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Characterization and Representation of Patient Use of Virtual Health Technology in Primary Care

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CHARACTERIZATION AND REPRESENTATION OF
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VIRTUAL HEALTH TECHNOLOGY IN PRIMARY CARE

BY

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CHARACTERIZATION AND REPRESENTATION OF PATIENT USE OF VIRTUAL HEALTH TECHNOLOGY IN PRIMARY CARE

By

Wen-Jan Tuan

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Purpose. Advances in virtual care technology have made healthcare more convenient and accessible. The goal of this study was to elucidate current patient portal behaviors by examining the pattern of time and service type use of patients, via data provided by access logs within electronic health records, to increase communication and care coordination through online healthcare portals.

Methods. We conducted a retrospective study of patients in an academic healthcare center over a 5-year period using access log records in electronic health records (EHR). Dimensionality reduction analysis was applied to group portal functionalities into more interpretable and meaningful feature domains, followed by negative binomial regression analysis to evaluate how patient and practice characteristics affected the use of each feature domain.

Results. Patient portal usage was categorized into four feature domains: messaging, health information management, billing/insurance, and resource/education. Individuals having

more chronic conditions, lab tests or prescriptions generally had greater patient portal usage. However, patients who were male, elderly, in minority groups, or living in rural areas persistently had lower portal usage. Individuals on public insurance were also less likely than those on commercial insurance to use patient portals, though Medicare patients showed greater portal usage on health information management features and uninsured patients had greater usage on viewing resource/education features. Having Internet access only affected the use of messaging features, but not other feature.

    Conclusions. Efforts in enrolling patients in online portals does not guarantee patients using the portals to manage their health. While promoting the use of virtual health tools as part of patient-center care delivery model, primary care clinicians need to be aware of technological, socioeconomic, and cultural challenges faced by their patients.

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CHAPTER I

INTROUDCTION

1.1 Background and Need

The cost of healthcare in the United States has continued to rise over the past decades. In 2017, total healthcare spending was 3.5 trillion dollars, which was 2.5 times more than the nation's healthcare spending in 2000 (CMS, 2018). Healthcare costs also account for a large share of the nation's gross domestic product (GDP). The overall medical spending in 2017 comprised 17.9% of the country's GDP and is expected to reach about 19.7% of the nation's GDP in 2026. The healthcare spending per capita of the United States was nearly twice as much as the other high-income countries (Papanicolas, Woskie, & Jha, 2018). The total amount of US spending on medical care is equivalent to the size of the fifth largest economy of the world. Nonetheless, life expectancy in the U.S. is among the lowest when compared to other developed countries (Fenelon, Chen, & Baker, 2016; WHO, 2015). The United States has also performed poorly in health care insurance coverage and health outcomes.

The cause of those increased costs and shortfalls in patient outcomes are complex and multifaceted. The literature shows that the U.S. healthcare system tends to emphasize the consequences of disease (e.g., impairment, disability) and recovery efforts (Bradley & Taylor, 2013; Nash, Fabius, Skoufalos, Clarke, & Horowitz, 2016). This drives the healthcare industry to develop elaborate and over-utilized treatment plans that are often expensive but may not address the underlying cause of the disease. Moreover, while focusing on the advances in medical interventions, our healthcare systems have failed to take into consideration the

emergence of new diseases or health determinants related to global urbanization and post-industrial evolution.

Yet, health is more than health care. The health of a population is driven by biological, behavioral, and societal influences (Kindig & Stoddart, 2003). Prior to the mid-20th century, the causes of illness and deaths among most of the world's population were mainly attributed to infectious diseases. Those illnesses were often acute, contagious, and fatal. Since the late 20th century, the causes of sickness have gradually shifted to cognitive and behavioral factors associated with life styles, consumption patterns, and social environments (Berwick, Nolan, & Whittington, 2008). These diseases tend to be non-communicable and recurring over time, and they often result in long-term disability and poor quality of life. In 2014, an estimated 60% of adults in the United States were chronically-ill, and four in ten adults had two or more chronic diseases (Buttorff, Ruder, & Bauman, 2017). Thus, chronic diseases have become leading drivers of the nation's annual healthcare costs.

1.1.1 Rise of Chronic Disease

Many chronic diseases are preventable through early screenings or adoption of positive health behavior. Unlike treating acute illness, the care of chronically-ill patients requires longitudinal, comprehensive, and heuristic approaches involving collaborative support from both the healthcare and non-healthcare sectors, such as education, finance, insurance, environmental protection, and public safety. A systematic review has shown that chronic disease management and interventions in primary care settings can be cost effective and can achieve desired and sustainable health outcomes at the same time (Goetzel, Ozminkowski, Villagra & Duffy, 2005). To respond to the growing population with chronic diseases, the modern healthcare industry has begun adjusting its focus from specialty care to patient-centered primary care.

Although clinical interventions and preventive care have been proven beneficial to the health of individuals, the effectiveness of the medical intervention can only reach a certain extent. Ultimately, it is up to individuals to take responsibility for their own health. Research has shown that healthcare accounts for less than 20 percent of the healthy outcomes of the population (Remington, Catlin, & Gennuso, 2015). A person' health is primarily affected by life styles, socioeconomic and environmental factors. As clinicians have started recognizing the importance of cognitive and behavioral influences on healthcare outcomes, the contemporary primary care practices are no longer simply to view patients as passive recipients of treatments. Clinicians have begun incorporating care strategies that emphasize behavior change, wellness development, and community support as an integral part of healthcare interventions in primary care practices. An important feature of patient-centered primary care is the application of modern and personalized engagement and communication strategies that promote patient self-care in everyday activities, in concert with clinical care directly rendered in healthcare settings (Remington et al., 2015).

However, asking people to change their habits, beliefs, and behaviors can be challenging. An estimated 60% of patients are not compliant with their treatments, medication regiments, or health goals (Bodenheimer, 2005). People may also not make time or devote effort to preventive screenings and annual physical checkups because of work schedule conflicts, transportation problems, or other competing commitments. To facilitate patient engagement in managing one's own health, various innovative tools have been designed to help patients monitor their health status and motivate new healthy behavior through the use of information technology. These personalized healthcare tools not only empower patients with better self-care capability, but also

enable primary care clinicians to co-manage their patients' health in virtualized and asynchronous fashion.

1.1.2 Emergence of Virtualized Medicine

Advances in health information technology have quickly made virtualized medicine and asynchronous visits a popular care-delivery option in modern healthcare systems (Dorsey & Topol, 2016). Virtual care technology offers new ways to coordinate and deliver primary care services, as many essential care activities have become available through text messaging, mobile apps, video, and remote biosensors. Those innovative methods have brought disruptive changes to the business models of care by making treatments and services more affordable and accessible (Christensen, Waldeck, & Fogg, 2017). These new care technologies are not yet mainstream, but they have shown great promise for increasing patient access while reducing costs in various healthcare contexts.

Research shows virtual care has contributed to better population health management, patient experience, care quality, and cost control in the rapidly evolving healthcare environment (Nagykaldi, Aspy, Chou, & Mold, 2012; Ramsey, Lanzo, Huston-Paterson, Tomaszewski, & Trent, 2018). Such innovations also can improve healthcare access, especially for individuals living in areas with a shortage of health services or for those facing mobility challenges (Gordon, Adamson, & DeVries, 2017). Because it has become a useful complement to traditional visits, virtual care can further strengthen continuity of care practices in primary care settings.

