Association of Mobile Patient Portal Access With Diabetes Medication Adherence and Glycemic Levels Among Adults With Diabetes
Ilana Graetz, PhD; Jie Huang, PhD; Emilie R. Muelly, MD; Bruce Fireman, PhD; John Hsu, MD, MBA; Mary E. Reed, DrPH

Abstract

IMPORTANCE Online patient portals support self-management, and mobile devices expand portal access, but whether this translates to improvements in diabetes outcomes is unclear.

OBJECTIVE To examine the association of adding mobile patient portal access with diabetes medication adherence and glycemic levels among adults with diabetes.

DESIGN, SETTING, AND PARTICIPANTS This retrospective cohort study included patients with diabetes treated at Kaiser Permanente Northern California, a large, integrated health care delivery system, from April 1, 2015, to December 31, 2017. Inclusion criteria were adults with diabetes with an oral diabetes prescription at baseline and no insulin use. Data were analyzed from March 2018 to March 2019.

EXPOSURES Patient portal access status for each calendar month from April 2015 to December 2017, categorized as never used, used from a computer only, used from a mobile device only, or used from both computer and mobile device.

MAIN OUTCOMES AND MEASURES Medication adherence, measured by monthly percentage of days covered (PDC), and glycemic levels, measured by changes in glycated hemoglobin A1c (HbA1c) levels. The association of portal access with study outcomes was assessed using linear regression with patient-level fixed effects and adjusting for time-changing variables, stratified by baseline HbA1c level.

RESULTS Among 111,463 included patients (mean [SD] age, 63.79 [12.93] years; 59,918 [53.76%] men), the number of patients using the portal from both a computer and mobile device increased over time from 38,371 patients (34.42%) in April 2015 to 57,920 patients (61.71%) in December 2017. Among patients with no prior portal access, adding computer-only portal access was associated with an increase in PDC of 1.16 (95% CI, 0.63 to 1.70) percentage points and a change of −0.06 (95% CI, −0.08 to −0.03) percentage points in HbA1c level, and adding both mobile and computer portal access was associated with an increase in PDC of 1.67 (95% CI, 1.10 to 2.23) percentage points and a change of −0.13 (95% CI, −0.16 to −0.10) percentage points in HbA1c level. Among patients with higher baseline HbA1c level (>8.0%), changing from no portal access to both computer and mobile access was associated with an increase in PDC of 5.09 (95% CI, 3.78 to 6.40) percentage points and a change of −0.19 (95% CI, −0.27 to −0.15) percentage points in HbA1c level.

CONCLUSIONS AND RELEVANCE These findings suggest that providing patients with computer patient portal access and combining it with mobile patient portal access are associated with significantly improved diabetes medication adherence and glycemic control, with greater benefits (continued)
Abstract (continued)

among patients with more clinical need. Convenient access to portal self-management tools through a mobile device could significantly improve diabetes management.

Introduction

Patient portals that are tethered to a complete electronic health record (EHR) offer patients access to web-based tools for viewing laboratory test results, communicating with their health care team, and ordering prescription refills. These functions are particularly useful for improving the quality of care for patients with chronic conditions, such as diabetes, that require ongoing self-management. Our prior research found that the addition of mobile portal access increases the frequency and timeliness of portal use. Making patient portals easily accessible by a mobile device, either via a smartphone application or mobile-optimized website, puts access to portal functions literally in the patient’s pocket and may support more timely self-management practices, including medication refills, secure message exchanges with health care practitioners, and scheduling of appointments.

Suboptimal self-management of diabetes, such as poor medication adherence or inadequately monitored blood glucose levels, increases the risk for complications and other adverse events. Thus, strategies that support patients with diabetes and bolster self-management behaviors could reduce diabetes-related adverse events. Accordingly, policy makers and institutions have invested substantially in promoting patient portals as an ancillary tool to support care management, particularly for patients with chronic conditions, such as diabetes. However, incentive programs by the Centers for Medicare & Medicaid Services, such as Promoting Interoperability Stage 3 (formerly known as electronic health record meaningful use), do not require electronic access to health information by a mobile device. While previous studies have found that portal use is associated with lower glycemic levels among patients with diabetes and reported a positive association between ordering prescription refills via a portal and medication adherence for statin and antihypertensive medications, no studies have examined whether portal access is associated with adherence to oral diabetes medications, to our knowledge. Notably, no studies have examined whether the addition of increasing mobile-device portal access is associated with self-management behaviors, such as medication adherence, or glycemic levels for patients with diabetes, to our knowledge.

