Research and Applications

Patient portal engagement and diabetes management among new portal users in the Veterans Health Administration

Mark S. Zocchi ^{1,2} Stephanie A. Robinson,^{1,3} Arlene S. Ash,⁴ Varsha G. Vimalananda,^{1,5} Hill L. Wolfe,^{1,6} Timothy P. Hogan,^{1,7} Samantha L. Connolly ^{8,9} Maureen T. Stewart,^{1,2} Linda Am,¹ Dane Netherton,¹ and Stephanie L. Shimada^{1,6,10}

¹Center for Healthcare Organization and Implementation Research, VA Bedford Healthcare System, Bedford, Massachusetts, USA, ²Heller School for Social Policy and Management, Brandeis University, Waltham, Massachusetts, USA, ³The Pulmonary Center, Boston University School of Medicine, Boston, Massachusetts, USA, ⁴Department of Population and Quantitative Health Sciences, University of Massachusetts Medical School, Worcester, Massachusetts, USA, ⁵Department of Medicine, Section of Endocrinology, Diabetes, Nutrition and Weight Management, Boston University School of Medicine, Boston, Massachusetts, USA, ⁶Department of Health Law, Policy and Management, Boston University School of Public Health, Boston, Massachusetts, USA, ⁷Department of Population and Data Sciences, University of Texas Southwestern Medical Center, Dallas, Texas, USA, ⁸Center for Healthcare Organization and Implementation Research, VA Boston Healthcare System, Boston, Massachusetts, USA, ⁹Department of Psychiatry, Harvard Medical School, Boston, Massachusetts, USA, and ¹⁰Division of Health Informatics and Implementation Science, Department of Population and Quantitative Health Sciences, University of Massachusetts Medical School, Worcester, Massachusetts, USA

Corresponding Author: Mark S. Zocchi, MPH, VA Bedford Healthcare System, Center for Healthcare Organization and Implementation Research (CHOIR), 200 Springs Road, Bedford, MA 01730, USA; Mark.Zocchi@VA.gov

Received 27 January 2021; Revised 19 May 2021; Editorial Decision 24 May 2021; Accepted 26 May 2021

ABSTRACT

Objective: The study sought to investigate whether consistent use of the Veterans Health Administration's My Health eVet (MHV) online patient portal is associated with improvement in diabetes-related physiological measures among new portal users.

Materials and Methods: We conducted a retrospective cohort study of new portal users with type 2 diabetes that registered for MHV between 2012 and 2016. We used random-effect linear regression models to examine associations between months of portal use in a year (consistency) and annual means of the physiological measures (hemoglobin A1c [HbA1c], low-density lipoproteins [LDLs], and blood pressure [BP]) in the first 3 years of portal use.

Results: For patients with uncontrolled HbA1c, LDL, or BP at baseline, more months of portal use in a year was associated with greater improvement. Compared with 1 month of use, using the portal 12 months in a year was associated with annual declines in HbA1c of -0.41% (95% confidence interval [CI], -0.46% to -0.36%) and in LDL of -6.25 (95% CI, -7.15 to -5.36) mg/dL. Twelve months of portal use was associated with minimal improvements in BP: systolic BP of -1.01 (95% CI, -1.33 to -0.68) mm Hg and diastolic BP of -0.67 (95% CI, -0.85 to -0.49) mm Hg. All associations were smaller or not present for patients in control of these measures at baseline.

Conclusions: We found consistent use of the patient portal among new portal users to be associated with modest improvements in mean HbA1c and LDL for patients at increased risk at baseline. For patients with type 2 diabetes, self-management supported by online patient portals may help control HbA1c, LDL, and BP.

Key words: diabetes mellitus, Type 2, Veterans, patient portals

INTRODUCTION

Patient portals have been implemented widely across healthcare systems.¹ As of August 2020, the Veterans Health Administration (VHA) My HealtheVet (MHV) portal had over 5.5 million registrants, over 3.4 million of which were patients with authenticated accounts offering full access to all MHV portal features.^{2,3} Online patient portals can help facilitate care coordination for patients with complex chronic conditions, such as diabetes, chronic obstructive pulmonary disease, and congestive heart failure.^{4,5} A limited body of research and systematic reviews have shown some effect of portal use on clinical outcome measures, but overall results are inconclusive.^{6–8}

