control group on average before weighting. Mean values of HbA1c, LDL, and BP were similar between the two groups before weighting. All baseline characteristics were successfully balanced within 10% of a standardized mean difference after weighting by odds of propensity scores. We repeated weighting procedures and successfully weighted all characteristics for the treatment group and control group in each sample listed in the following outcome tables.

Table 8. Baseline Characteristics Before and After Propensity Score Weighting for HbA1c

	Unweighted			Weighted		
Variables	Telehealth	In-person	SMD	Telehealth	In-person	SMD
Age at first TH (years)	64.501	66.958	0.231	64.501	64.816	0.029
Female	0.587	0.512	-0.15	0.587	0.585	-0.005
Race/ethnicity						
White	0.488	0.537	0.099	0.488	0.484	-0.007
Black	0.457	0.395	-0.126	0.457	0.46	0.006

Hispanic	0.034	0.039	0.03	0.034	0.034	0.003
Other	0.021	0.028	0.046	0.021	0.021	<0.001
Insurance payer						
Medicare	0.534	0.584	0.099	0.534	0.532	-0.005
Medicaid	0.073	0.053	-0.083	0.073	0.078	0.018
Commercial	0.37	0.35	-0.043	0.37	0.367	-0.008
Self-pay/other	0.022	0.014	-0.062	0.022	0.023	0.011
Chronic conditions						
Cardiometabolic disease	0.969	0.962	-0.039	0.969	0.969	-0.002
Lung disease	0.214	0.154	-0.156	0.214	0.213	-0.002
Alzheimer's	0.007	0.005	-0.023	0.007	0.008	0.013
Depression	0.219	0.134	-0.224	0.219	0.218	-0.003
Cancer	0.093	0.066	-0.101	0.093	0.094	0.003
Chronic Kidney Disease	0.319	0.266	-0.116	0.319	0.323	0.010
Arthritis	0.343	0.252	-0.201	0.343	0.342	-0.003
Osteoporosis	0.059	0.051	-0.037	0.059	0.058	-0.005
Health Utilization						
Have any ED visits	0.27	0.192	-0.186	0.27	0.273	0.007
Have any IP visits	0.129	0.07	-0.2	0.129	0.134	0.015
OP visits per month	1.106	0.528	-0.523	1.106	1.127	0.015
Number of HbA1c tests	2.225	2.024	-0.202	2.225	2.237	0.012
Clinical measures						
HbA1c (%)	7.215	7.112	-0.067	7.215	7.214	-0.001
LDL (mg/dL)	90.162	89.317	-0.025	90.162	90.53	0.011
BMI (kg/m^2)	34.02	32.698	-0.181	34.02	33.818	-0.027
DBP (mm/Hg)	74.988	74.946	-0.006	74.988	75.166	0.024
SBP (mm/Hg)	131.942	131.647	-0.024	131.942	132.447	0.041
HbA1c>7%	0.45	0.42	-0.06	0.45	0.457	0.015
Medications						
Antidiabetic drugs	0.664	0.623	-0.085	0.664	0.662	-0.002
Antihypertensive drugs	0.735	0.685	-0.11	0.735	0.736	0.002
Hypolipidemic drugs	0.573	0.551	-0.043	0.573	0.57	-0.005
Environmental factors (%)						
Computer rate	87.621	87.536	-0.015	87.621	87.608	-0.002
Internet rate	78.222	78.29	0.008	78.222	78.21	-0.001
No telephone rate	2.126	2.094	-0.028	2.126	2.132	0.005
Trajectory group						
Trajectory group 1	0.379	0.626	0.510	0.379	0.377	-0.004
Trajectory group 2	0.490	0.336	-0.316	0.49	0.487	-0.006
Trajectory group 3	0.132	0.038	-0.341	0.132	0.137	0.014
N	10,979	17,599		10,979	17,599	

Notes: TH: telehealth. SMD: standard mean difference. ED: emergency department. OP: outpatient. IP: inpatient. LDL: low-density lipoprotein. BMI: body mass index. SBP: systolic blood pressure. DBP: diastolic blood pressure.