1.1.3 Evolving Consumer Demand

Since the beginning of the new millennium, innovative technologies, such as smart phones and wearable trackers, have changed how people utilize healthcare services. With rapid advancements in cybersecurity and digitalized health tools, modern healthcare organizations are

eager to connect patients to their caregivers so that technology can be effectively used to streamline care processes and preserve provider-patient relationship (Kruse, Frederick, Jacobson, & Monticone, 2017). Likewise, consumers are looking forward to technology-friendly healthcare environments that enable patients to receive medical consults, lab results, and prescriptions electronically. Surveys by the Office of the National Coordinator for Health Information Technology (ONC) have indicated that seven of ten individuals believe that the ability to access their electronic health records (EHR) online is of great value (Patel, Barker, & Siminerio, 2015). About 52% of patients reported being offered online access to their medical records in 2017, compared to 42% of patients offered online access in 2014 (Patel & Johnson. 2018).

Not only do consumers desire easier and more convenient health services through new information technology, Congress also requires that virtualized health technologies be available in every healthcare setting (ARRA, 2009). As part of the federal Electronic Health Records Incentive Program, meaningful use guidelines require healthcare organizations to offer patients the ability to view, download, and transmit (VDT) their health information via online portals or secure e-mail exchanges. Increasingly, we have seen benefits of adopting virtual care in primary care, such as expanding care capacity without rapidly adding more physicians and clinics. The use of virtual care is also estimated to generate $10 billion dollars annually across U.S. healthcare systems (Safavi & Dare, 2018).

1.1.4 Challenges in System Development and Technology Adoption

Developing virtual and asynchronous care capabilities requires robust health information exchange (HIE) infrastructures. HIE provides a set of common standards and protocols that enables the transmission and sharing of essential care information across EHR platforms and

online systems within and outside of healthcare entities. Healthcare organizations expect HIE to provide technological benefits that improve care quality and operational efficiency. However, technological advances do not guarantee healthcare organizations will receive the full benefits of leveraging HIE and virtual care interfaces unless those organizations can address interoperability, analytics, and security challenges effectively (Kash, Baek, Davis, Champagne-Langabeer, & Langabeer, 2017). Thus, system interconnectivity and compatibility have become more important than ever because care deliveries are rendered at multiple venues. Some of the interoperability aspects are recently included in Title III of the 21st Century Cures Act. Aside from better patient communication and care deliveries, one of HIE's biggest benefits is that virtual care interfaces allow clinicians to gather data and generate new insights through research and evaluation.

However, face-to-face patient encounters have long been a core component of conventional care services and, thus, remain highly valued by both patients and physicians. For healthcare organizations typically emphasizing in-person visits, the virtual care movement may cause considerable disruption for existing in-person-based medical practices as well as traditional care delivery models. Prior to 2015, only 10.4 percent of U.S. hospitals had met the meaningful use objective of providing patients with online access (Garrido, Raymond, & Wheatley, 2016). Less than 16% of patients could communicate with their caregivers via e-mail, and only 20 percent could schedule appointments online (Garrido et al., 2016). As technology and federal regulations continue to evolve, it remains to be seen how well primary care clinicians will incorporate new technology and workflows into their practices in the next few years.

1.1.5 Promoting Clinician Involvement

Getting people to adopt the virtual interface can be challenging. One of the major barriers is clinician involvement. We have seen many health IT implementations with a strong focus on technology-driven approaches in recent years. Although implementation strategies are consistent with organizational objectives, many of those technical transformations have failed to account for the culture and social contexts of the healthcare organization (Liberati et al., 2017). Thus, the effectiveness of the implementation process has often been diminished, leading to adoption failure. In too many cases, deploying new information technologies (such as virtual care platforms) involved more than just software/hardware installation. It also required changes in operational processes, which can cause disruption to existing clinical workflows, leading to patient safety issues and losses in productivity (DHHS, 2016; Nambisan, Kreps, & Polit, 2013). Clinicians may also fear being overwhelmed with the number of online messages they could receive, and because they may be doing work for which they are not compensated.

Furthermore, virtual care is a key EHR access requirement for Stage 3 of meaningful use that demands at least 30% of actively-managed patients to communicate clinically relevant messages with their PCPs using online interfaces (CDC, 2017). Essentially, as part of the meaningful use guidelines of the federal Electronic Health Records (EHR) Incentive Program, healthcare organizations are required to offer patients the ability to view, download, and transmit their health information via online portals or secure e-mail exchange. Failure to reach these measures may compromise quality of care and result in payment penalties.

1.2 Problem Statement

Online portals and virtual care are relatively new means of healthcare delivery. Survey results reported by Patel and Johnson in 2018 indicated that most individuals accessed online portals to view their laboratory test results, followed by their medication lists and office visit summaries (see Figure 1). Patient adoption and engagement with virtual care technology have

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gradually increased over time. Healthcare organizations also see the benefits of virtual care and encourage their patients to take advantage of the virtual health technology.

However, the adoption of virtual care can be complicated. While the use of virtualized medicine has been growing in recent years, primary care clinicians have constantly struggled with the challenges of integrating virtual care technology into their day-to-day care practices. The government has worked with healthcare systems and industry advocacy groups to establish incentive programs and value-based reimbursement policies through legislation to stimulate the development of the virtual care applications, yet the lack of interoperability and intuitive user interfaces have prevented both clinicians and patients from engaging with the virtual health technology. Furthermore, although the ONC statistics show that more than half of the patient population in the U.S. had access to various online portal platforms in 2017 (Patel & Johnson, 2018), only a fraction of those patients were effectively utilizing virtual care tools.

Without a doubt, adding new technologies and care venues to the traditional face-to-face care delivery model can be challenging and shouldn't be taken lightly. By learning the usability and acceptability of a new care delivery method in real-world practices, healthcare system leaders and clinicians can gain useful insights into factors that support and impede virtual care adoption. Despite increasing availability of virtual care in the modern healthcare industry, very little is known about how people utilize patient portals and other online applications. For instance, how often do people use virtual care interfaces to schedule appointments and seek medical advice? Which other virtualized health features have been utilized by patients as part of primary care services? Understanding those utilization patterns is important for primary care practitioners to enhance patient engagement in virtual care and achieve better continuity of care. Failure or delays in incorporating virtual care into primary care practice may hinder patient

access and care experiences. It could also potentially harm the healthcare organization's overall care quality and financial stability in the long run.

1.3 Significance of the Current Study

As discussed earlier in this chapter, understanding the access and utilization of virtual care in primary care settings is vital to healthcare systems, clinicians, and governments alike. It is essential that health system researchers identify determinants that affect virtual care adoption and utilization to better comprehend care decision-making processes and, in turn, implement that new knowledge in emergent patient-centered and value-driven healthcare settings. Therefore, this study explores the determinants of online portals and virtual care utilization to improve the use of such measures to enhance (1) the ability of healthcare organizations to provide easy and timely access to essential primary care services; (2) the ability of the state and federal governments to focus policies and funding on more effective interventions from population health management aspects; and eventually, (3) the superior quality and experience of care made available to the consumer and the community, based on newly obtained evidence regarding the efficacy of virtual care strategies.

1.4 Research Objective and Hypothesis

The goal of this research is to bridge gaps in the knowledge of ongoing challenges in access to, and use of, online portals and asynchronous visits in primary care practices. Essentially, the recent virtual care development enables patients to receive care outside of brick-and-mortar medical settings. Commonly-available virtual care functionalities via online portals include online appointments, asynchronous consultations, lab result summaries, disease management, medication refills, and diet/lifestyle coaching. Virtual care promises to help patients become better informed, engaged, and involved in their care. The virtual care technology is also expected to enable clinicians to remain in frequent touch with their patients

by augmenting or even replacing many traditional in-person visits. To gain a better understanding of why and how patients use virtual care interfaces, the first objective of the current study is to explore virtual care functionalities frequently accessed by the patients. Therefore, the alternative hypothesis is described as follows:

H1: The amount of virtual care utilization varies by the functional area of the virtual care interface.

