



Association between telemedicine use and diabetes risk factor assessment and control in a primary care network

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Received: 22 December 2021 / Accepted: 28 April 2022 / Published online: 21 May 2022
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Abstract

Purpose Our study examined whether telemedicine use in primary care is associated with risk factor assessment and control for patients with diabetes mellitus.

Methods This was a retrospective, 1:1 propensity score matched cohort study conducted in a primary care network between February 2020 and December 2020. Participants included patients with diabetes mellitus, ages 18 to 75. Exposure of interest was any telemedicine visit. We determined whether hemoglobin A1c (HbA1c), blood pressure (BP) and low-density lipoprotein cholesterol (LDL-C) were assessed for each patient. For each risk factor, we also determined whether the risk factor was controlled when they were assessed (i.e., last HbA1c < 8.0%, BP < 130/80 mmHg, LDL-C < 100 mg/dL).

Results After 1:1 propensity score matching, we identified 1,824 patients with diabetes during the study period. Telemedicine use was associated with a lower proportion of patients with all three risk factors assessed (162/912 [18%], versus 408/912 [45%], $p < 0.001$). However, when individual risk factors were assessed, telemedicine use did not impact risk factor control. When compared with patients with in-person visit only, the odds ratio (OR) for HbA1c < 8% was 1.04 (95% CI 0.74 to 1.46, $p = 0.23$) for patients with any telemedicine visit. Similarly, the OR for BP < 130/80 mmHg was 1.08 (95% CI 0.85–1.36 $p = 0.53$), and the OR for LDL-C < 100 mg/dL was 1.14 (95% CI 0.76–1.72, $p = 0.52$).

Conclusions Telemedicine use was associated with gaps in risk factor assessment for patients with diabetes during the COVID-19 pandemic, but had limited impact on whether risk factors were controlled.

Keywords Telemedicine · Diabetes · Quality of care · Primary care

Background

Diabetes affects 34.2 million Americans, leading to increased cardiovascular risk and substantial morbidity and mortality [1]. Management of cardiovascular risk factors for diabetic patients, including hemoglobin A1c (HbA1c), blood pressure (BP), and low-density lipoprotein cholesterol (LDL-C), are essential to reduce complications of diabetes [2–5]. In recent years, assessment and control of these

risk factors are also increasingly used by health systems and payers as quality benchmarks [6]. Nonetheless, risk factor management in diabetic patients remains suboptimal in real world settings [7, 8], with data from the National Health and Nutrition Examination Survey (NHANES) showing that only one-fifth of adult individuals with diabetes were able to achieve control of all three risk factors in the last decade [3].

Primary care providers play a key role in diabetes management, including assessment and treatment of cardiovascular risk factors, such as elevated HbA1c, BP, and LDL-C [9, 10]. During the COVID-19 pandemic, telemedicine delivery of primary care expanded at an unprecedented pace, and was an important tool for many diabetic patients accessing care [11–13]. However, there has also been concern that telemedicine care rendered remotely through video or telephone technologies can affect care quality. Indeed, recent studies have shown that compared to in-person visits, telemedicine primary care and cardiology visits are associated with lower likelihood of BP assessment, laboratory

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testing, and medication changes [14, 15]. Telemedicine use will persist as an important modality for delivering primary care. Therefore, there is an urgent need to determine whether telemedicine use negatively impacts how well cardiovascular risk factors are assessed and controlled in diabetic patients.

To address this gap in knowledge we conducted a retrospective cohort study using electronic health record (EHR) data from a large academic medical center serving a diverse patient population. We identified diabetic patients visiting primary care providers from February 1st, 2020 to December 31st, 2020 and used a propensity score matching (PSM) approach to assess whether telemedicine use was associated with 1) assessment of cardiovascular risk factors including HbA1c, BP, and LDL-C during the study period, and 2) whether these risk factors were controlled when they were assessed.

Methods

Data extraction and patient sample

After approval by the Institutional Review Board, we queried our EHR (Epic Systems, Verona, Wisconsin, 2020) to identify all completed outpatient primary care visits (including internal medicine, family medicine, and geriatrics) at Columbia University Irving Medical Center (CUIMC) from February 1st, 2020 to December 31st, 2020. Of note, CUIMC transitioned to the Epic EHR on February 1st, 2020. For each visit, we extracted demographic and clinical information including date of birth, sex, race, ethnicity, primary payer, type of visit (in-person, or telemedicine via video or telephone) and International Classification of Disease, 10th Revision (ICD-10) codes associated with the visit. Following specifications published by the National Committee for Quality Assurance (NCQA) and American Diabetes Association (ADA) [16, 17], we defined the study population as patients ages 18 to 75 years old, with a diagnosis of diabetes (Type 1 or 2) associated with any visit during the study period, using ICD-10 codes E10–E13.