HbA1c

We first compared the patients with any telehealth use during the COVID-19 pandemic with those who only used in-person care (Table 9). The value of HbA1c significantly decreased for the telehealth group versus the non-telehealth group over time by 0.146% (95% CI: -0.178% to -0.1145, p<0.001) on average. The proportion of patients with average HbA1c over 7% had a decrease of 0.023 (95% CI: -0.034, -0.011, p<0.001) in the treatment group over time compared with the comparison group. Significant decreases were also found in the proportion of patients with HbA1c over 7.5% and over 8% separately.

Table 9. The Impact of Telehealth on HbA1c, Any Telehealth vs In-Person Only

	DID estimates
HbA1c (%)	-0.146*** [-0.178,-0.114] <0.001
Proportion of patients with HbA1c >7%	-0.023*** [-0.034,-0.011] <0.001
Proportion of patients with HbA1c >7.5%	-0.016** [-0.028,-0.004] 0.010
Proportion of patients with HbA1c >8%	-0.022*** [-0.030,-0.014] <0.001
N treatment	10,979
N control	17,599

Notes: DID: difference-in-difference. Estimates are listed and followed by 95% CI and p-value: * p<.05, ** p<.01, *** p<.001. Baseline characteristics, time fixed effect, and zip code fixed effects were controlled in regressions. Standard errors were clustered at the zip code level.

Secondary outcomes

The outcomes related to LDL, BMI, and BP were presented in Table 10. The value of LDL significantly was decreased in the telehealth group versus non-telehealth group over time by 1.384 mg/dL (95% CI: -2.173 mg/dL to -0.596 mg/dL, p<0.001) on average. Both BMI and BP gained benefits from the uptake of telehealth during the pandemic. The value of BMI was averagely decreased by 0.095 kg/m^2 (95% CI: -0.145 kg/m^2 to -0.045 kg/m^2, p<0.001) in the telehealth group over time compared to the in-person group. For measurements of BP, only diastolic BP was decreased by 0.196 mm/Hg (95% CI: -0.380 mm/Hg to -0.013 mm/Hg) by telehealth on average compared to the in-person care only over time.

Table 10. The Impact of Telehealth on Secondary Outcomes, Any Telehealth vs In-Person Only

	DID estimates	N treatment	N control
LDL (mg/dL)	-1.384*** [-2.173,-0.596] 0.001	8,824	14,795
BMI (kg/m^2)	-0.095*** [-0.145,-0.045] <0.001	12,453	20,345
SBP (mm/Hg)	-0.061 [-0.285,0.162] 0.589	12,427	20,273
DBP (mm/Hg)	-0.196* [-0.380,-0.013] 0.036	12,427	20,273

Notes: DID: difference-in-difference. LDL: low-density lipoprotein. BMI: body mass index. SBP: systolic blood pressure. DBP: diastolic blood pressure. Estimates are listed and followed by 95% CI and p-value: * p<.05, ** p<.01, *** p<.001. Baseline characteristics, time fixed effect, and zip code fixed effects were controlled in regressions. Standard errors were clustered at the zip code level.

Sensitivity analysis

We examined whether the impact of telehealth on outcomes varied across different frequency levels of telehealth use. Half of the patients in the telehealth group used at least two telehealth visits during the pandemic. Comparing with patients who only had one telehealth visit, we found that the HbA1c had a decrease of 0.114% (95% CI: -0.187% to -0.042%, p=0.002) on average over time among patients with two or more telehealth visits and a decrease of 0.143% (95% CI: -0.230% to -0.057%, p=0.001) on average over time among patients with three or more telehealth visits (Table 11). Significant decreases were also found in the proportion of patients with HbA1c over 7.5% and over 8% separately for both comparison groups.

Table 11. The Impact of Telehealth on HbA1c, Multiple Telehealth Visits vs One Telehealth Visit Only

	2+ vs 1	3+ vs 1
	DID estimates	DID estimates
HbA1c (%)	-0.114** [-0.187,-0.042] 0.002	-0.143** [-0.230,-0.057] 0.001
Proportion of patients with HbA1c >7%	-0.008 [-0.024,0.008] 0.308	-0.010 [-0.032,0.011] 0.347
Proportion of patients with HbA1c >7.5%	-0.018* [-0.032,-0.004] 0.012	-0.026** [-0.044,-0.007] 0.006
Proportion of patients with HbA1c >8%	-0.020** [-0.032,-0.007] 0.003	-0.022** [-0.037,-0.006] 0.007
N treatment	5,806	3,178
N control	5,191	5,171

Notes: DID: difference-in-difference. Estimates are listed and followed by 95% CI and p value: * p<.05, ** p<.01, *** p<.001. Baseline characteristics, time fixed effect, zip code fixed effects were controlled in regressions. Standard errors were clustered at the zip code level.