Use of patient portals is hypothesized to improve health outcomes through communication, self-efficacy, health literacy, and medication adherence.⁹ Evaluation frameworks for eHealth technologies have posited that by making clinical information accessible, portals influence health behaviors and processes of care via communication, self-management, and coordination of care, resulting in improved health quality and outcomes.¹⁰ VHA patients report that MHV enables them to be more engaged in their health care by improving access to their health information and patient-provider communication.¹¹

Studies in and outside the VHA have found use of patient portals can improve medication adherence and reduce missed office appointments.^{12–15} MHV portal features that support communication and health information sharing include secure messaging between patients and providers, viewing laboratory or radiology test results, access to clinical notes, and easy download of medical records through the “Blue Button” feature.^{10,16} Secure messaging gives patients direct access to their healthcare teams between office visits,^{17,18} sometimes leading to changes in the care plan between appointments.¹¹ Through the Blue Button feature, patients can view and share their electronic health record with non-VHA providers.¹⁹ These features support better understanding of health issues by facilitating patient information seeking and preparation for medical appointments by reviewing previous labs and notes.¹¹

Despite these studies, the association of portal use and clinical outcomes is still not well understood.²⁰ Complicating relationships between portal use and outcomes are underlying sociodemographic, health status, and health literacy differences between portal and nonportal users.^{21,22} Among patients that use portals, few studies have examined portal use over an extended period of time (eg >12 months) and whether consistent use of patient portals is associated with health outcomes. In one study of 200 patients with coronary artery disease, hemoglobin A1c (HbA1c) levels improved significantly (−0.19%) in the active and super user groups at 6 months over a 12-month period.²³ However, this improvement was not found at 12 months and other physiologic measures (cholesterol, blood pressure [BP], body mass index) did not improve at either 6 or 12 months. Another study of 453 hypertensive patients found that among portal users, the most active users had greater reductions in diastolic BP (−5.25 mm Hg) compared with patients using the portal less frequently.²⁴ These studies suggest that among the population of portal users, there may be a dose-response relationship between consistent use and benefit.

Among VHA patients with diabetes, studies of MHV use have generally found a concordant relationship between portal use and

positive health outcomes. In one analysis (n = 446), patients with diabetes who used the MHV secure messaging feature at least twice a year for 2 or more years were more likely to improve their glycemic control compared with those who never used it, and those who received proactive secure messages from their clinical teams reported a higher degree of diabetes self-efficacy and engaged in better diabetes self-management than did patients who did not.²⁵ A larger VHA study (n = 111 686) showed that patients with diabetes who were users of the MHV prescription refills feature for 2 or more years were more likely to improve BP control and lower low-density lipoprotein (LDL) levels compared with patients who had not used this feature.²⁶ Last, a study of the Blue Button feature (n = 3762 users, 26 424 nonusers) found that Blue Button users had lower odds of duplicate HbA1c testing compared with nonusers.²⁷

Studies outside the VHA have also found a relationship between portal use and positive health outcomes among patients with diabetes. Secure message intensity has been associated with better glycemic control and increased outpatient utilization.²⁸ Portal users who exclusively used the prescription refill feature have been found to have better medication adherence and improved LDL levels compared with those who did not use the online refill feature.¹²

The objective of this study was to examine the association between consistent patient portal use and diabetes-related health outcomes in a large, national sample of new portal users over a 3-year period. In this study, we focused on new and active users of the MHV patient portal and sought to understand whether there is a dose-relationship between consistent portal use and improved health outcomes. In contrast to studies on portal use that compare portal users with nonusers or categorize portal use in terms of frequency (eg, never, occasional, or frequent use), consistent use over a longer time period has yet to be explored. We defined consistent portal use in terms of the number of distinct months a portal user engaged with the portal in a year (ie, 1–12) and examined health outcomes and portal utilization in each of 3 years following portal registration.

MATERIALS AND METHODS

Study design and selection

We conducted a retrospective cohort study of VHA patients with type 2 diabetes who registered for MHV between January 1, 2012, and December 31, 2016 (n = 477 220 patients, prior to exclusions). Outcome and portal activity data for each patient were collected for 3 years, following their year of MHV registration. For example, for patients who registered for the portal in 2012 data were collected from 2013 to 2015. For patients that registered for the portal in 2016, data were collected from 2017 to 2019.