For these patients we further extracted from Epic all HbA1c, outpatient BP, and LDL-C values assessed during the study period. For laboratory tests, available results included those from CUIMC affiliated laboratories as well as commercial vendors including Quest Diagnostics and Labcorp.

Outcomes definitions

For assessment of cardiovascular risk factors, a patient is defined as having the risk factor assessed if there was a recorded measurement of that risk factor (i.e., HbA1c, BP, or LDL-C) during the study period. For patients who had an

individual risk factor assessed, we followed NCQA specification and defined HbA1c as controlled if the last recorded HbA1c value during the study period was < 8% [17]. For BP goal, guidelines recommend either < 130/80 or 140/90 mmHg [5, 18]. We used < 130/80 mmHg as a cutoff in this study as prior studies have shown decreased adverse cardiovascular outcomes in patients with systolic BP < 130mmHg [19]. With regards to LDL-C level, we use the same threshold from a recent NHANES analysis and defined control as the last LDL-C level < 100 mg/dL [3].

Telemedicine use

The primary exposure was category of telemedicine use. Specifically, we defined a primary care visit as telemedicine if it was conducted using video technology or using telephone, based on Epic scheduling data. We operationalized our main exposure variable as binary: patients who completed in-person visits only versus those who completed any telemedicine visit.

Covariates

We identified clinical and demographic characteristics with known associations with diabetic risk factor control including age, race, insurance type and comorbidities [20]. We used patient-reported race and ethnicity to classify patients into the following race/ethnicity categories: White, non-Hispanic; Black, non-Hispanic; Asian, Hawaiian & Pacific Island, non-Hispanic; non-White Hispanic; and Other/Declined/Unknown. Patient insurance was categorized as Commercial, Medicare, or Medicaid, using the primary payer field associated with the last visit during the study period. Using a similar approach as described above we identified patients with a diagnosis of atherosclerotic cardiovascular disease (ASCVD), hypertension, or type 1 diabetes mellitus through visit-associated ICD-10 codes. Because patients with a greater total number of visits may receive more intensive risk factor management and also have more opportunities to have telemedicine visits, we adjusted for the total number of visits at the patient level by classifying patients as having 1, 2, or 3+ primary care visits of any type during the study period.

Statistical analysis

Descriptive statistics were used to describe patient demographics and clinical characteristics according to telemedicine use. Chi-squared and two sample *t* test were used for categorical and normally distributed continuous variables, respectively. Using 1:1 nearest neighbor match without replacement, we generated PSM cohorts for patients with in-person visit only versus those with any telemedicine

visits. For each risk factor (HbA1c, BP, and LDL-C), we first fitted a logistic regression model on the PSM matched cohort of patients to determine the association between telemedicine use and whether or not the risk factor was assessed. We then restricted the sample to the subgroup of patients with the risk factor assessed, and fitted a second logistic regression model to determine the association between telemedicine use and whether or not the risk factor was controlled. All logistic regression models were adjusted for covariates including age, race/ethnicity, payer type, comorbidities including atherosclerotic cardiovascular disease and hypertension, whether the patient had type 1 diabetes, and categories of total primary care visits, as described above. Furthermore, because disparities in telemedicine use have been described for older patients and for those with socioeconomic barriers [13, 21, 22], we conducted additional sensitivity analyses for subgroups of patients who were 65 years or older, for non-Hispanic Black patients, for non-White Hispanic patients, and for patients with Medicaid. All analyses were conducted using Stata statistical software, version 16 (StataCorp, College Station, TX).

Results

Patient population and baseline characteristics

A total of 40,602 patients had at least one primary care visit at CUIMC during the study period. Of these, 4932 patients had type 1 or 2 diabetes and were between the age of 18–75 years, meeting the inclusion criteria for the study population. After PSM, we identified 912 patients who had in-person visit only and 912 patients who had at least one telemedicine visit. After PSM, demographic and clinical characteristics were well-balanced between the two groups (Table 1).