For secondary outcomes in Table 12, we only found a decrease of 0.086 kg/m^2 (95% CI: -0.163 kg/m^2 to -0.009 kg/m^2, p=0.029) in BMI and a decrease of 0.280 mm/Hg (95%

CI: -0.482 mm/Hg to -0.078 mm/Hg, p=0.007) in DBP over time when we compared the group with at least two telehealth visits with the group with only one telehealth visits. Comparing the group with only one telehealth visit, we only found a higher decrease of 0.496 mm/Hg (95% CI: -0.716 mm/Hg to -0.277 mm/Hg, p<0.001) in DBP on average over time in the group with at least three telehealth visits (Table 13).

Table 12. The Impact of Telehealth on Secondary Outcomes, Two Or More Telehealth Visits vs One Telehealth Visit Only

	DID estimates	N treatment	N control
LDL (mg/dL)	-0.789 [-2.042,0.464] 0.216	4,699	4,122
BMI (kg/m^2)	-0.086* [-0.163,-0.009] 0.029	6,498	5,970
SBP (mm/Hg)	-0.131 [-0.495,0.233] 0.479	6,502	5,941
DBP (mm/Hg)	-0.280** [-0.482,-0.078] 0.007	6,502	5,941

Notes: DID: difference-in-difference. LDL: low-density lipoprotein. BMI: body mass index. SBP: systolic blood pressure. DBP: diastolic blood pressure. Estimates are listed and followed by 95% CI and p value: * p<.05, ** p<.01, *** p<.001. Baseline characteristics, time fixed effect, zip code fixed effects were controlled in regressions. Standard errors were clustered at the zip code level.

Table 13. The Impact of Telehealth on Secondary Outcomes, Three Or More Telehealth Visits vs One Telehealth Visit Only

	DID estimates	N treatment	N control
LDL (mg/dL)	-0.703 [-2.146,0.741] 0.338	2,554	4,126
BMI (kg/m^2)	-0.079 [-0.183,0.025] 0.137	3,559	5,945
SBP (mm/Hg)	-0.367 [-0.823,0.088] 0.113	3,561	5,926
DBP (mm/Hg)	-0.496***		

	[-0.716,-0.277] <0.001	3,561	5,926

Notes: DID: difference-in-difference. LDL: low-density lipoprotein. BMI: body mass index. SBP: systolic blood pressure. DBP: diastolic blood pressure. Estimates are listed and followed by 95% CI and p value: * p<.05, ** p<.01, *** p<.001. Baseline characteristics, time fixed effect, zip code fixed effects were controlled in regressions. Standard errors were clustered at the zip code level.

Discussion

We evaluated the impact of telehealth use during the pandemic on glycemic control and other clinical outcomes among patients with type 2 diabetes using electronic health records over years (March 2019-February 2021). After weighting the baseline covariates, we found patients using telehealth had better control of HbA1c, LDL, and diastolic BP than patients using in-person care only during the pandemic. The value of HbA1c significantly decreased for the telehealth group versus the non-telehealth group over time by 0.146% on average. Patients in the telehealth group also had 2.3% fewer people with uncontrolled HbA1c (> 7%) than the comparison group over time. The telehealth use also showed modest benefits in the control of LDL, diastolic BP, and BMI levels.

No published study to our knowledge has assessed the impact of telehealth use on diabetes care using real-world evidence due to limited access to health care before the pandemic. Our modest findings are generally consistent with prior work on evaluating clinical outcomes of designed telehealth programs and clinical trials. A review found a reduction of 0.18% in HbA1c by telehealth compared with usual care.[102] This small decrease in this study was pooled from clinical trials and we note that it is comparable in magnitude to our measured reduction of 0.146% while this review focused on type 1 diabetes. Another published study also demonstrated that telehealth had a similar or superior performance to usual care on other outcomes examined in this study.[8] However, these studies are based on clinical trials. The present study used real-world evidence and the findings should be interpreted with caution.