This study evaluates whether the addition of mobile portal access is associated with adherence to oral diabetic medications and glycemic levels for patients with diabetes. In a population of patients with diabetes, we examined changes in medication adherence and glycemic levels as patients added portal access devices over time, with particular attention to patients with greater clinical need.

Methods

This study was reviewed and approved by the institutional review board of the Kaiser Foundation Research Institute, which waived the requirement for informed consent in this data-only study. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline for cohort studies.

Setting

Kaiser Permanente Northern California (KPNC) is a large, integrated health care delivery system that provides comprehensive care to more than 4 million patients. All KPNC members who register online can use a free EHR-tethered portal to access their medical records, view laboratory results, send and receive secure messages with their health care team, schedule appointments, and request prescription refills. The portal has been available since late 2005, and in 2013, KPNC introduced a mobile portal access device.
mobile-optimized version of the website and iOS and Android applications to facilitate mobile access to the portal. Our study period began April 1, 2015, when portal-automated data sources first became available for research containing portal access by device type.

Study Population
Our study included adults 18 years or older with diabetes who were active members of KPNC. Presence of diabetes was defined using the 2015 clinical diabetes chronic conditions registry.18 Because our focus was on medication adherence, we included only patients who had filled at least 1 prescription for an oral diabetes drug (≥30 days of supply) during the baseline period, defined as 1 year prior to the beginning of the study, April 1, 2014, to March 31, 2015. Since medication adherence is difficult to calculate for insulin, we excluded patients who had filled a prescription for insulin during the baseline and study periods, April 1, 2014, to December 31, 2017. In analyses examining glycemic control, we included the subset of patients with at least 1 test result for glycated hemoglobin A1c (HbA1c) level during the study year.

Data
We used portal administrative data to capture portal use and access device, categorized as mobile (ie, via smartphone or tablet) or computer (ie, via desktop or laptop), and EHR data to capture prescription refills for oral diabetes drugs and glycemic levels, as measured by HbA1c laboratory test results, control variables, and demographic characteristics. Race/ethnicity was self-reported by patients. Socioeconomic status was based on census block and categorized as lower socioeconomic status if at least 20% of residents had household incomes below the federal poverty level or at least 25% of residents aged 25 years or older had less than a high school education.

Outcome Variables
Medication Adherence
Medication adherence was measured as the monthly percentage of days covered (PDC), which was based on the number of days' supply of oral diabetes prescription drug dispensed in each month of the study. We allowed for carryover for the last prescription of the prior year and during the year. For patients using multiple classes of diabetes drugs, we conservatively assigned the PDC of the drug class with the highest monthly PDC in the given month. Patients were considered adherent if they had PDC of 80% or more.

Glycemic Levels
Using the EHR, we captured all HbA1c level values for patients in our study cohort during the study. We chose to focus on HbA1c level because it is reliably captured, has been previously shown to improve with portal use,7,11,12 and is associated with risk of adverse clinical events.

Exposure Variables
We identified initial portal access status based on the 12-month baseline period. After initial portal access, we assumed that patients had continued portal use. Next, we created a time-changing variable capturing portal access during each month starting April 1, 2015, and ending December 31, 2017. For each month, portal access was categorized into 1 of 4 groups: never used, computer only, mobile only, or computer and mobile access. The first 4 months of change status were considered an exposure transition period. Since our goal was to measure the mean association of portal access with the study outcomes rather than the direct association of any given portal action, we used this transition washout period so that any medication refill ordered (typically up to 100 days' supply) at the same time as a portal access transition did not contribute directly toward the adherence outcome measure.
Control Variables
For a general measure of patients’ time-changing historical medication burden, restricted for our purposes to prescription drugs, we calculated the number of prescription drugs filled during a 6-month period lagged by 6 months. We captured time-changing health care utilization data using 2 binary dummy variables if the patient had any clinical encounters during a 6-month period lagged by 6 months from the index month. One indicator captured use of any outpatient visits, including in-person office or telehealth visits (video or telephone). The second indicator variable captured any emergency department visits or hospitalizations. Temporal trends were measured using a monthly dummy indicator for each study month (range, 1-33).