Assessment of diabetic risk factors

For each risk factors analyzed, telemedicine use was associated with a substantially lower proportion of patients having the risk factor assessed during the study period, for both the overall and PSM cohorts (Table 2). In propensity matched multivariable models adjusting for demographic and clinical covariables, telemedicine use continued to be associated with lower odds of assessment for all three risk factors.

Table 1 Demographic and clinical characteristics of patients with diabetes mellitus by telemedicine use, without and with propensity matching

	All patients			Propensity matched		
	In-person visits Only (<i>n</i> = 1296)	Telemedicine visit (<i>n</i> = 3636)	<i>p</i> value	In-person visits Only (<i>n</i> = 912)	Telemedicine visit (<i>n</i> = 912)	<i>p</i> value
^a Age	61.3 (10.6)	60.5 (10.7)	0.02	61.1 (10.7)	61.1 (10.7)	0.98
Sex						
Female	1408 (68%)	2228 (78%)	<0.001	463 (51%)	464 (51%)	0.96
Race						
White, non-Hispanic	293 (23%)	298 (8%)	< 0.001	146 (16%)	151 (17%)	0.94
Hispanic, non-White	498 (38%)	2185 (60%)		418 (46%)	409 (45%)	
Black	153 (12%)	430 (12%)		113 (12%)	112 (12%)	
Asian, Hawaiian and Pacific Islander	46 (4%)	55 (2%)		18 (2%)	23 (3%)	
Other/declined/unknown	306 (24%)	668 (18%)		217 (24%)	217 (24%)	
Primary insurance						
Commercial	449 (35%)	606 (17%)	<0.001	270 (30%)	260 (29%)	0.69
Medicare	600 (46%)	1766 (49%)		436 (48%)	431 (47%)	
Medicaid	247 (19%)	1264 (35%)		206 (23%)	221 (24%)	
Total number of visits						
1	675 (52%)	462 (13%)	<0.001	343 (38%)	337 (37%)	0.59
2	378 (29%)	820 (23%)		328 (36%)	348 (38%)	
3 or more	243 (19%)	2354 (65%)		241 (26%)	227 (25%)	
Medical conditions						
Type 1 Diabetes	58 (4%)	131 (4%)	0.16	45 (5%)	29 (4%)	0.06
ASCVD	183 (14%)	491 (14%)	0.58	118 (13%)	110 (12%)	0.57
Hypertension	758 (58%)	2395 (66%)	<0.001	545 (60%)	545 (60%)	1.00

^aAge is reported as mean (standard deviation) in years

Table 2 Risk factor assessment and control in patients with diabetes mellitus by telemedicine use, without and with propensity matching

	All patients			Propensity matched		
	In-person visits only	Telemedicine visit	<i>p</i> value	In-person visits only	Telemedicine visit	<i>p</i> value
Hemoglobin A1c						
Assessed	701/1296 (54%)	1411/3636 (39%)	<0.001	527/912 (58%)	245/912 (27%)	<0.001
Last HbA1c < 8%	464/701 (66%)	913/1411 (65%)	0.50	348/527 (66%)	165/245 (67%)	0.72
Last HbA1c, %	7.7 (1.9)	7.8 (1.7)	0.56	7.7 (1.8)	7.6 (1.7)	0.70
Blood pressure						
Assessed	1273/1296 (98%)	3024/3636 (83%)	<0.001	899/912 (99%)	709/912 (67%)	<0.001
Last BP < 130/80 mm Hg	391/1273 (31%)	897/3024 (30%)	0.49	275/899 (31%)	190/709 (31%)	0.80
Last Systolic BP, mm Hg	133 (18)	135 (19)	0.01	134 (18)	133 (19)	0.48
Last Diastolic BP, mm Hg	78 (9)	79 (9)	0.86	79 (9)	78 (10)	0.45
LDL-C						
Assessed	598/1296 (46%)	932/3636 (26%)	<0.001	450/912 (49%)	181/912 (20%)	<0.001
Last LDL-C < 100 mg/dL	396/598 (66%)	594/932 (64%)	0.32	304/450 (68%)	129/181 (71%)	0.36
Last LDL-C, mg/dL	87 (39)	90 (42)	0.18	87 (40)	83 (40)	0.21

Values for hemoglobin A1c (HbA1c), systolic and diastolic blood pressure (BP), and low-density lipoprotein cholesterol (LDL-C) are expressed as mean (standard deviation); other values are expressed as proportions (percent)

When compared with patients with in-person visit only, the odds ratio (OR) for HbA1c assessment was 0.24 (95% Confidence Interval [CI] 0.19–0.29, $p < 0.001$) for patients with any telemedicine visits. Similarly, the OR for BP assessment was 0.02 (95% CI 0.01–0.03 $p < 0.001$), and the OR for LDL-C assessment was 0.24 (95% CI 0.19–0.29, $p < 0.001$) (Table 3).