The second objective is to investigate personal, clinical, and system-related factors influencing patients' decisions when utilizing virtual care in primary care settings. Reasons for driving patients' use of virtual care can vary according to individual need and disease condition. This objective allows assessing whether the likelihood of patients utilizing virtual care tools in primary care practice is affected by patient demographics, chronic disease conditions, or other healthcare system characteristics.

H2A: The level of virtual care utilization varies by patient age, sex, race, language, insurance type, and chronic disease condition.

H2B: The level of virtual care utilization varies by clinician practice experience, teaching/community clinic, and urban/rural location.

Understanding the pattern can help clinicians to predict the likelihood that patients will utilize virtual care applications. The knowledge will also help health system leaders assess the impact of virtual care on the quality and outcomes of care, compared to patients who have no or little use of virtual care in primary care settings.

1.5 Population

This study focuses on the virtual care utilization of the adult patients who are actively managed by family physicians at the University of Wisconsin (UW) Department of Family Medicine and Community Health (DFMCH). Adult patients are defined as individuals whose

age is between 18 and 89 years old. To be considered actively managed, patients must have a primary care physician at one of the 18 family medicine clinics and have at least one clinically meaningful interaction (e.g., office visit, phone call, medication refill, MyChart or e-visit) with the health system in the past three years. The analysis will be conducted on de-identified data extracted from the enterprise electronic medical record database (Epic Systems Corporation). The study is considered secondary research and is exempt from the university's Institutional Review Board.

CHAPTER II

LITERATURE REVIEW

2.1 Virtual Care and Asynchronous Care

Advances in information, communication, and decision technologies have enabled the healthcare industry to provide innovative ways to deliver care services through telephones, video, mobile apps, text messaging, online portals, and biosensors. These approaches are often known as telehealth, telemedicine, e-visits, mobile health (mHealth), or virtual health (McGrail, Ahuja, & Leaver, 2017). While those terminologies are interchangeably used in the literature, the present study will generally refer to healthcare activities delivered or communicated in a digitalized form as virtual care. Moreover, the study differentiates virtual care from virtual health because virtual health can involve health activities and information beyond medical care rendered through patients' caregivers or care teams.

Similar to traditional in-person visits, virtual care is comprised of a range of essential care-related activities, such as diagnoses, consultation, and drug prescription. In essence, virtual care can be defined as "any interaction between patients and/or members of their circle of care, occurring remotely, using any forms of communication or information technologies, with the aim of facilitating or maximizing the quality and effectiveness of patient care" (Jamieson et al., 2015, p.2). Operationally, a healthcare encounter is considered a virtual visit when there are clinically meaningful interactions (e.g., medical assessment and consultations) between patients and their caregivers via electronic or phone communication.

Virtual care can occur at anytime and anywhere online or by phone. Despite absence of physical contacts, a virtual visit can occur in either a simultaneous or asynchronous manner. For instance, physicians can perform telemedicine sessions through real-time video interfaces with their patients. Healthcare providers can also respond to patients' health questions via telephone,

messaging, or online portals in an asynchronous fashion. Unlike traditional office visits, virtual care practice is not restricted by time or location, which makes capacity planning and staff allocation more flexible and efficiency. Virtual care has also become the cornerstone of modern digitized health systems.

2.2 Health Policy on Digitized Healthcare

The idea of digitized health systems is not new to medical communities. Prior to 2009, the majority of healthcare providers documented important medical information on paper and shared them via mail or fax machines. This often led to delay in treatments or medical errors. For example, patients treated at an emergency room or a new physician's office without an updated medication list could easily encounter adverse events caused by harmful drug interactions or allergies. It was time-consuming for clinicians and care teams to review patient charts to identify best treatments or interventions for their patients' health conditions. Lack of information transmission capabilities also makes community-level collaborations with public health agencies difficult and inefficient (DHHS, 2016).

The need to replace paper-based health records with advanced health information systems was first outlined by the National Academic of Medicine 17 years ago, due to concerns of using paper-based medical charts, such as inaccurate medical data, poor treatment quality, increased costs, and uncoordinated care (Washington et al., 2017). In 2003, the Institute of Medicine (IOM) made recommendations about eight core care delivery functions that electronic health records (EHR) systems should be capable of performing in order to promote greater safety, quality and efficiency in health care delivery (Institute of Medicine, 2003). The concept of digitized health transformation became one of the top priorities in the national health policy agenda.

The American Recovery and Reinvestment Act (ARRA) was enacted by Congress in 2009 to stimulate our nation's economy. One segment of the ARRA is the Health Information and Technology for Economic and Clinical Health (HITECH) Act. Unlike the ARRA with general policies spanning across energy, education, and tax aspects, the HITECH Act has a specific goal to advocate the development of the national healthcare infrastructure through promoting the use of EHRs and other advanced technologies. For instance, the HITECH Act provides opportunities for the Department of Health and Human Services (DHHS) and its affiliating agencies to lead the nation's health IT transformation through implementing meaningful use (MU) of electronic health records via a broad range of financial incentives over a 10-year period. The mission of the Act is to modernize the nation's healthcare systems so that healthcare can be more efficient and affordable (Washington, DeSalvo, Mostashari, & Blumenthal, 2017).

In essence, the Department of Health and Human and Services (DHHS) serves as the designated administration agency for implementing the HITECH Act (HealthIT.gov, 2018). The Office of the National Coordinator (ONC) for Health Information Technology (established in 2004) at the DHHS is in charge of managing and facilitating the development of the policy goals of the HITECH Act. Congress further allocated $2 billion in discretionary funds for the ONC to form strategies and leadership to support the law (Blumenthal, 2011). The ONC takes on crucial roles in coordinating nationwide efforts to develop various Health IT standards and to exchange protocols, as well as establish guidelines and steps for implementing the federal EHR incentive programs. Two advisory committees are established under the ONC: the health IT Policy committee and the health IT Standards committee. The health IT Policy committee

focuses on designing technical infrastructure, and the health IT Standards committee focuses on the certification of the health IT use (HealthIT.gov, 2018).

To meet the requirement of subtitle A - Promotion of Health Information Technology, the HITECH Act further authorizes the Centers for Medicare and Medicaid Services (CMS) to provide incentive payments to hospitals and clinicians who demonstrate the meaningful use of electronic health records. The EHR incentive programs are administrated through three stages over a 10-year period. Participation in these programs was voluntarily for eligible entities in 2011 and continued on a voluntary basis until 2018 (CDC, 2017). We are currently in the midst of the third stage of the MU implementation. Stage 3 has a strong focus on system interoperability across states and EHR platforms. Approximately $27 billion dollars have been distributed to hospitals and physicians as incentives to adopt certified EHR technology and thus meet meaningful use requirements (DHHS, 2016).

Recognizing the complexity of EHR systems, CMS continues to modify its implementation rules to allow healthcare providers to choose the measures most relevant to their patient population or practice. National statistics shows that more than 500,000 physicians had enrolled in meaningful use programs in 2016 (Halamka & Tripathi, 2017). As of 2015, approximately 87% of office-based physicians had adopted EHRs in their practices (Henry, Pylypchuk, Searcy, & Patel, 2016). That adoption rate had doubled from 42% in 2008 (Figure 1). The adoptions demonstrate HITECH's key success in promoting clinical quality reporting, e-prescribing, and medication reconciliation to improve patient care. Today, the HITECH Act continues to move forward with the meaningful use requirements of EHRs with innovation initiatives and value-based incentive programs.

