

The impact of a comprehensive electronic patient portal on the health service use: an interrupted time-series analysis

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Background: There is little empirical research on the potential benefit that electronic patient portals (EPP) can have on the care quality and health outcomes of diverse multi-ethnic international populations. The purpose of this study is to determine the extent to which an EPP was associated with improvements in health service use. **Methods:** Using a quasi-experimental interrupted time-series approach, we assessed health service use before (April 2012–September 2015) and after (October 2015–December 2016) the implementation of a comprehensive EPP at four hospitals in Madrid, Spain. Primary outcomes were number of outpatient visits, any hospital admission, any 30-day all-cause readmission and any emergency department visit. **Results:** Implementation of the EPP was associated with a significant decline in readmissions. Among patients with chronic heart failure, EPP implementation was associated with a significant decline for all outcome measures, and among patients with COPD, a decline in all outcomes except readmissions. Among patients diagnosed with malignant hematological diseases, no significant changes were identified. **Conclusions:** EPPs hold promise for reducing hospital readmissions. Certain patient populations with chronic conditions may differentially benefit from portal use depending on their needs for communication with their providers.

Introduction

In *Crossing the Quality Chasm*, a report that draws attention to and provides means for addressing healthcare quality, the Institute of Medicine recommends patients receive timely access to medical information so as to improve care quality and reduce medical errors.¹ This call for increased transparency, along with the continued development of and investment in health information technology, the availability of internet-enabled mobile devices and the increased use of electronic health records, have contributed to many healthcare organizations developing electronic patient portals (EPP). These healthcare-related online applications allow patients to communicate with their providers and access sections of the medical record, such as immunizations, laboratory results and radiography.^{2,3} Other EPPs provide secure messaging capabilities, the ability to refill medication and schedule medical appointments.⁴ Patient portals may improve healthcare as they provide patients with timely, high-quality data that can better inform them of their health status, which may result in educated decisions about their healthcare.⁵

Access to clinical information may help patients uncover salient aspects of their health, which can lead to the formulation of

important questions and more nuanced patient–provider interactions.^{6,7} Successful encounters between patient and providers may help establish a strong therapeutic alliance and promote shared decision making (SDM). There is evidence that suggests that patients engaging in SDM may be more satisfied with their healthcare, adhere to treatment regimens and report improvements in health status.⁸

The evidence on the effectiveness of EPPs is mixed. On the one hand, access to a comprehensive patient portal may help persons with chronic conditions prevent adverse events and successfully monitor their ailment. In an evaluation of an EPP for diabetic patients, researchers found use of the secure messaging function (a tool used to securely communicate with clinical staff via electronic text messages) was positively associated with patients' glycemic control.⁹ Improvements in statin adherence, and subsequent decreases in low-density lipoprotein, have also been seen among diabetic patients who used the refill function (a tool used to reauthorize existing medication prescriptions) in their portal,¹⁰ an intervention with significant potential for reducing the risk of heart disease and kidney failure.¹¹ On the other hand, evidence gathered by systematic reviews highlight numerous studies finding no

association or mixed results linking patient portal use with service use^{12,13} and other disease-related outcomes. The number of available studies on patient portals remains low⁴ and our study adds to this literature.

Investment in EPPs may lead to changes in service use. Individuals who used portals, relative to non-users, had a significant increase in the rate of clinic office visits, telephone encounters, after-hour clinic visits, hospitalizations and emergency department visits.¹⁴ Although no clear evidence is available,⁷ a positive association could exist between greater portal functionality and service use. For example, users of portals that provided tailored service recommendations and educational resources, in addition to patient clinical information, accessed preventive services at greater rates than non-users.¹⁵

The majority of peer-reviewed literature on EPPs have been descriptive, focusing on use statistics, patient engagement or satisfaction.¹⁶ Little research extends to the impact of portals on healthcare use. Existing service use research is mixed and has predominately emanated from the United States.¹⁷ It is critical to elucidate the impact of patient portals on diverse multi-ethnic international populations to understand the potential benefit of this technological advancement on care quality and health outcomes. Our study extends the current body of literature in two ways: (i) evaluating the impact of an innovative and comprehensive EPP; and (ii) focusing on a large Spanish-speaking population seeking services within a Madrilenian safety net healthcare system. Using a quasi-experimental approach with administrative data, we determine the extent to which an EPP affected the health service use of patients receiving medical care within a hospital setting. Drawing from Andersen's framework of access to medical care,^{18,19} we consider the EPP as an enabling factor that increases the likelihood of access to healthcare by providing greater availability of information and services to the patient with the potential of eliminating commonly experienced barriers to care such as long wait times and lack of transportation. We thus hypothesize that the introduction of a portal will increase the rate of outpatient service use and decrease the rate of hospitalization and emergency department use.