Control of diabetes risk factors

When risk factors were assessed, how well they were controlled were similar between patients with in-person visits only versus those with telemedicine visits, both for the overall and the PSM cohorts (Table 2). In propensity matched multivariable models restricted to patients for whom the individual risk factors were assessed and adjusting for demographic and clinical covariables, telemedicine use did not significantly impact risk factor control. When compared with patients with in-person visits only, the OR for HbA1c < 8% was 1.04 (95% CI 0.74–1.46, $p = 0.23$) for patients with any telemedicine visit. Similarly, the OR for BP < 130/80 mmHg was 1.08 (95% CI 0.85–1.36 $p = 0.53$), and the OR for LDL-C < 100 mg/dL was 1.14 (95% CI 0.76–1.72, $p = 0.52$) (Table 4).

Subgroup analyses

Subgroup analyses for patients ≥ 65 years, non-White Hispanic patients, non-Hispanic Black patients, and those with Medicaid insurance are shown in Appendix Tables 1 through 3. Similar to the main analysis, telemedicine use was associated with lower odds of assessment for each individual risk

factor (i.e., HbA1c, BP, or LDL-C), although model for BP assessment for non-Hispanic Black patients could not be fitted due to collinearity. In patients for whom the individual risk factor was assessed, there were generally no statistically significant associations between telemedicine use and risk factor control.

Discussion

Our study is among the first to examine the impact of primary care telemedicine use on cardiovascular risk factor assessment and control for diabetic patients during the COVID-19 pandemic. We found that diabetic patients with telemedicine visits were significantly less likely to have had assessment of cardiovascular risk factors including HbA1c, BP, and LDL-C. However, when these risk factors were assessed, telemedicine use was not significantly associated with whether or not they were controlled. These findings were also consistent in subgroups of patients who may have technology barriers for telemedicine use, such as the elderly, Black or non-White Hispanic patients, and those with Medicaid insurance [13]. Taken together, our findings suggest that primary care telemedicine expansion can worsen gaps in cardiovascular risk factor assessment in patients with diabetes, but the impact on control of these risk factors may be more attenuated.

Our findings are consistent with recent reports that telemedicine visits are less likely to contain BP measurement or laboratory testing in the general population of patients [14, 15], and further extend the literature on how telemedicine use impacts diabetes care more specifically. Features

Table 3 Association of telemedicine use with risk factor assessment in propensity matched cohort of patients with diabetes mellitus