Certified EHR
Basic EHR

| Year | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |

Certified EHR: 71.9%, 85.2%*, 94%*, 96.9%*, 96%
Basic EHR: 9.4%, 12.2%, 15.6%, 27.6%*, 44.4%*, 59.4%*, 75.5%*, 83.8%*
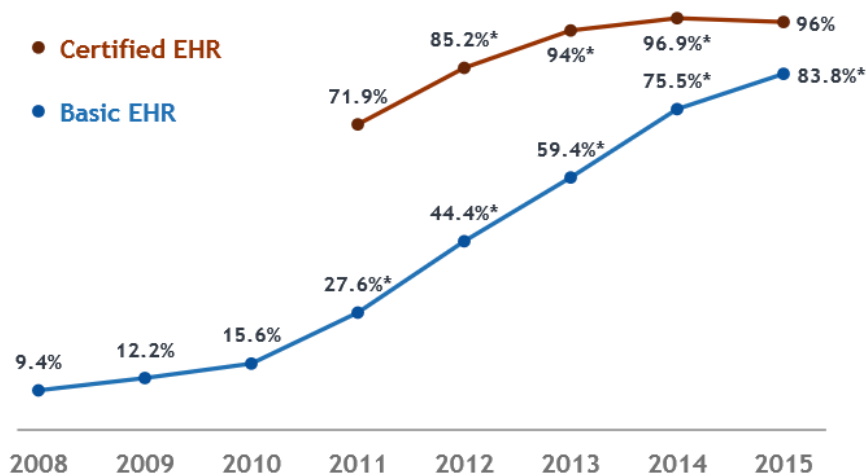
Note. $^*p<0.05$. A certified EHR is EHR technology that meets the technological capability, functionality, and security requirements adopted by the Department of Health and Human Services. Possession means that the hospital has a legal agreement with the EHR vendor, but is not equivalent to adoption. From ONC/American Hospital Association (AHA), AHA Annual Survey Information Technology Supplement

Figure 1, Trend in EHR adoption between 2008 and 2015

2.3 Regulatory Requirements in Providing Patients Access to EHRs

One of the meaningful use objectives is to accelerate the development of health information tools that allow patients to access their electronic medical information via online portals or virtual platforms. Developing virtual care capabilities requires robust health information exchange (HIE) infrastructures. HIE provides a set of common standards and protocols enabling essential care information to be transmitted and shared across EHR platforms and online systems within and outside healthcare entities. Aside from better patient communication and care deliveries, the use of virtual care platforms allows clinicians to gather data and generate new insights through research and evaluation, a significant benefit of HIE

Yet for a healthcare industry typically reliant on brick-and-mortar facilities, this movement can mean significant disruption for clinicians and their practice as well as for traditional care delivery models. Despite growing EHR adoption rates in both the hospital and

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office settings, only 10.4 percent of U.S. hospitals had met the meaningful use objective of providing patients with online access in 2015 (Garrido, Raymond, & Wheatley, 2016). Less than 16 percent of patients could communicate with their caregivers via e-mail, and only 20 percent could schedule appointments online (Garrido et al., 2016). Nonetheless, as mobile communication devices become more advanced and populated, an increasing number of consumers begin looking for virtual health tools to keep them connected to their caregivers.

Providing patients access to the online portal is promulgated as an important EHR access requirement for Stage 1 of meaningful use (CDC, 2017). The second stage meaningful use requires patients to start using some of the virtual healthcare features. An example is to ask primary care providers (PCP) to show that at least 5 percent of their patients are able to communicate clinically relevant messages with their PCPs using the virtual interface. The target will be raised to 35 percent in Stage 3. Failure to reach these measures may compromise quality of care and result in payment penalties

2.4 Increasing Privacy Concerns

Recent advances in information technology have also raised concerns that privacy rules regulated in the Health Insurance Portability and Accountability Act (HIPAA) of 1996 do not provide sufficient protection. As the healthcare industry continues its evolution through regulatory and technological changes, healthcare professionals sense the importance of strengthening their roles as stewards of the privacy and security of patient information (Callahan, 2008). Statistics by ONC (2017) indicate that the majority of individuals feel EHRs are well-protected, but practitioners have concerns when health information is exchanged with providers outside the practitioner's health system (Figure 2).
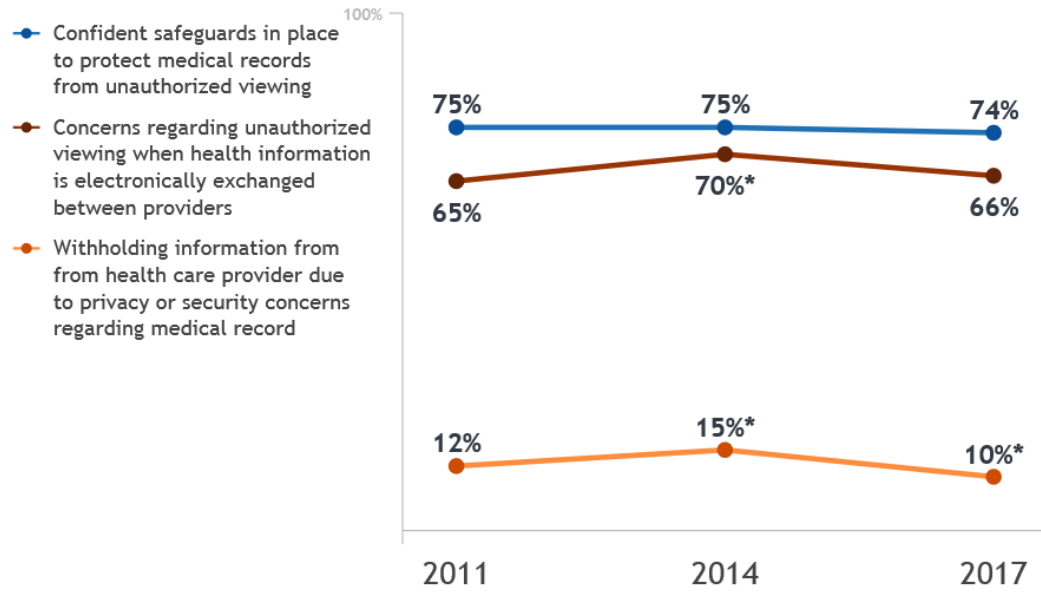
Figure 2. Perceptions of the privacy and security of medical records and health information exchange.

Industrial advocacy groups, such as American Health Information Community (AHIC), Nationwide Health Information Network (NHIN), and National eHealth Collaborative have called for additional regulations to enforce security compliance to protect patient privacy and data confidentiality (Rinehart-Thompson, Hjort, & Cassidy, 2009). The HITECH Act has placed more restricted rules regarding how information can be shared and disclosed for patient care or research purposes. It also requires healthcare systems to develop new policies, procedures, and staff training into infrastructure and governance for both EHRs and virtual care.

2.5 Development of Virtual Care Applications

As mentioned in the previous sections, the increasing usage of virtual care tools, such as patient portals and mHealth apps, can be partially attributed to consumers' growing interest in online applications and wearable devices (Baldwin, Singh, Sittig & Giardina, 2017). A patient portal is defined as a "secure online website that gives patients convenient, 24-hour access to

personal health information from anywhere with an Internet connection" (HealthIT.gov, 2019, para. 1). It is usually an integral part of electronic health record systems maintained by healthcare organizations and their EHR vendors. A basic online portal should provide patients access to their personal health information relating to diagnoses, laboratory test results, medication list, visit summary, and wellness materials. Increasingly, patient portals include interactive capabilities, such as secure email communication or messaging with clinicians, appointment scheduling, health goals, and billing and insurance records. The main goal of the patient portal is to improve how patients and clinicians interact, leading to better care support and patient outcomes (Irizarry, DeVito Dabbs & Curran, 2015). It will serve as an avenue for healthcare systems to offer family support and ongoing education and resources on the disease process and treatment.