Diagnosis of diabetes was determined using International Classification of Diseases–Ninth and Tenth Revisions–Clinical Modification diagnoses codes from VHA inpatient and outpatient visits that occurred between January 1, 1999, and December 31, 2016. A diagnosis of type 2 diabetes was defined by having 1 inpatient diagnosis or 2 outpatient diagnoses of type 2 diabetes. We excluded patients first diagnosed with type 2 diabetes after portal registration because we wanted to characterize the association between portal use and outcomes among new portal users already living with diabetes prior to study period. We further excluded patients who did not have at

least 1 VHA primary care or specialty care visit in each calendar year (the MHV registration year and in each of the 3 follow-up years), as these patients were likely to be receiving all or most of their care outside the VHA. Finally, because our primary objective was to examine whether consistent use of the patient portal among new portal users was associated with improved diabetes control, we excluded inactive users, which we defined as having no portal activity for a full calendar year during their follow-up period, and limited our cohort to active portal users.

After excluding patients diagnosed with diabetes after account creation ($n = 124\,342$), patients without a primary or specialty care visit in each year ($n = 60\,022$), inactive users ($n = 195\,096$), and patients who died during follow-up ($n = 2\,717$), the final analytic sample included 95 043 patients (Figure 1). The Institutional Review Board at VA Bedford Healthcare System approved this research.

Data collection

To create the study cohort, we extracted and linked patient-level MHV activity data to administrative data from the VHA's national repository, the Corporate Data Warehouse (CDW). From the CDW, we collected data on patient demographics, healthcare utilization, diagnoses, and clinical laboratory results.

MHV portal activity data were collected from January 1, 2013, to December 31, 2019. We defined portal "activity" as any use of the MHV key features (ie, ordering prescription refills, secure messaging providers, and downloading/viewing health records). We did not consider any system-generated activity (eg, notifications) or administrative activity (eg, logging in, setting or resetting passwords, etc.) in our definition. The primary outcomes of interest were annual mean HbA1c, LDL levels, and systolic and diastolic BP measurements. To obtain annual means, all available laboratory test results in the CDW were averaged for each person-year. To determine control at baseline, we calculated the percentage of time in the baseline year a patient was estimated to have sustained control of HbA1c, LDL, and BP. Controlled HbA1c was defined as $<8.0\%$, controlled LDL as <100 mg/dL, and controlled BP as a systolic BP <140 mm Hg and a diastolic BP <85 mm Hg.^{29–31} Time in control was calculated based on the Rosendaal method, which uses linear interpolation to assign a value to each day between patients' successive measurements.³² After interpolation, the percentage of time during the year in which the interpolated values fell inside the region of control (eg, HbA1c $<8.0\%$) was calculated.

The primary exposure of interest was the interaction between months of portal activity in a year and control of HbA1c, LDL, and BP at baseline. Patients that used any of the MHV key features in a given month were counted as having portal activity for that month, regardless of the number of days of use in that month. As a measure of a patient's baseline physiological health, we created dummy variables indicating whether HbA1c, LDL, and BP were inside the region of control for at least 75% of the patient's baseline year (ie, year of portal registration).

Other patient-level covariates included several demographic characteristics (age at registration, sex, race, marital status, rurality), eligibility priority status (an indicator of service-connected disability used to determine a Veteran's financial responsibility of their care),³³ VHA healthcare utilization, and Nosos comorbidity risk score. For healthcare utilization, we included the number of days in a year a patient had a VHA primary care visit, a specialty care visit (including both medical specialties and social supports), a visit for diagnostic testing (eg, laboratory, electrocardiography, ultrasound),

Figure 1. Study sample.

an urgent care or emergency department visit, or an inpatient hospitalization. These health service utilization categories included tele-

phonic, video, and face-to-face encounters between a patient and a healthcare provider. Nosos scores are used to predict a patient's costs in relation to the national average of all VA patients. Nosos scores are calculated by VA annually and are scaled so a value of 1 is equal to the population average.³⁴ Nosos scores and healthcare utilization were top-coded at the 99.9th percentiles to remove influence of extreme outliers from the data.