	HbA1c Assessed		BP Assessed		LDL-C Assessed	
	OR (95% CI)	<i>p</i> value	OR (95% CI)	<i>p</i> value	OR (95% CI)	<i>p</i> value
Telemedicine use						
In-person only	Ref		Ref	Ref	Ref	Ref
Telemedicine	0.24 (0.19–0.29)	<0.001	0.02 (0.01–0.03)	<0.001	0.24 (0.19–0.29)	<0.001
Age (per 10 years)	1.05 (0.93–1.20)	0.40	1.12 (0.94–1.35)	0.19	1.08 (0.95–1.23)	0.22
Sex						
Female	1.34 (1.09–1.65)	0.005	1.21 (0.89–1.66)	0.22	1.34 (1.08–1.66)	0.007
Race						
White, non-Hispanic	Ref	Ref	Ref	Ref	Ref	Ref
Hispanic, non-white	0.94 (0.70–1.28)	0.71	0.58 (0.36–0.95)	0.03	0.61 (0.45–0.83)	0.002
Black	0.87 (0.59–1.28)	0.48	0.62 (0.33–1.15)	0.13	0.73 (0.49–1.07)	0.11
Asian, Hawaiian and Pacific Islander	0.61 (0.29–1.27)	0.19	0.31 (0.11–0.91)	0.03	0.62 (0.30–1.29)	0.20
Other/declined/unknown	0.93 (0.66–1.29)	0.65	0.53 (0.31–0.90)	0.02	0.79 (0.56–1.10)	0.16
Primary insurance						
Commercial	Ref	Ref	Ref	Ref	Ref	Ref
Medicare	1.15 (0.87–1.52)	0.34	1.56 (1.03–2.36)	0.04	0.93 (0.70–1.24)	0.64
Medicaid	1.08 (0.81–1.45)	0.60	1.54 (1.02–2.31)	0.04	0.71 (0.52–0.96)	0.03
Total number of visits						
1	Ref	Ref	Ref	Ref	Ref	Ref
2	2.70 (2.11–3.45)	<0.001	5.06 (3.61–7.08)	<0.001	2.00 (1.55–2.57)	<0.001
3 or more	3.91 (2.96–5.18)	<0.001	14.6 (8.58–24.8)	<0.001	2.44 (1.94–3.23)	<0.001
Medical conditions						
Diabetes type 1	0.54 (0.31–0.96)	0.04	1.79 (0.70–4.54)	0.22	0.77 (0.44–1.37)	0.38
ASCVD	1.12 (0.82–1.53)	0.47	1.95 (1.10–3.46)	0.02	1.24 (0.90–1.70)	0.19
Hypertension	0.92 (0.73–1.14)	0.44	1.24 (0.89–1.71)	0.20	0.91 (0.72–1.15)	0.43

of telemedicine visits, such a lack of medical assistants taking vitals during rooming and additional delays between visit and blood draw, may explain why these gaps are more common when telemedicine is used as a substitution for in-person care. In contrast, prior studies have shown that telemedicine utilized as a supplement as opposed to a substitution for primary care, such as through remote patient monitoring, can improve diabetes risk factor measurements [23–27]. Future research should continue to explore how to best integrate these tools into primary care visits for diabetic patients [28, 29].

Importantly, our study did not find a significant relationship between telemedicine use and risk factor control when the individual risk factors were assessed. Although telemedicine use can lead to decreased risk factor assessment, telemedicine may nonetheless have helped patients access care and thereby maintain risk factor control. Indeed, a recent large national study using Optum claims data showed that for more than 1.3 million patients with diabetes seen in 2019 and in 2020, mean weekly HbA1c was nearly identical (7.16% versus 7.14%) despite nearly 30% of visits in 2020 delivered via telemedicine [30]. Furthermore, while there have been previous reports that select patient populations

such as the elderly or racial/ethnic minorities may have more challenges utilizing telemedicine [13], and while we did find that Black and non-White Hispanic patients had poorer risk factor control, it was reassuring that our subgroups analyses did not demonstrate a significant relationship between telemedicine use and risk factor control in these subgroups. Nonetheless, we cannot exclude the possibility of a sampling bias due to our observation design: i.e., patients who had risk factor assessed in our study may be better engaged with primary care, which can mask the impact of telemedicine use on risk factor control, both in general and for the subset of patients who may experience technology-driven disparities.

Our results are also consistent with prior literature on the challenges that remain for managing cardiovascular risk factors in patients with diabetes. Previous studies have described large gaps in diabetes care regarding cardiovascular risk factor control [3, 8]. As described previously, a recent study based on NHANES data showed that only 21% of patients with diagnosed diabetes had all three measurements controlled between 2015 and 2018 [3], which only modestly improved from the previous decade [7, 8]. In this analysis, 67% of diabetic patients

Table 4 Association of telemedicine use with risk factor control in propensity matched cohort of patients with diabetes mellitus