Although patient portals are constructed by healthcare organizations mainly for facilitating information exchange and care coordination as an extension of care services, health apps are usually developed to promote social networking and the community experience, with interactive features allowing users to continuously track their activities and compare themselves with friends, family, and the general population on their social network. Compared to most patient portals, mHealth apps seems to be more consumer-centric in design and easier to use (Baldwin et al., 2017). Research indicates that patient portals are designed to store basic health information to enhance information dissemination and care workflows (Baird & Nowak, 2014). They are also created to help healthcare systems and clinicians meet reporting or reimbursement criteria (e.g., meaning use requirements). Thus, the design of the portal interface is often provider-centric rather than patient-centric. Medical information in the patient portal is often fragmented and abstruse from the patient's aspect.

2.6 Benefits of Virtual Care

Virtual care has shown positive impacts on patient health by enabling and stimulating patients to manage and monitor their care. A conscientious primary care physician can monitor physiologic and laboratory data remotely, or delegate staff on a care team to engage in proactive e-mails and other asynchronous communications to replace an office visit or avert emergency room care. The effects of virtual care are especially noteworthy for patients with chronic diseases when the tools are coupled to case management (Otte-Trojel, Rundall, de Bont, van de Klundert, & Reed, 2015; McGrail, Ahuja, & Leaver, 2017). For instance, chronically-ill patients utilizing virtual care services are found with better care outcomes and greater satisfaction because of the flexibility in how, when, and where they interact with their caregivers (McGrail, Ahuja & Leaver, 2017). Patients utilizing virtual care interfaces are more likely to adhere to their appointments and treatment plans, leading to more effective disease management processes.

Research also shows that using virtual care tools to monitor clinical conditions (e.g., vital signs or disease-related parameters) at the patients' home or work significantly reduces mortality rates for individuals with congestive heart failure, stroke, and chronic obstructive pulmonary disease (COPD). However, the strength of the virtual care intervention seems to vary across studies (Ammenwerth, Schnell-Inderst, & Hoerbst, 2012; Franklin, 2013). Due to the lack of comparative effectiveness research to examine the impact of virtual care interventions on patient outcomes, conclusive evidence is needed to support incorporating virtual care technology in patient care, such as secure texting, patient portal or mHealth apps.

Nonetheless, a wide range of virtual care platforms and functionalities have been introduced gradually in primary care practices in the past decade. Increased physicians and patients have embraced online portals and virtual care as part of standard care processes.

Primary care clinicians foresee that virtual care can result in better communication with their patients (Twiddy, 2015). Patients value the ability to interact with caregivers between visits, as well as the convenience of requesting medication and referrals online, leading to greater care quality and patient outcomes (Sorondo, Allen, Fathima, Bayleran, & Sabbagh, 2016). The use of virtual care in primary care practices has shown great potential to enhance continuity of care, which has been a hallmark and primary objective of primary care.

2.7 Continuity of Care

Continuity of care (COC) plays a vital role in achieving higher care quality, better health outcomes, and lower overall medical costs in primary care practices (Jee & Cababa, 2006; Saultz & Lochner, 2005). The American Academy of Family Physicians defines COC as "the process by which the patient and his/her physician-led care team are cooperatively involved in ongoing health care management toward the shared goal of high quality, cost-effective medical care." (AAFP, 2018, para. 1). Primary care teams apply COC's principles to build a long-term, patient-centered partnership through coordinated care that is delivered and managed from a whole-person perspective. The longitudinal nature of COC enables caregivers to acquire a complete view of the patient's medical history, as well as socioeconomic and contextual determinants that affect the patient's ongoing illness and future health (Rosser & Schultz, 2007). Repeated interactions also help patients develop familiarity and trust with their healthcare providers, leading to lasting cooperation and treatment compliance (Tarrant, Dixon-Woods, Colman, & Stokes, 2010). COC has been linked to increased patient adherence with treatments (Freeman, Olesen, & Hjortdahl, 2003), lower hospital and emergency room visit rates (Casalino et al., 2014; Christakis, Mell, Koepsell, Zimmerman, & Connell, 2001), better health outcomes (Saultz & Lochner, 2005), and greater patient engagement and satisfaction (Fan, Burman, McDonell, & Fihn, 2005; Saultz & Lochner, 2005).

The continuity of care practice in primary care has been affected by the adoption of new health information technology in recent years. Rapid advancements in health information technology have made virtual medicine and asynchronous visits a popular care delivery alternative in contemporary healthcare systems (Dorsey & Topol, 2016; Draper & Sorell, 2012). A growing number of traditional primary care services have enabled communication with patients through video, SMS, mobile apps, and remote biosensors. Those innovative methods contribute to better population health management (Ramsey, Lanzo, Huston-Paterson, Tomaszewski, & Trent, 2018), patient experience (Kruse, Argueta, Lopez, & Nair, 2015; Otte-Trojel, Rundall, Bont, Klundert, & Reed, 2015), care quality, and cost control in the rapidly evolving healthcare environment (Nagykaldi, Aspy, Chou, & Mold, 2012; Shane-McWhorter et al., 2014). Such innovations also can improve healthcare access, especially for individuals living in areas with a shortage of health services or patients facing mobility challenges (Gordon, Adamson, & DeVries, 2017; Turner et al., 2015). Virtual care can significantly complement traditional office visits and can further strengthen continuity of care practices in primary care.

2.8 Patient Engagement Framework

Virtual care technology has empowered patients to manage their health and enhance continuity of care in many ways. The literature shows that patient engagement is a crucial component to drive the adoption and utilization of virtual care in primary care setting (Irizarry et al., 2015; Lafata et al., 2018). In a simple sense, patient engagement is any effort to involve a person in his or her own health or health care management. Patients with a greater level of engagement in their health tend to seek information about treatment options, participate in their care decisions, and take action to support care processes (Irizarry et al., 2015). Virtual care through patient portals and mobile apps expands patient-provider communications and care coordination so that people can freely access care information and exchange health concerns in a

timely fashion. It enhances patients' ability to take an active role in their own healthcare

decisions and outcomes.

A patient engagement framework is developed to guide healthcare organizations to

strengthen provider-patient relationships through the use of health information technology and

EHR tools (HIMSS, 2014; Walker, Sieck, Menser, Huerta, & McAlearney, 2017). The

framework consists of a five-stage continuum of strategies and resources to inform, engage, and

empower patients so they can collaborate in and contribute to their care (Figure 3). The first

stage is the "Inform Me" phase, which requires healthcare organizations to provide simple tools

making healthcare more convenient and accessible for patients. For instance, patients are given

access to health information from their electronic medical records through patient portals. The

information also can include provider biographies, facility locations, and service instructions that

can help patients better prepare for their visits.