Statistical analysis

Data were observed at the person-year level for 3 consecutive calendar years following the year of portal registration (ie, the baseline year). First, we described patient characteristics, healthcare utilization, mean physiological measures, and time in control. We then described use of the MHV key features and examined which key features were used most often. For the main analysis, we estimated the association of months of portal activity in a year with each of the 4 physiological outcomes (mean HbA1c, LDL, systolic BP, and diastolic BP) using multivariable random-effect linear regression models. As the primary predictor of interest, we interacted the number of months of portal activity with a dummy variable indicating the baseline year control of the physiological outcome ($0 = \geq 75\%$ time in control of the outcome in the baseline year, $1 = <75\%$ time in control of the outcome in the baseline year):

$$Y_{it} = \beta_0 + \beta_1(MHVmonths_{it}) + \beta_2(BaselineControl_{it=0}) + \beta_3(MHVmonths_{it} \times BaselineControl_{it=0}) + \beta X_{it} + \beta Z_i + \lambda_{it} + \mu_t + \epsilon_{it}$$

Here, i indexes the patient and t indexes the calendar year relative to the baseline year ($t = 1, 2, 3$). The $\mu_t + \epsilon_{it}$ represent the random intercept. λ_{it} is the number of years elapsed since baseline, βX_{it} is a vector of the time-varying covariates (Nosos risk score healthcare utilization) in time t , and βZ_i is a vector of time-invariant covariates (age at registration, sex, race, marital status, rurality, priority status, baseline physiological measurements, and the calendar year of portal registration). Y_{it} is the physiological outcome of interest in year t . $MHVmonths_{it}$ is set equal to the number of months of MHV use (1-12) the patient had in year t . $BaselineControl_{it=0}$ is the dummy variable indicating control of the outcome Y in the baseline year ($1 = <75\%$ time in control, 0 otherwise). The interaction term, $MHVmonths_{it} \times BaselineControl_{it=0}$, is set equal to the number of MHV months in year t for patients that were $<75\%$ time in control in the baseline year and zero otherwise. From the regression coefficients, we estimated the marginal effects of months of portal activity on HbA1c, LDL, and BP annual means for patients inside and outside the region of control at baseline. Finally, we conducted exploratory analyses in different subgroups of patients with sufficient sample (older veterans, rural veterans, and Black or African American veterans) and compared these results with our main findings.

Approximately 10.3% ($n = 9766$) of the sample was missing a baseline LDL measurement, 7.3% ($n = 6953$) was missing HbA1c, and 1.2% ($n = 1104$) was missing a BP reading at baseline. Less than 1% of the observations during the follow-up years were missing any one of the covariates. Observations with any missing data were excluded in regression models (complete case analysis). Cluster robust standard errors are used to adjust for correlation within individuals. Multicollinearity was assessed using a variance inflation factor cutoff of 10. All analyses were conducted using Stata 15.1 (StataCorp, College Station, TX).

Table 1. Characteristics of the study sample (N = 95 043)

Patient characteristics	
Age at registration, y	62.8 ± 10.2
Sex	
Male	90 704 (95.4)
Race	
White	68 954 (72.6)
African American or Black	13 872 (14.6)
Hispanic or Latino	5823 (6.1)
Other	2727 (2.9)
Missing/unknown	3667 (3.9)
Marital status	
Married	63 344 (66.6)
Widowed	4599 (4.8)
Divorced/separated	19 876 (20.9)
Single	6573 (6.9)
Missing/unknown	651 (0.7)
Rurality	
Rural	34 000 (35.9)
VA priority status	
SCD 50% or greater	45 400 (47.8)
SCD <50%	20 327 (21.4)
No SCD, low income	28 211 (29.7)
Other	1061 (1.1)
Measures of health and healthcare use at baseline	
Nosos comorbidity risk score	1.9 ± 3.5
VA healthcare utilization	
Primary care visits	5.2 ± 4.7
Specialty care visits	12.7 ± 16.2
Diagnostic visits	6.2 ± 6.1
ED/urgent care visits	0.5 ± 1.2
Hospitalization	9512 (10.0)
Physiological measures	
HbA1c, %	7.4 ± 1.5
LDL, mg/dL	91.2 ± 31.6
Systolic BP, mm Hg	132.4 ± 12.9
Diastolic BP, mm Hg	76.2 ± 8.7
Baseline TIC	
HbA1c TIC <75%	29 246 (33.2)
LDL TIC <75%	34 411 (40.4)
BP TIC <75%	44 260 (47.1)

Values are mean ± SD or n (%).