	‡HbA1c < 8% (n = 772)		†BP < 130/80 mm/Hg (n = 1508)		§ LDL-C < 100 mg/dL (n = 631)	
	OR (95% CI)	p value	OR (95% CI)	p value	OR (95% CI)	p value
Telemedicine use						
In-person only	Ref	Ref	Ref	Ref	Ref	Ref
Telemedicine	1.04 (0.74–1.46)	0.23	1.08 (0.85–1.36)	0.53	1.14 (0.76–1.72)	0.52
Age (per 10 years)	1.29 (1.07–1.57)	0.008	1.05 (0.91–1.20)	0.51	1.24 (1.00–1.53)	0.049
Sex						
Female	1.20 (0.88–1.64)	0.26	1.21 (0.97–1.52)	0.10	0.70 (0.48–1.01)	0.06
Race						
White, non-Hispanic	Ref	Ref	Ref	Ref	Ref	Ref
Hispanic, non-White	0.48 (0.30–0.78)	0.003	0.70 (0.51–0.97)	0.03	0.44 (0.26–0.76)	0.003
Black	0.57 (0.31–1.04)	0.07	0.51 (0.33–0.79)	0.002	0.40 (0.21–0.78)	0.007
Asian, Hawaiian and Pacific Islander	0.37 (0.12–1.14)	0.08	1.46 (0.69–3.07)	0.32	1.04 (0.26–4.20)	0.96
Other/declined/unknown	0.65 (0.38–1.11)	0.12	0.74 (0.52–1.05)	0.09	0.49 (0.28–0.88)	0.02
Primary insurance						
Commercial	Ref	Ref	Ref	Ref	Ref	Ref
Medicare	0.66 (0.43–1.03)	0.07	0.96 (0.70–1.30)	0.77	1.53 (0.96–2.46)	0.08
Medicaid	0.62 (0.39–0.98)	0.04	1.11 (0.80–1.53)	0.53	0.95 (0.57–1.59)	0.85
Total number of visits						
1	Ref	Ref	Ref	Ref	Ref	Ref
2	1.02 (0.68–1.53)	0.92	0.79 (0.60–1.04)	0.09	1.39 (0.88–2.18)	0.16
3 or more	1.01 (0.66–1.56)	0.95	0.95 (0.70–1.27)	0.71	1.32 (0.81–2.16)	0.27
Medical conditions						
Diabetes type I	0.31 (0.12–0.85)	0.02	1.67 (0.97–2.87)	0.07	1.07 (0.40–2.81)	0.90
ASCVD	0.68 (0.44–1.07)	0.09	1.19 (0.86–1.66)	0.30	2.41 (1.27–4.59)	0.007
Hypertension	0.88 (0.63–1.24)	0.48	0.55 (0.43–0.70)	<0.001	1.28 (0.87–1.87)	0.21

achieved HbA1c control, 48% of patients achieved BP control and 60% of patients achieved LDL control. Our findings are also similar. When cardiovascular risk factors were assessed, less than 70% of diabetic patients in our sample had HbA1c < 8% and LDL-C < 100 mg/dL, while only a third of patients had BP < 130/80 mmHg. Non-Hispanic Black and non-White Hispanic patients were even less likely to have control of these risk factors. While the limitations of EHR data capture can explain some of these findings, these results highlight continuing challenges for diabetic risk factor management, especially in setting of COVID-19 pandemic related care disruptions [31]. Indeed, one previous study conducted during the peak of the COVID-19 pandemic in Italy concluded that the most vulnerable patients with diabetes were those most likely to lose access to care during the pandemic. These included patients with high complication burden and complex pharmacotherapy treatments. These results highlight that new approaches to ensure all patients have access to care, whether it be in-person or through telemedicine, is a vital component for achieving better cardiovascular risk factor control [32].

This study has several limitations. Our retrospective design is necessarily hypothesis generating, and we cannot exclude unmeasured confounders due to the use of EHR data. Furthermore, our study used data during the COVID-19 pandemic, which contained time periods when patients had more restricted access to care. Because data was not available regarding risk factor assessment in patients with diabetes mellitus during prior years, we could not extrapolate our findings outside of the context of the COVID-19 pandemic. Residual confounding may also remain as clinical characteristics may differ between patients with and without risk factor assessment, and our findings should be considered descriptive. Moreover, our study only used BP and laboratory values recorded in our EHR. Patients may have had additional BP measurements outside our health system, and although our EHR included data feed from major outside laboratories, such as Quest and Labcorp, it is likely that there were outside HbA1c and LDL-C values that we were unable to capture, especially for telemedicine users. Nonetheless, these limitations are mitigated by our use of a primary care population as the study sample, since patients receiving primary care would be more likely to have most

office visits and laboratory testing within our healthcare system.

Conclusions

Cardiovascular risk factors, including HbA1c, BP, and LDL-C, were less likely to be assessed during the COVID-19 pandemic for primary care patients with diabetes mellitus who used telemedicine. However, when they were assessed, telemedicine use did not impact whether these risk factors were controlled. Future studies will need to examine the long term impact of routine telemedicine use on diabetes management, and to identify best approaches to implement telemedicine as a component of high quality primary care.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s40618-022-01814-6>.