While modest, our findings may still be viewed as clinically meaningful for diabetes care. For HbA1c, one paper assessing how clinicians interpret HbA1c readings found that a sustained level between 7% and 7.5% would prompt 87% of clinician respondents to consider changing therapy. This suggests that our modest finding of decreasing the share of patients with HbAc1 over 7% by about 2% may still be viewed as clinically meaningful by some clinicians. Telehealth is not particularly expanded for diabetes care during this public health emergency. The benefits of telehealth found in this study are still notable for patients and providers. Our findings indicate that telehealth may have mitigated the concern of glycemic control deteriorating with the cessation of in-person diabetes care. This study confirms the value of telehealth in providing diabetes care during the COVID-19 pandemic in the U.S.

There are several limitations to be addressed in this study. Telehealth was expanded across all insurance payers during the pandemic and patients receiving telehealth are not randomly assigned. Therefore, we implemented a quasi-experimental method of difference-in-difference with propensity score weighting to mitigate the selection bias and control observed factors related to telehealth use. However, some unobserved factors may still bias the estimates in this study, such as the performance of providers in delivering telehealth, available health care settings for lab tests around patients' addresses during the pandemic, family or community support, etc. Lab tests were limited due to the COVID-19 pandemic, which may bias results if the pandemic induced worse HbA1c levels generally and telehealth facilitated more testing and reporting. However, we did not assess whether telehealth was used as a complement to in-person care (e.g., additive) or an alternative to it (e.g., substitute) in this study. Second, the sample comprised electronic health records from three health systems in Louisiana. Diabetes patients likely received routine measurements on these biomarkers in primary care clinics which are not covered in our analyses. Findings from this study might not be fully generalized to telehealth users in other systems or from other states. Third, we evaluated the impact of telehealth services delivered by either audio or video, not for a specific type of telehealth service. The findings of the impact of telehealth on utilization may vary by type of telehealth. However, we are unable to evaluate the impact of telehealth on health utilization separately for audio-based and video-based telehealth in the present study. Some other telehealth devices, like continuous glucose monitoring devices, were not controlled in this study.

In conclusion, despite the limitations in the present study, we report an improvement in glycemic control and other clinical outcomes in patients with type 2 diabetes receiving care delivered by telehealth during the pandemic. These results seem to be very encouraging and highlight the importance of more constant diabetes care. Our study emphasizes the usefulness of delivering care by telehealth in situations of a public health emergency. Current telehealth services are temporally expanded due to the COVID-19 pandemic. It is still not clear whether federal and state governors will permanently cover telehealth services after the end of the pandemic. Our findings may encourage CMS and other payers to embrace and promote the use of telehealth services beyond the pandemic. Future research will be needed to learn whether the routine use of telehealth will lead to improvements in glycemic control, lower complication rates, enhanced medication compliance, higher patient satisfaction, and other outcomes of interest.

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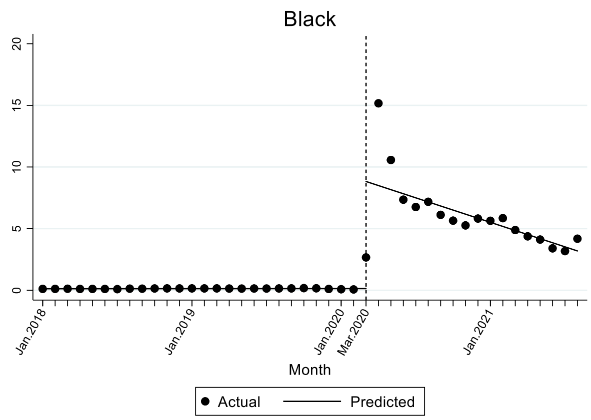
APPENDIX

Table S1. The Impact of Telehealth on Health Utilization After Excluding Who Only Used Telehealth Services for Non-Diabetes Care (Per 1,000 Beneficiaries Per Month)

	DID estimates
OP visits	197.394*** [168.081,226.706] <0.001
IP visits	5.240*** [3.602,6.879] <0.001
ED visits	13.012*** [8.874,17.150] <0.001
HbA1c tests	4.481*** [2.199,6.763] <0.001
N treatment	15,338
N control	21,652

Notes: DID: difference-in-difference. OP: outpatient (in-person). IP: inpatient. ED: emergency department. Estimates are listed and followed by 95% CI and p-value: * p<.05, ** p<.01, *** p<.001. Baseline characteristics, time fixed effect, and zip code fixed effects were controlled in regressions. Standard errors were clustered at the zip code level.