BP: blood pressure; ED: emergency department; HbA1c: hemoglobin A1c; LDL: low-density lipoprotein cholesterol; SCD: service-connected disability; TIC: time in control.

RESULTS

Patient characteristics

The final sample included 95 043 unique patients. Baseline characteristics of the study sample are presented in Table 1. Most of the patients in the study sample were male (95%) and White (73%). Almost half had a service-connected disability rated 50% or greater (48%), two-thirds were married (67%), and over a third lived in a rural area (36%). On average, patients in the sample made 5.2 ± 4.7 VA primary care appointments, 12.7 ± 16.2 specialty care visits, 6.2 ± 6.1 visits for diagnostic testing, 0.5 ± 1.1 emergency department or urgent care visits, and 10% were hospitalized at a VA facility in the baseline year. The baseline mean Nosos risk score was 1.9 ± 3.5, mean HbA1c was 7.4 ± 1.5%, mean LDL was 91.2 ± 31.6 mg/dL, and mean BP was 132.4/76.2 ± 12.9/8.7 mm Hg. At baseline, 33%, 40%, and 47% of patients had uncontrolled HbA1c, LDL, and BP, respectively. Characteristics of patients with type 2 di-

Table 2. Use of my HealtheVet patient portal features

	n (person-years)	%	Months of portal use per year		Days of portal use per year	
			Mean	SD	Mean	SD
Any portal use	285 129	100	7.2	3.6	19.2	21.8
Key features						
Prescription refills	237 798	83.4	6.4	3.4	10.1	9.1
Appointment views	179 061	62.8	4.1	3.2	9.1	16.3
Secure messaging	151 689	53.2	4.5	3.2	12.2	14.3
Lab views	130 019	45.6	2.5	2.0	4.2	6.4
Clinical notes	41 914	14.7	2.4	2.4	5.2	12.8
Full health record download	36 211	12.7	1.8	1.8	3.3	10.2
Other health record activity	21 100	7.4	1.4	1.0	1.7	2.2
Total key features used in year						
0	65 865	23.1	5	3.4	7.7	8.7
1	62 728	22.0	6.4	3.4	13	13.7
2	68 716	24.1	7.9	3.2	20.5	18.8
3	50 753	17.8	8.8	2.9	27.5	23.8
4	21 955	7.7	9.1	2.8	31.8	27.3
5	11 120	3.9	9.9	2.4	43.5	35.3
6	3136	1.1	10.5	2	57.3	42.5
7	65 865	23.1	5	3.4	7.7	8.7

Means for key features only include patients that used that feature in the year. Months and days of use by key feature only include patients that used that feature in at least 1 day in the year (ie, means exclude patients that never used that feature in the year).

abetes that never registered for the MHV patient portal are available in the [Supplementary Table 1](#). Compared with the study sample, these patients were older, less likely to be White, more likely to be male, less likely to be married, and less likely have a service-connected disability. Additionally, these nonusers had fewer health-care visits and spent greater time in control of HbA1c, LDL, and BP at baseline.

MHV portal use

[Table 2](#) shows overall MHV portal use and use of the key features during the 3 year study period. On average, patients in the study sample used MHV for 7.2 ± 3.6 months per year and 19.2 ± 21.8 days per year. Prescription refills was the most used key feature; 83% of portal users used this feature annually (mean use = 6.4 months per year among refill users). Clinical notes, Blue Button full medical record downloads and other Blue Button functions were used less frequently than the other features. While most patients (64%) used between 2 and 4 of the key features, approximately 1 in 8 patients (12.7%) used 5 or more of the features in a year.

In bivariate analyses, more months of MHV use was associated with male sex, White race, older age, and residing in a rural area. Greater healthcare utilization and a higher Nosos comorbidity risk score were also associated with more months of MHV use ([Supplementary Table 2](#)).

Physiological measurements

In [Figure 2](#), we present the multivariable linear model results stratified by controlled and uncontrolled HbA1c, LDL, or BP measurements in the baseline year. Increasing number of months of MHV use was significantly associated with improvements in HbA1c, LDL, and BP among patients for whom these measures were not in control at baseline. Increasing months of MHV use had minimal or no effect for patients whose HbA1c, LDL, or BP were controlled at baseline.