Methods

Participants

Study sites were a purposive sample of four hospitals, located in the metropolitan area of Madrid, Spain, operating under the Madrilenian Health System (Servicio Madrileño de Salud) that implemented a pilot EPP program. Three sites were public and not-for-profit while one site was private and for-profit. Hospitals ranged in size from small (<250 beds) to large (>500 beds) with two sites serving as teaching hospitals (Supplementary Appendix S1). Data for this evaluation were extracted from the administrative databases of the four study sites and spanned April 2012 through December 2016.

The patient population was comprised of Spanish citizens and legal residents who obtained health insurance through Spain's universal healthcare system. Each beneficiary was automatically assigned to a hospital system based on their residential address. Only patients who received services at one of the four study sites were eligible to access the EPP ($N=909\ 724$). Six months prior to the portal's release (April 2015), there was a widespread advertising campaign publicizing portal capabilities and functionality. Promotional activities and materials included handouts, waiting room posters, clinical and medical staff recommendations, announcements on the hospital websites, an instructional online video²⁰ and word of mouth.

Intervention

The EPP, a platform that is directly linked to a patient's electronic health record, allows users to access their healthcare information and

facilitates communication with their medical providers, across all hospital settings and departments. Specifically, patients can (i) view and modify their patient profiles (i.e. address, phone number and e-mail); (ii) schedule and/or manage appointments by remotely accessing their hospital's scheduling system to make, cancel or reschedule appointments for non-urgent services; (iii) view curated medical records (i.e. laboratories, x-rays, sonograms and prescriptions); (iv) directly message healthcare staff (i.e. nurses and physicians); (v) videoconference with a medical professional; and (vi) upload personal diagnostics (i.e. blood glucose levels from a personal blood glucose meter). Patients could access the portal through a password-protected site on their personal computers (desktop/laptop), internet-capable mobile phones and tablets. Each patient could personalize their portal experience based on their medical needs and preferences.

Variables

The electronic health record data used in the analysis included patient demographics (age and sex), admission type (outpatient, inpatient, and emergency), admission date, primary diagnosis at admission and diagnosis-related group codes. Outcomes were any hospitalization, any emergency department use, any 30-day all-cause readmission and number of outpatient visits. In sub-group analyses, we assessed service use outcomes among patients with a primary diagnosis for malignant hematological disease, chronic obstructive pulmonary disease (COPD) and chronic heart failure (CHF); variables were selected based on their prevalence within study sites as well as data reliability and availability. The primary covariates of interest (see model below) are an indicator for patient portal exposure (0=before portal initiation and 1=after portal initiation), a time variable representing months since the start of the study period and an interaction between patient portal exposure and number of months after portal initiation (the latter variable is set to zero before portal initiation and tracks the number of months after portal initiation).

Statistical analysis

An interrupted time-series design was used to evaluate the impact of the EPP on health service use. This analytic approach is considered a strong quasi-experimental research design²¹ that accounts for auto-correlation, baseline levels and outcome trends.²² Pre-period observations and trends act as controls for post-period observations. In this study, pre-intervention period trends (April 2012–September 2015) allow for the creation of counterfactual post-intervention period values (October 2015–December 2016) against which the actual post-period values are compared. At equally spaced monthly intervals, between April 2012 and December 2016, service use was measured in the aggregate for all four study sites. We used an algorithm developed by Linden (2015) to run our single-group interrupted time-series analyses.²³ We estimated the following model:

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

\hat{Y}_t is our health service use outcome measured monthly, T_t represents months since the start of the study period, P_t is an indicator of portal exposure, $P_t T_t$ is an interaction that represents months since the portal initiation and ε_t is the error term. A statistically significant effect estimate for β_2 (intercept) would indicate an immediate portal effect on outcomes; while, a statistically significant β_3 (change in slope from pre- to post-periods, and the main parameter of interest) suggests a portal effect over time. Due to consistent increase in acute service use within this hospital system, we focused on slope change as opposed to level shift.