A



Black
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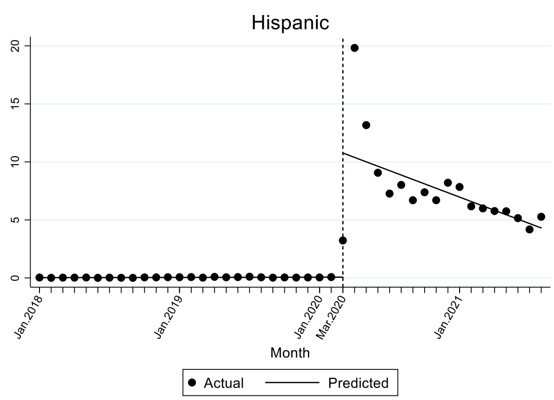
Jan.2018
Jan.2019
Jan.2020
Mar.2020
Jan.2021
Month
Actual
Predicted

B.



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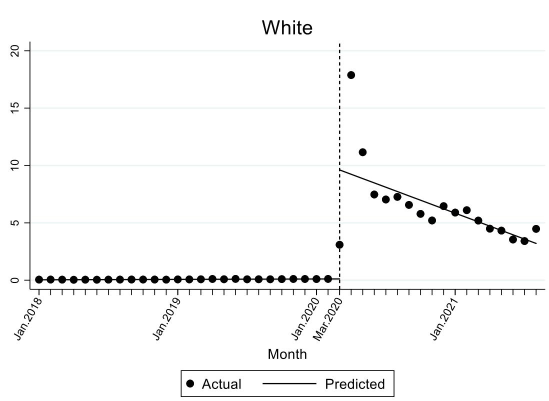
Mar.2020
Jan.2021
Month
Actual
Predicted

C.



White
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Month
Actual
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D.

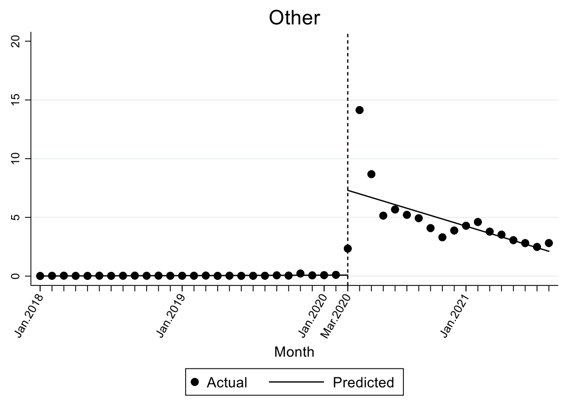
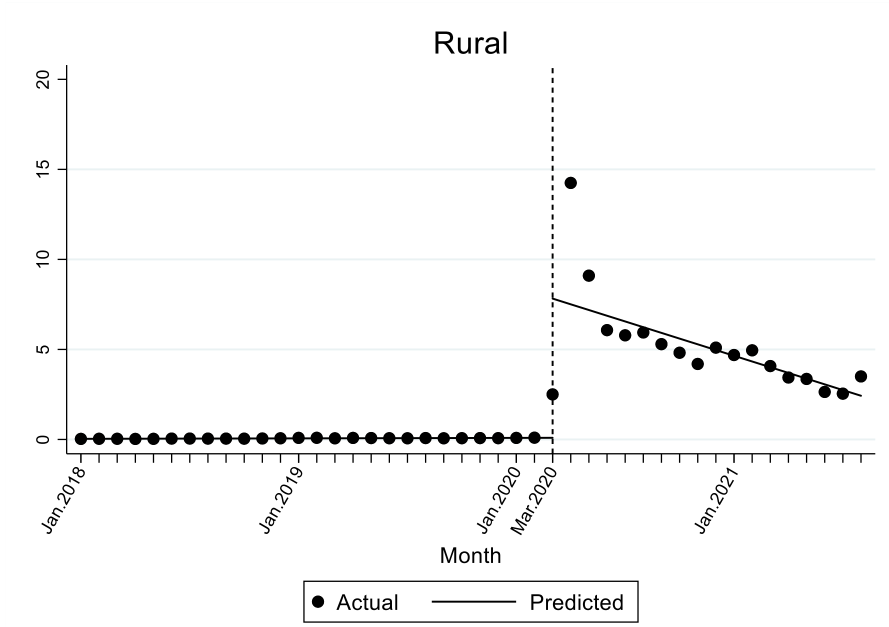


Figure S1. ITS Estimates of Monthly Shares of Outpatient Visits Delivered by Telehealth by Race/Ethnicity

A.