Compared with patients with 1 month of MHV portal use, patients with 12 months of use lowered mean HbA1c % by -0.41%

(95% confidence interval [CI], -0.46% to -0.36%), lowered LDL by -6.25 (95% CI, -7.15 to -5.36) mg/dL, lowered systolic BP by -1.01 (95% CI, -1.33 to -0.68) mm Hg, and lowered diastolic BP by 0.67 mm Hg (95% CI, -0.85 to -0.49). Minimal or no association between months of MHV use and the physiological outcomes was found for patients with any of HbA1c, LDL, or BP in control at baseline ([Supplementary Table 3](#)). Coefficients of the model covariates are presented in the [Supplementary Table 4](#).

In exploratory analyses we estimated the marginal effect of months of portal use for rural veterans, older veterans (≥ 70 years of age), and Black or African American veterans. For older veterans with uncontrolled HbA1c at baseline, more months of portal activity did not have as large an effect on lowering HbA1c % than it did for younger (< 70 years of age) veterans. For rural and Black or African American veterans, we did not find any differential effect of portal use on physiological outcomes. Marginal plots by subgroup are available in the [Supplementary Figure 1](#).

DISCUSSION

Relatively little is known about how portal users engage with portals over time, what features they tend to use, and how this is related to disease-specific outcomes. To our knowledge, this is the first study to examine consistency of patient portal use over a 3-year period in a large national sample of new portal users with type 2 diabetes. We found that more months of portal use per year was associated with lower annual means in HbA1c and LDL for patients who did not have good control of those measures at baseline. Reductions in BP measurements were small and not clinically meaningful. Patients not in control of physiological measures are most in need of intervention to reduce the risk of diabetes-related morbidity and mortality. Our study suggests that consistent engagement with patient portals may be one way to help achieve control for some of these key outcomes for patients with diabetes.

Figure 2. Regression results. BP: blood pressure; DPB: diastolic blood pressure; HbA1c: hemoglobin A1c; LDL: low-density lipoprotein cholesterol; SPB: systolic blood pressure; TIC: time in control.

Maintaining diabetes control requires continuous self-management. Portals facilitate patients self-management by providing a means to readily access healthcare information and communicate with their healthcare team.¹¹ Thus, it remains imperative to investigate the impact of varying levels of use on key diabetes-related outcomes. Few studies have examined consistency of portal use among registered or active users, and whether more consistent engagement with a portal and its features over time is associated with better outcomes. Our study extends prior findings and demonstrates a dose-response relationship, showing that consistent use of patient portals may be beneficial for patients who are struggling to maintain diabetes control. While the mean improvements observed in HbA1c were not large, they were similar in magnitude to behavioral interventions aimed at improving diabetes self-management (eg, 0.1%-0.9% improvement in HbA1c).³⁵⁻⁴⁰

Most patients in our sample used multiple portal features; use of prescription refills was the most popular. Online refills and secure messaging have been found to be effective in chronic disease self-management,^{26,28} but less is known about the impact of viewing clinical notes or test results on clinical outcomes.^{41,42} Further work is needed to identify which features are most beneficial to patients with diabetes. Use of certain key features may benefit patients newly diagnosed with diabetes differently than patients who have been actively managing their diabetes for longer. For example, secure messaging may be more valuable to a newly diagnosed diabetes patient

to ask questions about glucose monitoring and insulin compared with a patient for whom such monitoring is an established routine. Or, increased use of the portal may occur over a period of time when both the provider and patient are making a concerted effort to change medications to better control HbA1c, LDL, or BP. In this case, use of secure messaging may help facilitate communication between the patient and provider and online prescription refills may be used by the patient to receive medications.⁴³

Future research could also examine consistency of portal engagement among populations less likely to adopt or use patient portals (eg, rural patients, older patients, and minority patients) in greater detail. Interventions to increase portal adoption and use may benefit from paying closer attention to the needs of diverse patients.¹² While our exploratory analysis did not find large differences among these populations, older veterans did appear to benefit less from increased portal use compared with younger veterans regarding HbA1c control. Additional work is necessary to determine what factors may be driving differential effects.