Acknowledgements Dr. Grauer was supported by grant number T32HS026121 from the Agency for Healthcare Research and Quality. Dr. Kronish received support from the Agency for Healthcare Research and Quality (R01 HS024262) and the National Heart, Lung and Blood Institute (R01HL152699). The content is solely the responsibility of the authors and does not necessarily represent the official views of the Agency for Healthcare Research and Quality or the National Heart, Lung and Blood Institute.

Data availability The data sets during and/or analyzed during the current study available from the corresponding author on reasonable request.

Declarations

Conflict of interest On behalf of all the authors, the corresponding author states there is no conflict of interest.

Informed consent As approved by our institution's IRB the requirement to obtain informed consent was waived for this study.

Research involving human participants and/or animals After approval by the Institutional Review Board (IRB), we queried our EHR (Epic Systems, Verona, Wisconsin, 2020) to identify all completed outpatient primary care visits (including internal medicine, family medicine, and geriatrics) at Columbia University Irving Medical Center (CUIMC) from February 1st, 2020 to December 31st, 2020. Of note, CUIMC transitioned to the Epic EHR on February 1st, 2020.

References

1. Prevention CfDCa. National Diabetes Statistics Report. Centers for Disease Control and Prevention, U.S. Dept of Health and Human Services. <https://www.cdc.gov/diabetes/data/statistics-report/index.html>. Published 2020. Accessed 13 Aug 2021.
2. Khaw KT, Wareham N, Luben R et al (2001) Glycated haemoglobin, diabetes, and mortality in men in Norfolk cohort of European prospective investigation of cancer and nutrition (EPIC-Norfolk). *BMJ* 322(7277):15–18
3. Wang L, Li X, Wang Z et al (2021) Trends in prevalence of diabetes and control of risk factors in diabetes among US adults 1999–2018. *Jama*. <https://doi.org/10.1001/jama.2021.9883>
4. Targets G (2018) Standards of medical care in diabetes-2018. *Diabetes Care* 41(Suppl 1):S55–s64
5. Disease C, Management R (2018) Standards of medical care in diabetes-2018. *Diabetes Care* 41(Suppl 1):S86–s104
6. HIEQRSMETSUS (2019). https://www.cms.gov/Medicare/Quality-Initiatives-Patient-Assessment-Instruments/QualityInitiativesGenInfo/Downloads/2020-QRS-Measure-Tech-Specs_20190925_508.pdf. Accessed 13 Aug 2021
7. Stark Casagrande S, Fradkin JE, Saydah SH, Rust KF, Cowie CC (2013) The prevalence of meeting A1C, blood pressure, and LDL goals among people with diabetes, 1988–2010. *Diabetes Care* 36(8):2271–2279
8. Ali MK, Bullard KM, Saaddine JB, Cowie CC, Imperatore G, Gregg EW (2013) Achievement of goals in U.S. diabetes care, 1999–2010. *N Engl J Med* 368(17):1613–1624
9. Finley CR, Chan DS, Garrison S et al (2018) What are the most common conditions in primary care? Systematic review. *Can Fam Phys* 64(11):832–840
10. Davidson JA (2010) The increasing role of primary care physicians in caring for patients with type 2 diabetes mellitus. *Mayo Clin Proc* 85(12 Suppl):S3–4
11. Weiner JP, Bandeian S, Hatef E, Lans D, Liu A, Lemke KW (2021) In-Person and telehealth ambulatory contacts and costs in a large US insured cohort before and during the COVID-19 pandemic. *JAMA Netw Open* 4(3):e212618
12. Mann DM, Chen J, Chunara R, Testa PA, Nov O (2020) COVID-19 transforms health care through telemedicine: evidence from the field. *J Am Med Inform Assoc* 27(7):1132–1135
13. Ye S, Kronish I, Fleck E et al (2021) Telemedicine expansion during the COVID-19 pandemic and the potential for technology-driven disparities. *J Gen Intern Med* 36(1):256–258
14. Alexander GC, Tajanlangit M, Heyward J, Mansour O, Qato DM, Stafford RS (2020) Use and content of primary care office-based vs telemedicine care visits during the COVID-19 pandemic in the US. *JAMA Netw Open* 3(10):e2021476
15. Yuan N, Pevnick JM, Botting PG et al (2021) Patient use and clinical practice patterns of remote cardiology clinic visits in the era of COVID-19. *JAMA Netw Open* 4(4):e214157
16. Disease C, Management R (2020) Standards of medical care in diabetes-2020. *Diabetes Care* 43(Suppl 1):S111–s134
17. National Committee for Quality Assurance (2013) “National Committee for Quality Assurance (NCQA) Healthcare Effectiveness Data and Information Set (HEDIS) 2013 Diabetes Mellitus Measures” http://www.ncqa.org/Portals/0/HEDISQM/DM_2013_Measures_9.13.12.pdf. Accessed 13 Aug 2021.
18. Whelton PK, Carey RM, Aronow WS et al (2018) 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA guideline for the prevention, detection, evaluation, and management of high blood pressure in adults: executive summary: a report of the American college of cardiology/American heart association task force on clinical practice guidelines. *Hypertension* 71(6):1269–1324
19. Bundy JD, Li C, Stuchlik P et al (2017) Systolic blood pressure reduction and risk of cardiovascular disease and mortality: a systematic review and network meta-analysis. *JAMA Cardiol* 2(7):775–781
20. Mohammed K, Ali M, Kai McKeever Bullard P, Giuseppina Imperatore M, Lawrence Barker P, Edward W. Gregg P (2012) Characteristics associated with poor glycemic control among adults with self-reported diagnosed diabetes — national health and nutrition examination survey, United States, 2007–2010. Published 2012. Accessed 23 June 2021