Statistical Analysis
We assessed the associations of portal access with outcomes (PDC and HbA1c level) using linear regression with patient-level fixed effects to account for unmeasured time-stable patient-level characteristics, such as general medication-use behavior unrelated to portal use, adjusting for temporal trend and time-varying numbers of drugs and health events. Using patient-level fixed effects accounts for time-stable patient-specific characteristics, including adherence behavior. In addition, we statistically adjusted for several time-changing measures, including medication burden and health care utilization.

Since we were particularly interested in the association of mobile portal use with glycemic control among patients whose glycemic levels show room for improvement, we also conducted additional analyses stratified to examine these subgroups using baseline HbA1c levels (HbA1c level > 8% or HbA1c ≤ 8%; to convert to proportion of total hemoglobin, multiply by 0.01).19

We conducted additional sensitivity analyses in which portal access was defined by portal use of the refill function. Similar to portal access, we assumed that patients had continued to have access to the refill function on the portal after their initial use with a device. This provided a more direct estimate of how portal refill access by device was associated with adherence. Both measures of portal access provided similar results.

All analyses were conducted using Stata statistical software version 14 (StataCorp). A 2-tailed P < .05 was considered statistically significant. Data were analyzed from March 2018 to March 2019.

Results
Overall, 111,463 patients were included in the beginning of the study in April 2015, and 93,857 patients (84.2%) were still included in the end of the study in December 2017. At baseline, among 111,463 patients with diabetes treated at KPNC (mean [SD] age, 63.79 [12.93]; 59,918 [53.76%] men), 45,205 patients (40.56%) were white, and 26,647 patients (23.91%) lived in neighborhoods with lower socioeconomic status (Table). Among these patients, 80,683 patients (72.39%) had data for at least 1 HbA1c test result. During the initial 6-month baseline period from April 1, 2014, to September 30, 2014, the median (interquartile range [IQR]) number of drugs used was 2 (1-2), 93,018 patients (83.45%) had 1 or more outpatient visits, and 14,686 patients (13.18%) had 1 or more emergency department visits or hospitalizations.

Portal Access
Computer-only portal access decreased from 33,332 patients (29.90%) in April 2015 to 14,473 patients (12.98%) in December 2017, while the number of patients using both mobile and computer access increased from 38,371 patients (34.42%) to 57,920 patients (61.71%) (Figure 1). The number of patients using only a mobile device to access the portal remained limited (824 patients [0.74%] to 1,112 patients [1.01%]) throughout the study. The number of patients who had never accessed the portal decreased from 38,635 patients (34.66%) to 27,304 patients (24.50%) during the study. The number of patients who used the portal refill function via a computer and mobile device increased.
during the study from 8094 patients (7.26%) in April 2015 to 20,487 patients (21.83%) in December 2017 (eFigure in the Supplement).

Medication Adherence

At baseline, 79,750 patients (71.55%) were adherent to at least 1 diabetes medication (defined as PDC ≥80%). Among patients with no prior portal access, adding computer-only portal access was associated with an increase in PDC of 1.16 (95% CI, 0.63 to 1.70) percentage points (P < .001), and adding mobile and computer portal access was associated with an increase in PDC of 1.67 (95% CI, 1.10 to 2.23) percentage points (P < .001) (Figure 1). Going from computer-only portal access initially

Table. Patient Baseline Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Patients, No. (%) (N = 111,463)</th>
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<tbody>
<tr>
<td>Age, y</td>
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<tr>
<td>18-44</td>
<td>8,338 (7.48)</td>
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<td>45-64</td>
<td>47,764 (42.85)</td>
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<tr>
<td>65-74</td>
<td>31,947 (28.66)</td>
</tr>
<tr>
<td>≥75</td>
<td>23,414 (21.01)</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>59,918 (53.76)</td>
</tr>
<tr>
<td>Women</td>
<td>51,545 (46.24)</td>
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<tr>
<td>Race/ethnicity</td>
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<td>White</td>
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<tr>
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<td>10,614 (9.52)</td>
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<td>Asian</td>
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<td>Other</td>
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<td>Neighborhood socioeconomic status*</td>
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<tr>
<td>Higher</td>
<td>83,766 (75.15)</td>
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<td>Lower</td>
<td>26,647 (23.91)</td>
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<td>Comorbidities, No. b</td>
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<td>1</td>
<td>64,537 (57.90)</td>
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<td>2</td>
<td>16,098 (14.44)</td>
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<tr>
<td>3</td>
<td>3,655 (3.28)</td>
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<td>Glycated hemoglobin A₁c level, %</td>
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<tr>
<td>&lt;7</td>
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<td>7 to ≤8</td>
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<td>&gt;8</td>
<td>22,661 (20.33)</td>
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<tr>
<td>Medication adherence, PDC c</td>
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<tr>
<td>&lt;80%</td>
<td>31,713 (28.45)</td>
</tr>
<tr>
<td>≥80%</td>
<td>79,750 (71.55)</td>
</tr>
</tbody>
</table>