We used Newey–West²³ standard errors to account for heteroscedasticity and autocorrelation. We performed the Cumby–Huizinga

Table 1 Baseline characteristics of the patient population at four hospitals implementing an EPP: Madrid, Spain (April 2012–October 2015)

Population characteristics	FJD	HRJC	HIE	HGV	Study population
Population, N	472.912	210.327	155.863	70.622	909.724
Age, mean (SD)	44.0 (22.7)	41.5 (23.8)	37.8 (23.1)	41.2 (24.0)	42.1 (23.2)
Female, n (%)	267 715 (56.6)	114 456 (54.4)	82 648 (53.0)	39 586 (56.0)	504 405 (55.4)
Country of origin					
Spain, n (%)	357 937 (75.69)	179 971 (85.6)	130 970 (84.0)	57 357 (81.2)	726 235 (79.8)
Autonomous Community of Madrid, n (%)	212 547 (44.9)	123 990 (58.9)	92 994 (59.6)	41 272 (58.4)	470 803 (51.7)
Other Spanish regions, n (%)	145 390 (30.7)	55 981 (26.6)	37 976 (24.4)	16 085 (22.8)	255 432 (28.1)
Other countries, n (%)	87 256 (18.4)	27 123 (12.9)	22 192 (14.2)	12 400 (17.6)	148 971 (16.4)
Outcomes					
At least one hospitalization, n (%)	280 506 (59.3)	90 676 (43.1)	54 055 (34.7)	32 189 (45.6)	457 426 (50.3)
At least one 30-day all-cause readmission, n (%)	217 128 (45.9)	61 481 (29.2)	36 210 (23.2)	27 274 (38.62)	342 093 (37.6)
At least one emergency department visit, n (%)	404 762 (85.6)	190 001 (90.3)	136 545 (87.61)	66 441 (94.1)	797 749 (87.7)
At least one outpatient visits, n (%)	461 421 (97.6)	206 030 (98.0)	153 955 (98.8)	68 660 (97.2)	890 066 (97.8)
Medical conditions (n = 577 121)^a					
COPD, n (%)	3893 (0.8)	963 (0.5)	713 (0.5)	246 (0.3)	5815 (0.6)
CHF, n (%)	2513 (0.5)	962 (0.5)	520 (0.3)	266 (0.4)	4261 (0.5)
Malignant hematological disease, n (%)	802 (0.2)	234 (0.1)	158 (0.1)	37 (0.1)	1231 (0.1)

FJD, Hospital Universitario Fundacion Jimenez Diaz; HRJC, Hospital Universitario Rey Juan Carlos; HIE, Hospital Infanta Elena; HGV, Hospital General de Villalba.

a: Medical conditions were identified using DRG or ICD codes (only available when a hospitalization had previously occurred).

test,²⁴ plotted the residuals and the partial autocorrelation function to test for autocorrelation and to determine the number of time-series lags. Outcome stationarity was evaluated via the Kwiatkowski, Phillips, Schmidt and Shin test,²⁵ the augmented Dickey–Fuller test,²⁶ and the Phillips and Perron test.²⁷ When first-order autocorrelation of the errors was detected, we used Prais–Winsten regression models.^{23,28} Fourier terms were included into regression models to account for seasonal effects.²⁸ We checked the robustness of our findings empirically and graphically; one, iteratively evaluating each pre-intervention period as a mock start period; two, graphically plotting and determining the linearity of the pre-intervention outcome trend. Sub-group analyses were conducted to assess the extent to which individuals with malignant hematological diseases, COPD and CHF may have been differentially impacted by the patient portal.

Results

A total of 909 724 patients had access to the EPP (table 1). The patient population was predominately Spanish born (80%), on average 42 years of age, and comprised of 55% females. In the pre-intervention period (April 2012–October 2015), 50% of patients experienced at least one hospitalization, 38% experienced at least one all-cause readmission within 30-days of hospital discharge, 88% had at least one emergency department visit and 98% had at least one outpatient visit for any cause.