PATIENT ENGAGEMENT FRAMEWORK

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HIMSS Patient Engagement Framework. (Feb 2014) 18
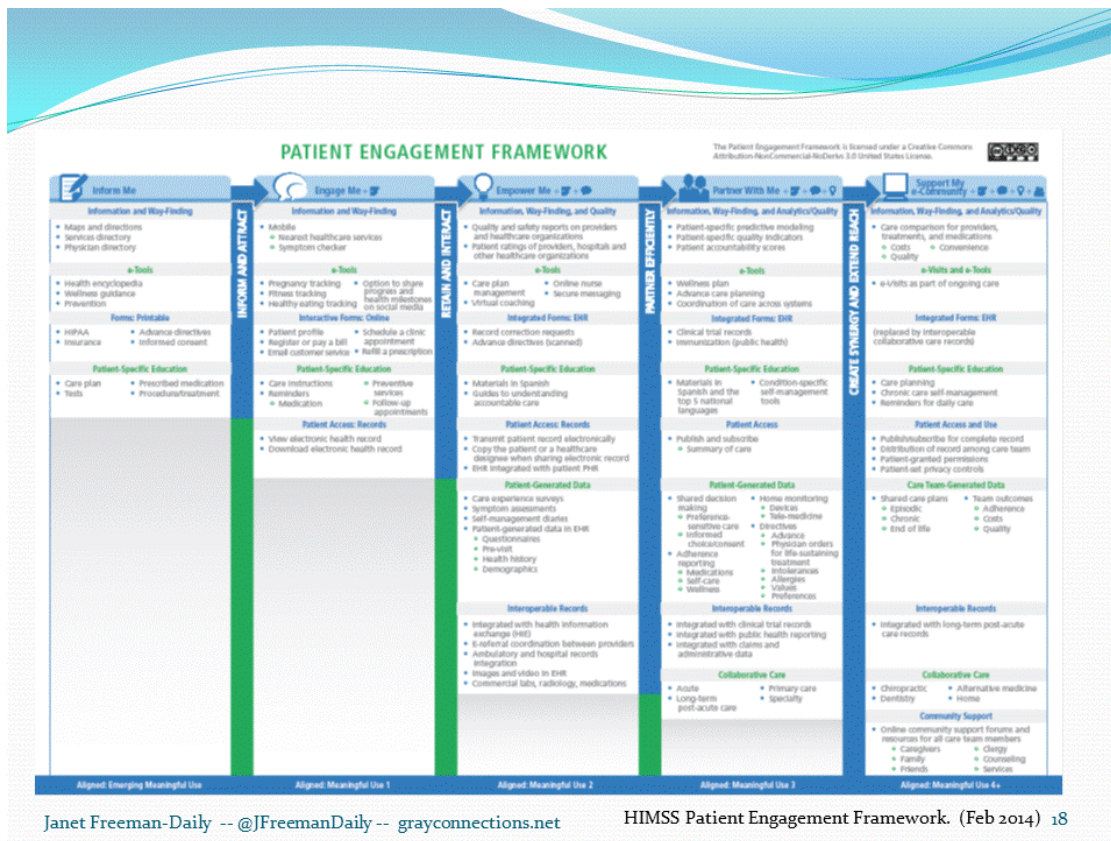
Note. HIMSS Patient engagement framework. Retrieved from https://www.himss.org/himss-patient-engagement-framework

Figure 3. Patient engagement framework

The next stage, called "Engage Me," increases the amount and complexity of information available for patients through virtual care platforms. Interactive functions are included in this phase to help patients set health goals and track their progress. Simple symptom checking algorithms are also provided to patients needed for non-emergence care. In essence, the Engage Me stage offers additional value to patients and clinicians by bringing diagnostic tools, incentives, and health coaching into this patient engagement phase.

The third stage is the "Empower Me" stage, which focuses on bi-directional communications between clinicians and patients. In this stage, patients are considered a

sufficient source of truth about their health issues and statues. In addition to providing

information to patients, the virtual care interface will collect patient-generated data directly from

the patients or from their personal health devices. Most patients are familiar with the feature and

functionality of the virtual care interface and understand how virtual care can be integrated as

part of the clinical workflow in primary care practices. Patients in the Empower Me stage begin

taking an active role in their care by providing much needed information, which allows their

caregivers to provide vital and valuable interventions. For instance, pre-visit information can be

gathered through interactive questionnaires in the patient portal or mobile apps. Patients in this

phase often participate in clinically-meaningful interactions with their care teams through virtual

care platforms. Those virtual care activities also meet the patient engagement goals of Stage 3

Meaningful Use requirements and the Merit-based payment system (MIPS).

The fourth stage is the "Partner with Me" stage when patients start transforming from

healthcare recipient roles to becoming full partners with their caregivers and care teams. The

partnering concept can be particularly beneficial for individuals with multiple chronic conditions

or an otherwise complex medical history. This stage focuses on supports and strategies for self-

management to help patients manage disease, promote healthy behavior, and maintain quality of

life. A wide range of information and tools should be accessible by patients through virtual care

platforms, enabling them to become contributors to their care services and outcomes. The

literature shows that patients who frequently use online portals or virtual care interfaces are

likely to have higher levels of patient activation for self-care as well as greater outcomes in

chronic disease management (Hibbard, Greene, Sacks, Overton, & Parrotta, 2017; Riippa, Linna,

& Rönkkö, 2014).

The "Support Me" stage is the fifth phase and the apex of the patient engagement framework. Engagement in this stage focuses on incorporating the social determinants of health to improve the health of the patients and the population as large. One of the key objectives of the health system in the "Support Me" phase is to connect clinicians and patients to others who can support their goals through social networks or data hubs in physical as well as virtual forms. As healthcare community partners, individuals will share certain health information with other health industry stakeholders (e.g., pharmacy and dentistry) and non-traditional caregivers (e.g., social worker, community health workers, media groups) to improve the patient's well-being and health (Nash, Fabius, Skoufalos, Clarke, & Horowitz, 2016).

In sum, the patient engagement framework provides systematic approaches for healthcare organizations to enhance patient-provider relationship and continuity of care to achieve better care quality, greater patient experience, and lower costs. Not only does patient engagement help healthcare systems attain important Meaningful Use requirements, but also the effort is in alignment with the Institute for Healthcare Improvement's Triple Aim (Berwick, Nolan, & Whittington, 2008). With the increased popularity and advancement of new health information technology, it is a matter of time for clinicians and patients to incorporate virtual care as part of standard care workflow. Nonetheless, each patient has unique healthcare needs and preferences. Understanding the trajectory of the patient's disease conditions and healthcare needs can motivate patients to engage learning and action options for their health. Thus, to optimize the effectiveness and benefits of virtual care in primary care practices, health system leaders will need to apply sophisticated analytics that predict each patient's future health challenges and engage patients to proactively manage their care anytime and anywhere.