Abbreviation: PDC, percentage of days covered.

SI conversion factor: To convert glycated hemoglobin A₁c to proportion of total hemoglobin, multiply by 0.01.

* Based on census block and categorized as lower if at least 20% of residents have household incomes below the federal poverty level or at least 25% of residents 25 years or older have less than a high school education.

b Includes asthma, hypertension, and heart failure.

c Based on the number of days supplied for a filled oral diabetes drug in each month of the study.
to adding mobile portal access was associated with an increase in PDC of 0.50 (95% CI, 0.18 to 0.82) percentage points ($P = .002$).

In the strata of patients with baseline HbA1c level higher than 8%, the change in PDC associated with adding portal access was significantly larger than in patients with baseline HbA1c level 8% or lower (Figure 2). For patients with baseline HbA1c level higher than 8% and no prior portal access, adding computer-only access was associated with an increase in PDC of 3.48 (95% CI, 2.24 to 4.71) percentage points ($P < .001$), and adding computer and mobile access was associated with an increase in PDC of 5.09 (95% CI, 3.78 to 6.4) percentage points ($P < .001$). Going from no portal access to mobile-only access was not associated with statistically significant changes in PDC overall.
or in stratified analyses (eTable 1 in the Supplement). Sensitivity analyses suggested an even stronger association of portal refill access with adherence improvements: during the 33 months of the study, patients who went from no portal access at baseline to computer and mobile access and using the portal’s prescription refill function had an increase in PDC of 2.70 (95% CI, 2.15 to 3.25) percentage points (eTable 2 in the Supplement).

HbA1c Levels
At baseline, 87,790 patients (78.76%) had HbA1c levels at 8% or lower. Figure 3 shows results from the adjusted linear regression analyses examining changes in HbA1c levels overall and stratified by baseline HbA1c level. Among all patients with data on HbA1c levels, adding mobile access among patients with only computer access initially was associated with a change of −0.07 (95% CI, −0.09 to −0.06) percentage points in HbA1c level (P < .001), while adding mobile and computer access among patients with no prior portal access was associated with a change of −0.13 (95% CI, −0.16 to −0.10) percentage points in HbA1c level (P < .001) (Figure 3). Adding computer-only portal access among patients with no portal access at baseline was associated with a change of −0.06 (95% CI, −0.08 to −0.03) percentage points in HbA1c level (P < .001).

In the stratified analyses among patients with baseline HbA1c level greater than 8%, the change in HbA1c levels associated with adding mobile portal access was significantly larger. Among patients with higher baseline HbA1c level and with no baseline portal access, adding mobile access was associated with a change of −0.25% (95% CI, −0.48% to −0.03%) percentage points in HbA1c level (P = .03), and adding computer and mobile access was associated with a change of −0.19 (95 CI, −0.27 to −0.15) percentage points in HbA1c level (P < .001) (eTable 3 in the Supplement). Among patients with higher baseline HbA1c, going from computer-only access at baseline to adding mobile access was associated with a change of −0.11% (95% CI, −0.16 to −0.06) percentage points in HbA1c level (P < .001).

Discussion
In this cohort study of patients with diabetes in an integrated health care delivery system offering a mobile-optimized patient portal and mobile applications, we found that for patients not previously using the portal or using it only from a computer, adding mobile access was associated with statistically significant improvements in adherence to oral diabetes drugs and lower glycemic levels. Notably, improvements associated with mobile portal access were greater among patients with higher clinical need at baseline (HbA1c level >8%). Nonetheless, even among patients with lower baseline glycemic levels (HbA1c level ≤8%), adding computer portal access and incrementally adding

Figure 3. Adjusted Changes in Glycated Hemoglobin A1c (HbA1c) Level and Portal Access

Linear regression with patient-level fixed effects and adjusting for the number of drugs filled during a 6-month period lagged by 6 months, any clinical visit (in-person, video or telephone, and emergency department or hospitalization) in the month prior, and monthly dummy indicator (range, 1-33).
mobile portal access over time was associated with statistically significant improvements in adherence to oral diabetes drugs and HbA1c levels.