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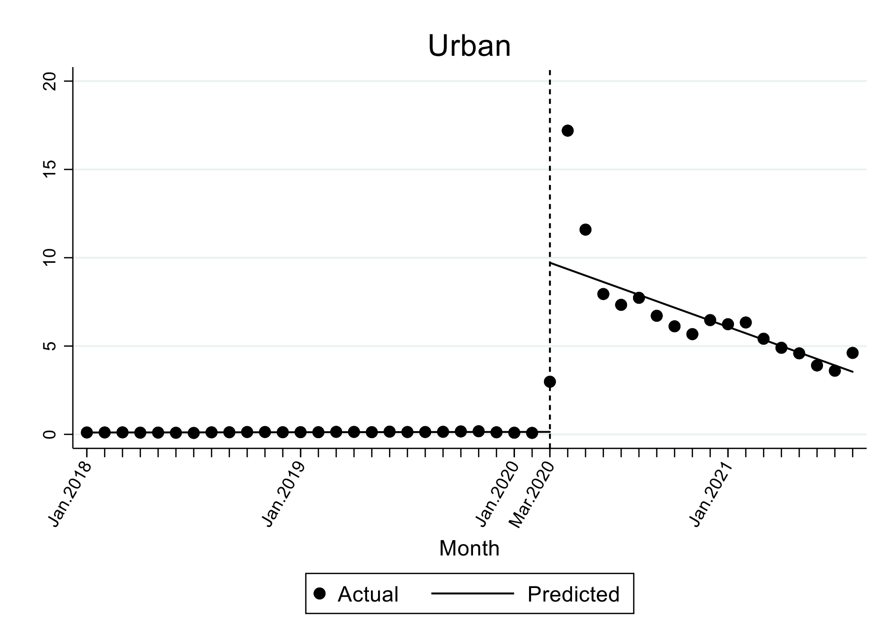
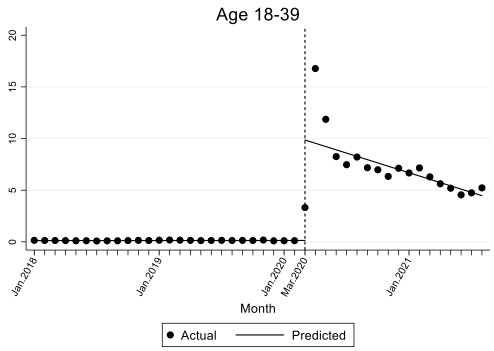


Figure S2. ITS Estimates of Monthly Shares of Outpatient Visits Delivered by Telehealth by Geography.

A.



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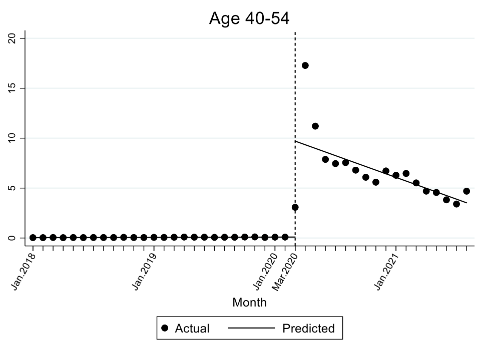

C.