These findings should be promising to clinical teams that encourage patients with poor control to register and regularly use online patient portals to help manage their diabetes and achieve control. Consistent use of patient portals throughout the year may help patients better control their diabetes than patients that use the portal intermittently. Interventions designed to promote more consistent use among those already using the portal may have additional bene-

fit for patients managing chronic disease. Furthermore, interventions targeted to new users should integrate mechanisms that facilitate consistent use. For example, new user interventions might want to consider multiple iterations of instruction and promote habitual use. Additionally, while we did not find that consistent portal use improved measures for patients in good control of these measures at baseline, future studies could explore the utility of patient portals in maintaining control for patients most at risk of falling out of control.

Our study has some limitations. The association we found between months of portal use and physiological outcomes could be confounded in ways we could not directly measure. Patients who interact with the healthcare system more may have more reason to use patient portal features.²⁸ Patients who use the portal more consistently could also be engaging in other self-management behaviors more often, or more effectively, than patients who use the portal less consistently (eg, diet, exercise, medication adherence). This difference could arise because the portal features support self-management, or owing to exogenous factors unrelated to the portal. We also did not directly measure the effect of individual patient portal features. Most patients used between 2 and 4 key features in a year, making it difficult to isolate the effect of any particular feature. It is possible that the associations we found are due to differential use of features among portal users. Future research into how patients use specific portal features to achieve control, and why using specific features might be preferred over others for managing diabetes, would help health systems better design interventions to encourage portal use.

Another limitation is that our models did not account for differences in providers, which may impact both portal use and health outcomes. Over a 3-year period, VHA patients with diabetes typically encounter several different primary and specialty care providers in different clinical contexts for varying lengths of time. A patient's level of engagement with the portal may be dependent on provider-level factors, such as how well their providers use secure messaging (eg, timeliness and quality of responses) or whether their providers encourage them to use different portal features (eg, view clinical notes or lab results following an appointment).^{44,45} While our models included overall healthcare utilization and a comorbidity risk score, provider differences may also play a role in portal use and outcomes in ways we could not measure. In addition, many VHA patients also receive primary or specialty care outside the VHA, and completeness of physiological testing data and use of the portal may depend on a patient's reliance on VHA for managing their diabetes. Finally, this was a study of the MHV patient portal, only available to patients in the VHA. However, this portal encompasses users nationwide and has analogous features to other patient portals found in private health systems, increasing the likelihood that our findings are generalizable to portal use in other healthcare settings and in other patient populations.

CONCLUSION

In this study, we examined consistency of portal use over the first 3 years after registering for the portal among patients with type 2 diabetes. We found a modest but significant dose-response relationship between months of portal use and diabetes physiological measures among patients with uncontrolled physiological measurements at baseline. HbA1c clinically improved the most. These findings show the potential value of consistent use of patient portals, especially for patients struggling to control their diabetes. Understandably, health

systems may focus on patient portal adoption given their limited uptake^{43,46}; however, this study spotlights the importance of developing interventions aimed to increase use of portals among both new users and those who have adopted but only use the portal intermittently.

FUNDING

This work was supported by Veterans Administration Health Services Research and Development grant number IIR 15-307. The views expressed are those of the authors and do not necessarily reflect the position or policy of the Department of Veterans Affairs or the U.S. government.

AUTHOR CONTRIBUTIONS

All authors made substantial contributions to the conception or design of the work. MSZ and SLS wrote the initial draft and SAR, ASA, VV, and HLW contributed to substantive revisions. MSZ and DN conducted the statistical analysis and managed the data. TPH, SLC, MTS, and LA critically reviewed and provided important intellectual content to the final draft. All authors were involved in data interpretation and approved the final version submitted for publication. MSZ had access to the data in the study and takes responsibility for data integrity and accuracy.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *Journal of the American Medical Informatics Association* online.

DATA AVAILABILITY STATEMENT

The U.S. Department of Veterans Affairs (VA) prohibits unauthorized sharing of data. The data used for this study are not permitted to be shared outside the VA firewall without a Data Use Agreement. This limitation is consistent with other studies based on VA data; however, VA data are available to researchers behind the VA firewall with an approved VA study protocol. For more information, please visit <https://www.virec.research.va.gov> or contact the VA Information Resource Center (VIREC) at VIREC@va.gov.

CONFLICT OF INTEREST STATEMENT

Authors have no competing interests to declare.

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