2.9 Unified Theory of Acceptance and Use of Technology

Factors influencing patients' attitudes toward and use of virtual care, such as EHRs and patient portal, have also been examined using social psychological theories and cognitive processing models. One of the cognitive processing models frequently used to illustrate the adoption of information technology in health care is the Unified Theory of Acceptance and Use of Technology (UTAUT) (Holden & Karsh, 2010; Venkatesh, Morris, Davis, & Davis, 2003). Building on the technology acceptance model, the motivational model, and planned behavioral theory, UTAUT forms a conceptual framework describing why and how individuals are motivated to use information technology (Holden & Karsh, 2010). The conceptual framework has been widely applied in health informatics literature to explain clinicians' and patients' perceived benefits and barriers for adopting EHRs and online virtual health platforms. In essence, the unified theory initially consists of four constructs: performance expectancy, effort expectancy, social influence, and facilitating conditions (Venkatesh et al., 2003). Figure 4 provides a graphic presentation of those constructs.
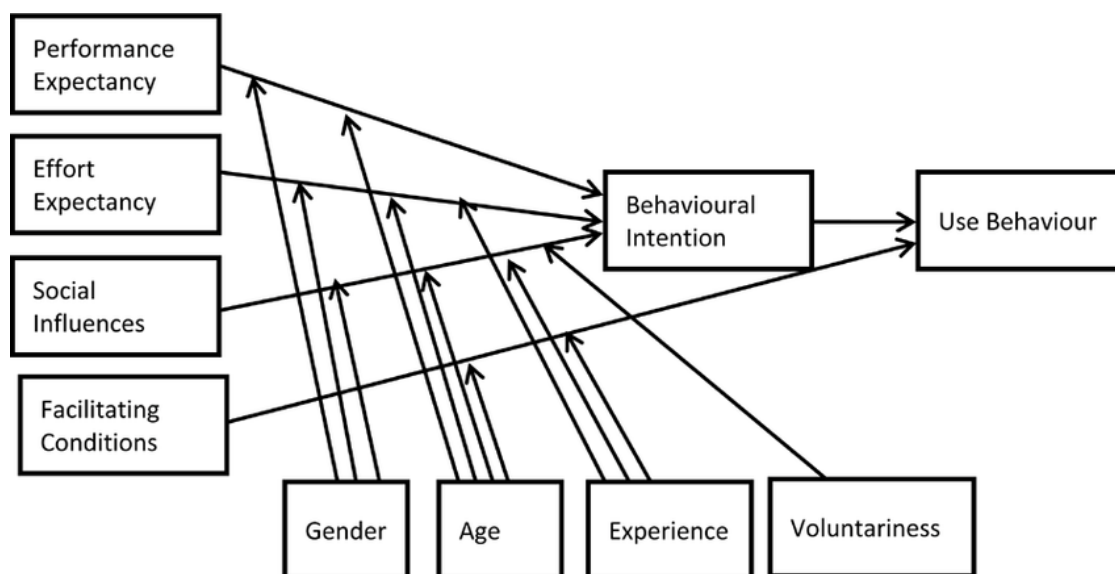

Figure 4. Unified theory of acceptance and use of technology

Performance expectancy and effort expectancy represent the technology aspect of cognitive attributes that determine the use of information technology, while social influence and facilitating conditions represent environmental influences associated with the contextual aspects of cognitive attributes. More specifically, performance expectancy is defined as the degree to which individuals expect that the use of the technology will result in performance gains. Effort expectancy can be explained as the anticipated complexity of the technology and the degree of energy needed to use it. Simply speaking, performance expectancy represents the usefulness of the technology, and effort expectancy denotes the ease of use of the technology. The two attributes often reflect the knowledge, experience, and self-efficacy of the individuals regarding information technology. The attributes also contribute to stronger effects on the intention to use information technology (Hoogenbosch et al., 2018). Besides intention to use, the usefulness and easy to use attributes affect how individuals access and utilize the technology.

Social influence illustrates the extent to which individuals believe that important others advocate using the technologies (Venkatesh et al., 2003). In essence, people can form beliefs about technology acceptance and use based on the influence of their peers and family. The social influence construct constitutes three dimensions: normative, coercive, and mimetic (Bozan, Davey, Parker, 2015; DiMaggio & Powell, 1983). Coercive and mimetic dimensions have shown significant effects on the adoption and use of patient portals and messaging among elderly patients (Bozan, Davey, Parker, 2015). Facilitating conditions are defined as the degree to which individuals perceive that an organizational and technical infrastructure is required to support use of the technology (Venkatesh et al., 2003). Besides affecting individuals' use intention, conditions that facilitate the use of the technology can directly exert the use behavior.

In 2012, three more constructs were added to UTAUT to explain the impact of the economic and affective attributes on technology acceptance and adoption (Venkatesh, Thong, & Xu, 2012). The three constructs are hedonic motivation, price value, and habit. Hedonic motivation illustrates the degree to which individuals' emotional responses (e.g., anxiety and joy) affect the intention of using information technology. Research shows that affection can play an important role in predicting a person's intention to use technology that is entertaining and sociable (van der Heijden, 2004). Price value indicates cognitive trade-offs between perceived benefits and monetary costs for using the technology. Different from effort expectancy, the price value attribute focuses on the economic aspect of the decision-making process. Habit is defined as the extent to which people tend to use or think about technology based on their prior experience and familiarity with that technology (Venkatesh et al., 2012). Habit also can be viewed as the continuation or automation of prior behavior. The impact of habit can vary based on the extent of interaction and familiarity that develop with the technology over time.

2.10 Diffusion of Innovations

A person's attitudes and intention toward adopting virtual care interfaces can also be explained using the diffusion of innovation theory (Emani et al., 2018; Rogers, 2003). The diffusion of innovation theory provides a conceptual framework using human information processing and motivational theories to illustrate how innovations are adopted by an individual or spread among a group of people. Research has applied the diffusion of innovation theory to understand differences in attitudes, perceptions, and use intention among adopters and non-adopters of patient portals (Emani et al., 2018; Hoogenbosch et al., 2018; Sun et al., 2018).

In essence, the theory articulates that an individuals' tendency to adopt new technology can be affected by five attributes: relative advantage, compatibility, complexity, trailability, and observability. Relative advantage indicates "the degree to which an innovation is perceived as being better than the idea it supersedes" (Rogers, 2003, p.229). In health care, the innovation can be messaging, patient portal, or other virtual care platforms, compared to in-person visits or telephone calls. Innovations perceived to have greater advantage are more likely to be adopted versus those perceived to have fewer advantages. Compatibility means that "the degree to which an innovation is perceived consistent with the existing values, past experiences, and needs of potential adopters" (Rogers, 2003, p. 15). An idea that is not compatible with a person's values, norms or practices will not be adopted as rapidly as an innovation that is compatible.

Complexity, also referred to as the simplicity or easy to use attribute, represents the degree to which an innovation is perceived as difficult or easy to understand and use. New technology that is easier to use and comprehend is more likely to be adopted than technology that requires the development of new skills and understandings. Trailability indicates "the degree to which an innovation can be experimented with on a limited basis" (Rogers, 2003, p. 16). An innovation (e.g., online appointment) that can be tried by potential users represents less uncertainty to the individuals who are considering it. Observability is the number of benefits of an innovation that are visible to intended adopters. Visible results reduce uncertainty and help adopters engage discussions and share experiences with their friends and peers.

These five attributes account for 49% to 87% of the variation in the adoption of new products (Rogers, 2003). However, the impact of these attributes on adoption rates can differ

based on the nature and context of the new technology. Recent studies in medical technology

innovations show that relative advantage, ease of use, and trailability have stronger influences

on individuals' intention to use patient portals (Emani et al., 2018), compared to compatibility

and observability. The technology use and acceptance of the individual can also vary according

to the feature or module of the virtual care platform (Ramsey et al., 2018, Sakaguchi-Tang,

Bosold, Choi, & Turner, 2017). For instance, making appointments and viewing lab results are

features frequently utilized in the patient portal, versus setting health goals and updating patient

notes. Those variations may be associated with user experience, feature desirability, and

complexity of use.

CHAPTER III
METHODOLOGY

Online portals and virtual care have rapidly become a popular way to coordinate and deliver primary care services in modern healthcare systems. Through innovative health information technologies, virtual care has brought disruptive changes to current care delivery models by making essential treatments and consultation services more affordable and accessible. Commonly-available virtual care functionalities via online portals include online appointments, asynchronous consultations, lab result summaries, disease management, medication refills, and diet/lifestyle coaching. The aims of this study are to identify core virtual care functionalities frequently accessed by the patients, and to investigate factors driving patients' decisions when utilizing virtual care in primary care settings. The hypotheses of the study are summarized as follows:

H1: The amount of virtual care utilization varies by the functional area of the virtual care interface.

H2A: The level of virtual care utilization varies by patient age, sex, race, language, insurance type, and chronic disease.