We hypothesized that use of the EPP would lead to a decrease in hospitalizations, 30-day all-cause readmissions, emergency department use and an increase in outpatient service use. In our interrupted time-series analyses, the rate of hospital admissions decreased by 0.44/10 000 per month (5.28/10 000 per year) in the post-intervention period, a marginally significant decline compared with the pre-intervention period ($b = -0.22$; $P = 0.07$). The rate of 30-day all-cause readmission decreased by 0.44/10 000 per month (5.2/10 000 per year) after the implementation of the EPP. This was a greater and statistically significant decline compared with the pre-intervention period ($b = -0.05$; 95%CI -0.07 to -0.02). The rate for any emergency department use decreased by 1.14%/10 000 (13.68/10 000 per year), a marginally significant decline compared with the pre-intervention period ($b = -1.32$; $P = 0.055$) (figure 1C). There was no significant change in the rate of outpatient visits (figure 1D). See Supplementary Appendix S2 for exact estimates of

the pre-intervention slopes and change in slope in the post-intervention period.

In sub-group analyses of patients diagnosed with CHF (table 2, panel 1), the EPP was associated with a significant decline in the slope for all outcome measures: any hospitalizations ($P < 0.01$); any 30-day all-cause readmission among those diagnosed with CHF ($P < 0.05$); any emergency department use ($P < 0.01$); and any outpatient service use ($P < 0.05$). Among patients diagnosed with COPD (table 2, panel 2), there was a significant decline in slope for any hospitalizations, and emergency department use and any outpatient service use (all $P < 0.01$), but no change in hospital readmissions. Among patients diagnosed with malignant hematological diseases (table 2, panel 3), there were no significant changes in slope for any hospitalization, emergency department visit, readmission or outpatient service use.

Discussion

In October of 2015, four hospitals belonging to the Madrilenian Health System in Madrid, Spain, initiated a comprehensive EPP that allowed patients to access vital clinical information, upload pertinent medical information and directly communicate with their providers via secure messaging or videoconferencing. Our analyses demonstrate that the EPP was able to significantly decrease the slope of rates for 30-day all-cause readmission and a marginally significant decline in emergency department use and hospitalization. Similar declines in acute healthcare utilization were identified among individuals with CHF and COPD.

Contrary to our hypothesis, EPP was not associated with an increase in outpatient visit rates. The current literature is mixed on the impact of patient portals on outpatient service use. Several systematic reviews reported portal use resulted in a decrease in office visit rates,^{4,13} while other studies suggested individuals who used portals increased their rates of clinic office visits, after-hour clinic visits and preventive services.^{14,15} Exposure to laboratory results, electronic communication via secure messaging and videoconferencing, and/or the ability to upload and discuss patient-initiated measures in the portal under study, may have acted individually or synergistically, to keep patients from seeking outpatient care until their next regularly scheduled appointment. Analysis of the ways in which the EPP was used and the regularity of messaging and videoconferencing is needed to better understand their effects