To our knowledge, this is the first study to examine the association of patient portal access with adherence to oral diabetes medications. In patients with initially higher glycemic levels and no portal access, the 5.09-percentage point increase in PDC associated with adding computer and mobile portal access could be translated into an additional 1.5 adherent days per month. We found a more modest but still statistically significant increase in adherence among patients with lower initial glycemic levels and in the overall population estimates, translating to increased adherence of approximately 0.5 additional days per month. Still, in an analysis focused on isolating the incremental benefit of adding mobile portal access on a population level, these measured improvements in diabetes-related adherence are likely only one example of the potential associations of mobile portal access with self-management behavior. Importantly, our concurrent finding of improvements in glycemic levels suggests that improvements in self-management behaviors, such as medication adherence, associated with mobile portal access have clinically meaningful associations with outcomes and could have implications for downstream adverse clinical events. It is possible that use of multiple tools available in the portal, not only prescription refills, contributed to the association of increased portal access with improvements in glycemic levels. Future studies should examine how mobile portal access is associated with other types of self-management practices and care-seeking behavior.

Notably, this is the first study to find an incremental benefit of adding mobile portal access beyond computer portal access, to our knowledge. Going from computer-only access to adding mobile access increased 2-fold the portal-associated improvement in HbA1c level (from a 0.06-percentage point lower HbA1c level with computer-only access to a 0.13-percentage point lower HbA1c level when adding mobile access). While the proportion of patients accessing the portal using only a mobile device remained extremely small (1%), among patients with higher clinical need and no prior portal access, adding mobile-only access was associated with a reduction of 0.25 percentage points in HbA1c level. Consistent with previous studies,17 we also found that computer-only access to portals was associated with a statistically significant reduction in HbA1c levels among patients with diabetes who did not initially have portal access. Given that HbA1c levels are significantly associated with long-term complications,19 these modest but clinically meaningful improvements in HbA1c levels associated with gaining mobile portal access may be associated with downstream prevention or reduction in complications or other adverse clinical health events.

With mobile device access increasing rapidly, mobile access to a patient portal can improve the convenience of using the portal to manage health care tasks and communicate with health care practitioners. Our previous study2 showed that the addition of mobile portal access was associated with more frequent and timely use of the portal. The convenience of being able to easily order prescription refills from a mobile device was likely directly associated with that study’s findings of improved medication adherence. With use of the portal-based prescription refill function by patients using both a mobile device and a computer increasing 3-fold during the 33-month study, from 7.26% of patients in April 2015 to 21.83% of patients in December 2017, sensitivity analyses suggest an even stronger association of portal refill access with adherence improvements. Our main results focus on overall associations of portal access; however, mobile portal access can support several other self-management behaviors in addition to prescription refills, such as scheduling visits with health care practitioners, tracking laboratory test results over time, and communicating with practitioners through secure messaging. Our overall results suggest that the added convenience of managing care using a mobile device may be contributing to improvements glycemic levels.

Despite the increasing availability of patient portals, most US adults with health insurance were still not using a portal in 2017.22 It is notable that ongoing the federal incentive programs do not require that electronic patient portal access specifically includes mobile-optimized access. In another study in KPNC,22 we reported that patients in ethnic and racial minority groups (ie, Hispanic, Asian, or black race/ethnicity) who lived in lower socioeconomic status neighborhoods or had lower.
medication adherence were significantly more likely to access the portal exclusively using a mobile device. Thus, adding mobile portal access may be an important gateway for reaching and improving care for patients with the highest clinical need, limited health care engagement, or other barriers to care. Our findings of improvements in adherence and glycemic levels for patients with diabetes associated with mobile portal access suggest that programs designed to increase access to portals should consider explicitly requiring that portals be easily accessible by a mobile device.