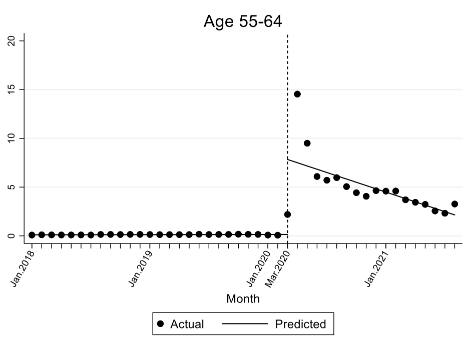

Figure S3. ITS Estimates of Monthly Shares of Outpatient Visits Delivered by Telehealth by Age

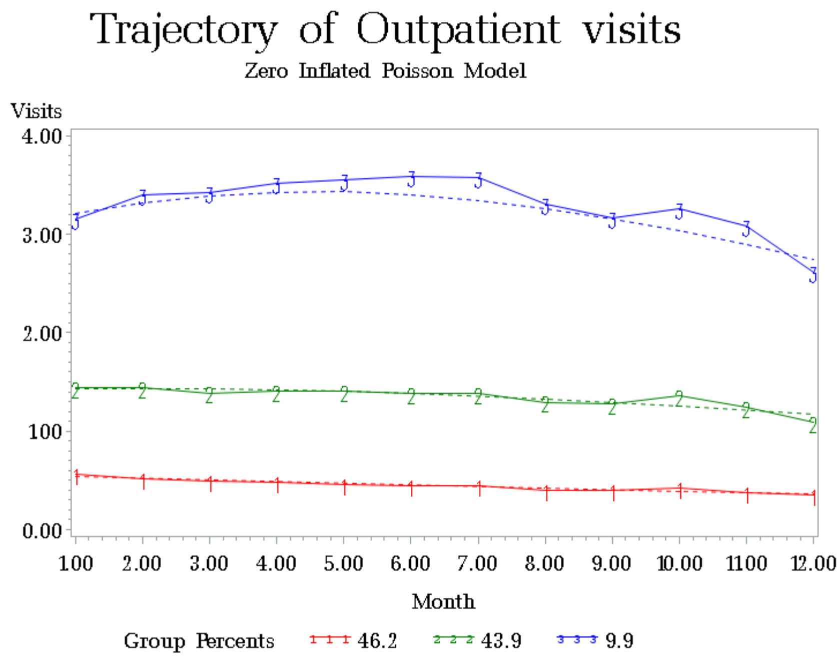

Figure S4. Trajectory Trend of Outpatient Visits in Medicaid Sample

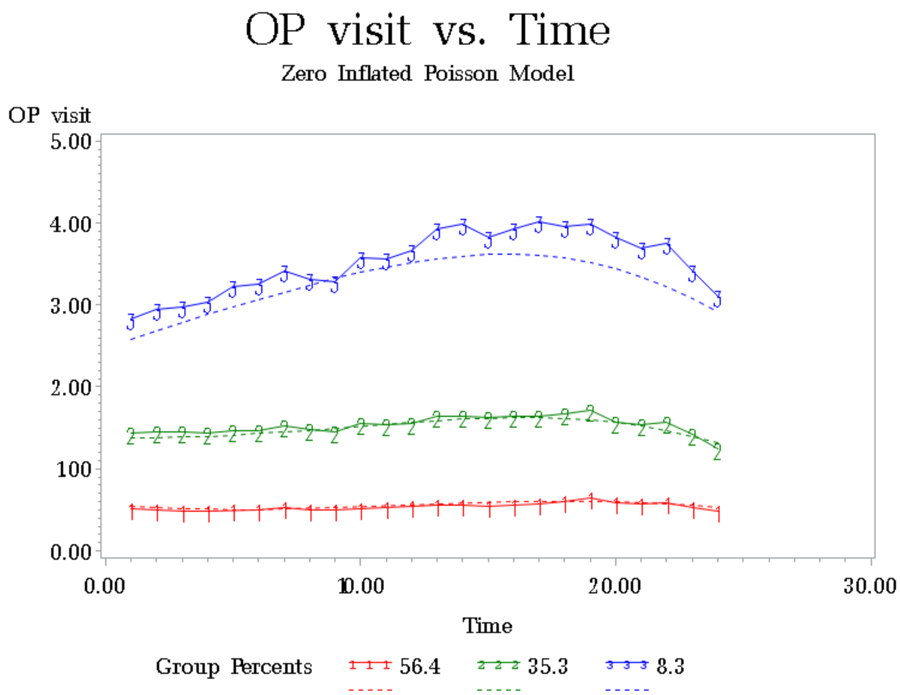

Figure S5. Trajectory Trend of Outpatient Visits in REACHnet Sample