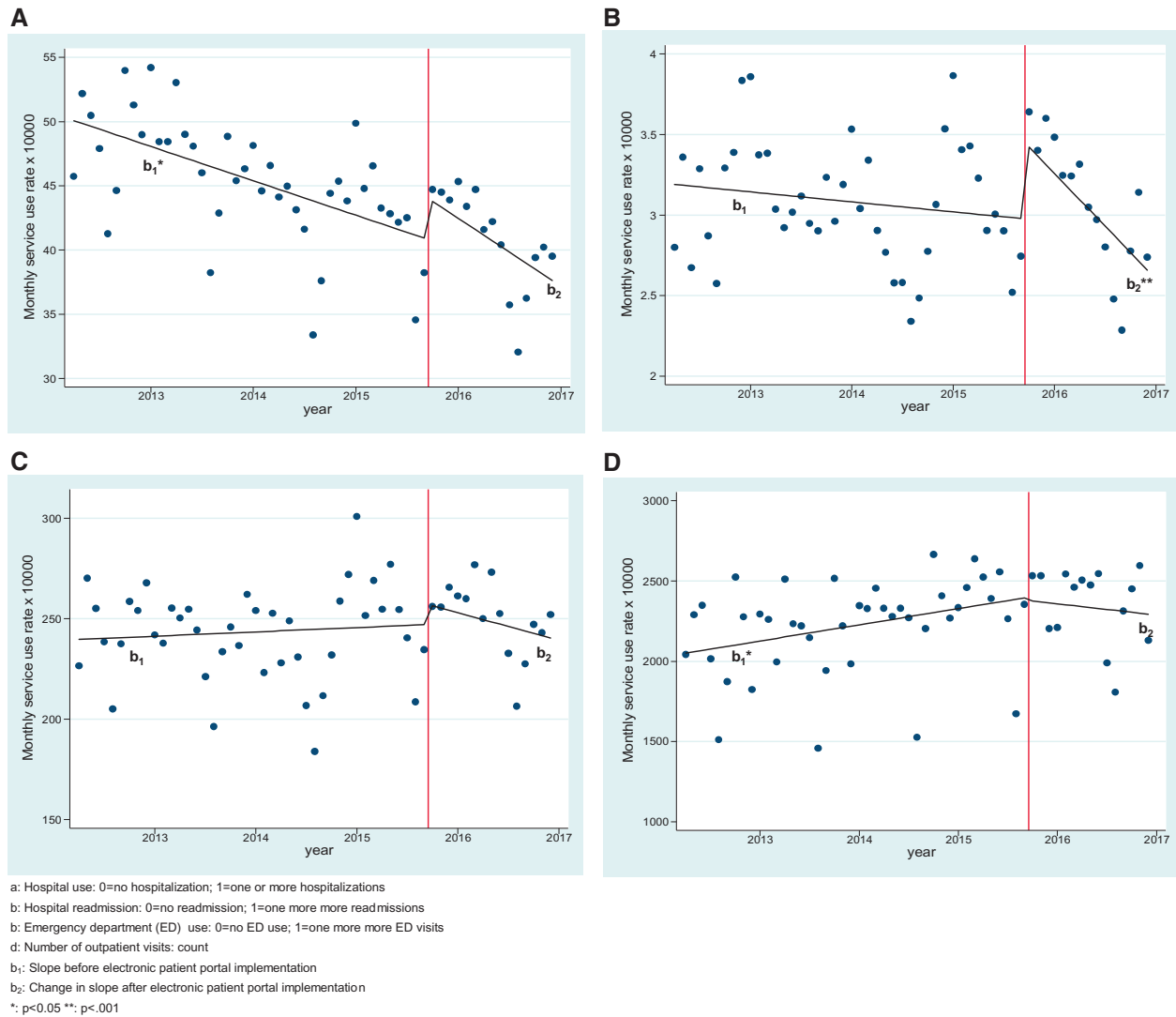


Figure 1 Hospital use before and after introduction of an EPP: Madrid, Spain (April 2012–December 2016). (A) Hospital admission^a, (B) 30-day all-cause hospital readmission^b, (C) emergency department visit^c, (D) number of outpatient visits^d.

on service use and shed light on the additional time spent by providers in these internet-based interfaces.

Sub-group analyses revealed that outpatient visits for those with CHF and COPD declined as did acute care utilization measures (with the exception of hospital readmissions for COPD). These results are contrary to prior studies that found no differences in ED use, hospitalization and outpatient service use among portal users with similar chronic conditions.^{29,30} However, research by Kruse and colleagues suggests that patient portals can improve patient satisfaction, empowerment and lead to better patient–provider communication, which may indirectly reduce service use.³¹ Significant reductions in outpatient visits for individuals with these chronic conditions suggest that direct access to clinicians and personal health information may have replaced the need for an in-person outpatient visit, potentially eliminating transportation barriers to care and other barriers that encumber the in-person visit.

An important finding was that the EPP led to no changes in service use for persons with a malignant hematological disease, evidence that enhanced access to medical information and communication capabilities may already have been put in place for persons experiencing these severe disorders. The majority of EPP research has primarily focused on the primary care setting,^{31,32} consequently focusing on a population with relatively moderate health conditions.

It is unclear whether EPP can influence acute care utilization among persons with hematological diseases that often require intensive treatment. Though, evidence suggests cancer patients are 10–12 times more likely than the general population to use EPP.³³ To date, there are no studies that assess EPP impact on service use among cancer patients,^{34,35} existing literature has focused on cancer patient's portal use.³³ Future research should assess the utility of patient portals among patients with similar disorders. This may yield ideas for a more expansive, user-friendly portal interface that can further enhance patient-centred care and improve costly service use.^{28,36}

The strength of our conclusions is limited by the possibility that unobserved events may have spuriously influenced our outcomes. First, while the interrupted time-series design is more robust than a simple pre-post design, as it adjusts for pre-intervention trends, there remains the possibility that other unobserved interventions may have had a similar trajectory in the pre-period. Second, because we lack data on which patients actually logged in and used the portal, our analysis assessed the impact of the initiation of the EPP on the overall patient population, as opposed to analyzing outcomes for those who used the EPP. This method addresses potential selection bias given that users may differ on important characteristics from non-users, but also leads to

Table 2 Trends in monthly service use before and after the implementation of an EPP: Madrid, Spain (April 2012–December 2016)^{a,b}