21. Eberly LA, Kallan MJ, Julien HM et al (2020) Patient characteristics associated with telemedicine access for primary and specialty ambulatory care during the COVID-19 pandemic. *JAMA Netw Open* 3(12):e2031640–e2031640
22. Eberly LA, Khatana SAM, Nathan AS et al (2020) Telemedicine outpatient cardiovascular care during the COVID-19 pandemic. *Circulation* 142(5):510–512
23. Lee JY, Lee SWH (2018) Telemedicine cost-effectiveness for diabetes management: a systematic review. *Diabetes Technol Ther* 20(7):492–500
24. Cohen LB, Taveira TH, Wu WC, Pirraglia PA (2020) Pharmacist-led telehealth disease management program for patients with diabetes and depression. *J Telemed Telecare* 26(5):294–302
25. McDonnell ME (2018) Telemedicine in complex diabetes management. *Curr Diab Rep* 18(7):42
26. Shea S, Weinstock RS, Teresi JA et al (2009) A randomized trial comparing telemedicine case management with usual care in older, ethnically diverse, medically underserved patients with diabetes mellitus: 5 year results of the IDEATel study. *J Am Med Inform Assoc* 16(4):446–456
27. Davis RM, Hitch AD, Salaam MM, Herman WH, Zimmer-Galler IE, Mayer-Davis EJ (2010) TeleHealth improves diabetes self-management in an underserved community: diabetes TeleCare. *Diabetes Care* 33(8):1712–1717
28. Casale PN, Vyavahare M, Coyne S et al (2021) The promise of remote patient monitoring: lessons learned during the COVID-19 surge in New York City. *Am J Med Qual* 36(3):139–144
29. Lu AD, Gunzburger E, Glorioso TJ et al (2021) Impact of longitudinal virtual primary care on diabetes quality of care. *J Gen Intern Med* 55:1–8
30. Patel SYMR, Barnett ML, Shah ND, Mehrotra A (2021) Diabetes care and glycemic control during the COVID-19 pandemic in the United States. *Jama Intern Med.* <https://doi.org/10.1001/jamainternmed.2021.3047>
31. Mehrotra ACM, Linetsky D, Hatch H, Cutler D, Schneider EC (2021) What impact has COVID-19 had on outpatient visits? <https://www.commonwealthfund.org/publications/2020/apr/impact-covid-19-outpatient-visits>. Accessed 12 Aug 2021
32. Bonora BM, Morieri ML, Avogaro A, Fadini GP (2021) The toll of lockdown against COVID-19 on diabetes outpatient care: analysis from an outbreak area in Northeast Italy. *Diabetes Care* 44(1):e18–e21. <https://doi.org/10.2337/dc20-1872>

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