Limitations
There are several limitations to this study. Because our study was conducted in a large, integrated delivery system with a diabetes registry and disease management programs, baseline levels of medication adherence and glycemic control were relatively high, which may offer a conservative estimate of potential associations of mobile portal access with medication adherence and glycemic control in other settings without such active outreach. Our results may not be generalizable to health care settings where access to information, clinical guidance, and pharmacy services is more fragmented. Also, while medication adherence measured by medication dispensed cannot guarantee which medications were actually used by patients, our findings of concurrent improvements in HbA1c levels confirm physiological improvements in diabetes control. Furthermore, although our study design and analytic approach were designed to account for time-stable (eg, medication-use behavior, health and diabetes-management engagement, and technology-use preferences, which likely vary among patients regardless of any patient portal technology) and time-varying characteristics (eg, care complexity and health care utilization), unmeasured confounders cannot be ruled out in this observational study. For example, it is possible that some patients had changes in their management practices, such as enrolling in a disease management program during the study, which we were unable to capture or adjust for in our models. Additionally, based on our outcomes, we excluded patients who did not have any oral diabetes medications filled during the baseline period and those without any HbA1c test results from our analyses on changes to HbA1c levels, which limits our study’s generalizability for patients without these measures. Notably, this study is the largest study to evaluate the association of mobile health with outcomes for patients with diabetes, to our knowledge. Still, future studies should continue to examine the role of mobile portal access in self-management behaviors and health outcomes, including downstream adverse clinical events.

Conclusions
This cohort study found that adding mobile portal access was associated with increased adherence to oral diabetes medications and lower HbA1c levels for patients with diabetes. These improvements were greater among patients with higher clinical need. Overall, our findings suggest that convenient access to patient portal tools for self-management through a mobile device could help patients with diabetes manage their health and improve outcomes.

ARTICLE INFORMATION
Accepted for Publication: December 19, 2019.
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Corresponding Author: Ilana Graetz, PhD, Rollins School of Public Health, Department of Health Policy and Management, Emory University, 1518 Clifton Rd NE, GCR, Ste 636, Atlanta, GA 30322 (ilana.graetz@emory.edu).
Author Affiliations: Rollins School of Public Health, Department of Health Policy and Management, Emory University, Atlanta, Georgia (Graetz); Kaiser Permanente Division of Research, Oakland, California (Huang, Muelly, Fireman, Reed); Mongan Institute, Department of Medicine, Massachusetts General Hospital, Boston (Hsu); Department of Health Care Policy, Harvard Medical School, Boston, Massachusetts (Hsu).
Author Contributions: Drs Reed and Huang had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Concept and design: Graetz, Huang, Hsu, Reed.

Acquisition, analysis, or interpretation of data: Graetz, Huang, Muelly, Fireman, Reed.

Drafting of the manuscript: Graetz, Fireman.

Critical revision of the manuscript for important intellectual content: Graetz, Huang, Muelly, Hsu, Reed.

Statistical analysis: Huang, Muelly, Fireman, Reed.

Obtained funding: Graetz, Reed.

Administrative, technical, or material support: Graetz, Reed.

Supervision: Muelly, Hsu, Reed.

Conflict of Interest Disclosures: Dr Huang reported receiving grants from the Agency for Healthcare Research and Quality (AHRQ) during the conduct of the study. Dr Hsu reported consulting for Cambridge Health Alliance, Community Servings, University of Southern California, and Delta Health Alliance and receiving grants from the National Institutes of Health and the AHRQ. Dr Reed reported receiving grants from the AHRQ during the conduct of the study. No other disclosures were reported.

Funding/Support: This study was supported by a grant from the National Institute of Diabetes and Digestive and Kidney Diseases (grant RO1DK085070; Dr Reed).

Role of the Funder/Sponsor: The funders had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

REFERENCES


**SUPPLEMENT.**

*eFigure.* Portal E-Refill Access Status

*eTable 1.* Adjusted Changes in Percentage of Days Covered for Oral Diabetes Drugs Associated With Portal Access Overall and Stratified by Baseline Glycated Hemoglobin A1c Level

*eTable 2.* Adjusted Changes in Percentage of Days Covered for Oral Diabetes Drugs Associated With Portal E-Refill Access Overall and Stratified by Baseline Glycated Hemoglobin A1c Level

*eTable 3.* Adjusted Changes in Glycated Hemoglobin A1c Level Associated With Portal Access Overall and Stratified by Baseline Glycated Hemoglobin A1c Level