Service use outcomes	Slope before EPP ^c implementation ^b (SE)	Change in slope after EPP implementation ^b (SE)
CHF^d		
Any hospital admission	0.86* (0.40)	-4.22** (0.73)
Any 30-day all-cause hospital readmission	0.59** (0.17)	-1.54* (0.60)
Any emergency department visit	0.62 (0.68)	-5.79** (1.19)
Number of outpatient visits	0.001* (0.001)	-0.005* (0.002)
COPD^e		
Any hospital admission	1.33** (0.31)	-4.38** (0.66)
Any 30-day all-cause hospital readmission	0.33* (0.10)	-1.07 (0.59)
Any emergency department visit	2.27** (0.45)	-5.08** (1.26)
Number of outpatient visits	0.02** (0.0002)	-0.004** (.001)
MHD^f		
Any hospital admission	-1.77* (0.56)	-1.46 (1.75)
Any 30-day all-cause hospital readmission	-0.17 (0.18)	0.15 (0.86)
Any emergency department visit	-1.54* (0.69)	-0.69 (2.69)
Number of outpatient visits	0.009* (0.001)	-0.008 (0.009)

a: Any service use outcomes were treated as dichotomous (0/1); number of visits was a count variable.

b: Newey–West standard errors.

c: Electronic patient portal.

d: Coronary heart failure.

e: Chronic obstructive pulmonary disease.

f: Malignant hematological diseases.

*: $P < 0.05$.

** : $P < 0.001$.

estimates that are conservative and biased in a downward direction. Future studies using data on EPP use, and the number and types of use, will allow us to investigate whether the impact on service utilization was greater for portal users and whether users differed in important characteristics from non-users. Third, while the data come from a healthcare system that is similar to other safety net institutions in Spain, our findings may not be generalizable to other settings and our evaluation should be considered as a case study of an EPP implemented in a real-world setting. Fourth, longer term follow-up studies are needed to provide time for full diffusion of the EPP to the healthcare system's patient population. Fifth, the exact date of EPP initiation varied by approximately 1 month across sites which may have caused a small level of misclassification bias in our estimates. Sixth, the electronic health records did not have measures of socioeconomic status (SES). The interrupted time series design controls for confounding due to SES, except in the unlikely event that patient distributions of SES were significantly altered at the time of intervention initiation.

Despite these limitations, our study demonstrates preliminary evidence on the effectiveness of an enhanced EPP. The ability to message and videoconference with providers, access health information, and upload salient, real-time health information, holds promise as a patient-centred intervention for improving treatment and preventing acute onset of symptoms. Future research on EPP implementation should place an emphasis on different patient population, barriers and facilitators of portal use, the influence of contextual factors, such as organizational and provider characteristics, and specialty care settings.

Public health implications

EPPs can eliminate many of the commonly experienced healthcare access barriers, such as transportation, childcare or employment-related time conflicts. The removal of access barriers can lead to improvements in patient satisfaction, health outcomes and reductions in healthcare expenditures. As patient portals become more commonplace, healthcare providers will undoubtedly spend more time tending to online communication and videoconferencing. Barriers to care will likely shift to include those pertinent to using a patient portal, such as access to the internet, personal computers and internet-enabled mobile devices. These barriers will undoubtedly be

influenced by age, socioeconomic status and technological literacy. Continued monitoring and assessment by public health researchers of the effectiveness of these new modes of treatment delivery, and how they impact underserved populations, will be necessary.

Our findings can guide the development of future EPPs, both locally and internationally. Results can inform hospital administrators, healthcare providers, policy makers and other stakeholders on the potential benefit of an innovative internet-based patient portal that possessed messaging and videoconference applications, allows patients to upload vital health information, and enables patients to schedule/manage medical appointments.

Supplementary data

Supplementary data are available at *EURPUB* online.

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Conflicts of interest: None declared.

Key points

- EPPs can eliminate many of the commonly experienced healthcare access barriers.
- The removal of access barriers can lead to improvements in patient satisfaction, health outcomes and reductions in healthcare expenditures.
- Public health research should continue to monitor and assess the effectiveness of this new mode of treatment delivery.

- Our findings can inform hospital administrators, healthcare providers, policy makers and other stakeholders on the potential benefit of an innovative internet-based patient portal that possessed messaging and videoconference applications, allows patients to upload vital health information, and enables patients to schedule/manage medical appointments.

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