H2B: The level of virtual care utilization varies by clinician practice experience, teaching/community clinic, and urban/rural location.

The goal of this research is to bridge gaps in the knowledge of ongoing challenges in access to, and use of, online portals and asynchronous visits in primary care practices.

3.1 Study Design and Setting

The research utilizes a retrospective longitudinal design using data extracted from an enterprise electronic health record system (Epic Systems, Verona, WI). Electronic health records (EHR) are real-time, patient-centered information that contains medical and treatment histories

of patients. Although electronic health record systems have primarily served as clinical applications to support care-related operations, a growing number of scholars has started using EHRs to conduct epidemiology and health services research. The use of EHRs enables healthcare researchers to assess a wide range of diseases and treatment outcomes from diverse and geographically distributed populations over a long period of time (Casey, Schwartz, Stewart, & Adler, 2016). Literature shows that research using EHRs can benefit from large sample sizes and generalizable populations that are unavailable in traditional studies relying on primary data collection methods (Chaudhry et al., 2006; Menachemi & Collum, 2011).

Recent advances in mobile technology and patient-centered medicine further enhance the integration of EHRs with provider-patient communication tools and social network applications. The emerging technologies and expanded EHR data capacities provide researchers opportunities to investigate complex communication and behavioral determinants of health by linking clinical care information to patient data generated outside of conventional care environments (Menachemi & Collum, 2011). The current study analyzes clinical care and patient communication data stored in EHRs, to examine the patterns of patients' virtual care encounters rendered at family medicine clinics managed by the University of Wisconsin Department of Family Medicine and Community Health. All personal identifiable information is removed or de-identified in the analysis to protect patient confidentiality. The study is considered secondary research and exempt from the University of Wisconsin Health Science Institutional Review Board.

The University of Wisconsin Department of Family Medicine and Community Health (DFMCH) is one of the nation's oldest family medicine departments, established in 1970. The department offers a wide spectrum of primary care services to more than 180,000 patients,

educational programs for 80 residents and fellows, community outreach services, and research

development in primary care and population health. Currently, DFMCH has over 160 family

physicians and operates 4 residency clinics, 10 community clinics, and 4 regional clinics in

southern Wisconsin. DFMCH is also part of the University of Wisconsin Health System (UW

Health), which is one of the largest multispecialty medical groups in Wisconsin, with more than

1,200 faculty physicians who provide care at approximately 45 UW Health clinical practice

locations and 62 clinical outreach locations throughout the state.

UW Health has used Epic Systems as its enterprise health record platform since 2007.

The use of EHRs has improved the coordination of patient care by giving clinicians accurate,

up-to-date information. In 2010, the organization rolled out the MyChart interface serving as a

patient portal that enables sharing EHRs and other health-related information with patients

treated at UW Health. The online portal offers patients a secure mechanism to view medical

records, receive test results, schedule appointments, make payments, and interact with care

providers via the Internet. The patient portal also allows UW Health to meet meaningful use

guidelines of the federal Electronic Health Records (EHR) Incentive Program stipulated by the

HITECH Act.

3.2 Study Timeframe and Population

The study examines virtual care utilizations rendered in primary care settings over a five-

year period, from January 2014 and December 2018. To be included in the analysis, EHR data

must come from individuals who are alive and have a primary care provider (PCP) at one of the

family medicine clinics during the study period. The duration of the PCP-patient affiliation also

has to last for at least consecutive 12 months. To ensure that patients are actively managed by a

PCP in the context of ongoing care, eligible individuals must have at least one office visit and at

least one non-face-to-face encounter (e.g., telephone, medication refill, e-visit) during the study period.

The age of the patient population ranges from 18 to 89 years old. Those patients also have a permanent home in Wisconsin. The study excludes individuals who reside in long-term care facilities (e.g., nursing home) or end-of-life settings (e.g., hospice).

3.3 Parameters of the Study

As discussed in Chapter 2, which introduced the conceptual framework of virtual care engagement and usage, various factors influence the utilization of virtual care in primary care at either the practice level, the PCP level, or the patient level. These variables can have direct and/or indirect effects on patients' intention to use virtual care platforms as well as the type of care available through online interfaces. For instance, prior research shows that older male adults seem less likely to adopt or utilize virtual care services versus younger male adults. Age and gender may be related to the frequency of virtual care utilization, although they do not directly influence a person' intention to use virtual care. Those variables introduce moderating effects on virtual care adoption and utilization. To adequately address a wide range of personal and system factors contributing to the pattern of virtual care usage, this study takes into account relevant practice, clinician, and patient attributes for making sound inferences about the use of virtual care services in primary care settings. Details about the contextual natures of these factors are discussed in the following subsections.

3.3.1 Practice Characteristics

To understand the variation of the virtual care utilization across different practice settings, the current analysis incorporates practice-level characteristics, such as the clinic's panel-FTE ratio, proximity, and availability as a residency training site. In population health

management, a panel consists of a group of patients assigned to a primary care provider or care team within a clinic. The average panel size of a clinic is defined as the average number of patients assigned to a clinic during the study period. The clinical full time equivalent (FTE) represents the amount of direct patient care by a PCP. The ratio of the panel size to the FTE illustrates the average number of patients managed by a full-time PCP at a clinic. A large panel-FTE ratio is often associated with worse patient access and poor care quality.

The site proximity of the clinic is measured by the clinic location in relation to the nearest metropolitan area and the geo-population distribution of Wisconsin. Clinics located within 0-5 miles in a metropolitan area are identified as urban clinics, those located with 6-10 miles in a number of clustered residential areas are identified as suburban clinics, those located within 11+ miles in rural townships or commuter towns are identified as exurban clinics.

3.3.2 Primary Care Provider (PCP) Characteristics

To account for the influences of primary care providers on the use of virtual care, the analysis includes PCP-specific factors such as clinical full time equivalent (FTE) and years of practice. The clinical FTE represents the amount of direct patient care that a provider expects to deliver each month. At UW Health, a full-time clinical FTE corresponds to 27 clinical hours per week. The clinical FTE is categorized at four levels: <0.5, 0.5-0.69, 0.7-0.89 and 0.9-1.0. Physician practice experience is measured by the years of practice in three categories: <5 year, 5-9 years and 10+ years.

3.3.3 Patient Characteristics

Patient demographics include sex, age, race/ethnicity, insurance type, PCP-patient duration, and comorbidity conditions. To best approximate virtual care utilization based on race and ethnicity, this analysis classifies the study population in two ethnic groups: Hispanic and

non-Hispanic. Furthermore, the study population is categorized into four racial groups: white, black, Asian, and Other. To produce stable rates in each group, American Indian, Pacific Islanders, and unknown races are aggregated into the Other race category due to their small numbers.

The insurance status of the patient is obtained from billing records in the EHR database. The study classifies the patient's insurance type into one of five payer categories including Medicare, Medicaid, private insurance, and other (uninsured and self-pay). The number of months that a patient is assigned to her/his PCP in the study period is computed to indicate the duration of the PCP-patient relationship. The current analysis also includes a set of chronic conditions frequently seen in primary care as comorbidities (Arndt, Tuan, White, & Schumacher, 2014). The number of comorbidities of each patient will serve as an indicator reflecting the overall health status of the individual.

Prior research in EHR access found that patients generally welcomed viewing their laboratory test results online (Giardina et al., 2015; Sabahi, Ahmadian, Mirzaee, & Khajouei, 2017). This is because online access provides patients timely and accurate information about their health conditions. Patients also perceived online delivery as a reliable method to retain confidentially for receiving test results. Nonetheless, while consumers generally want access to their health information, very few are currently taking advantage of this access. In this analysis, the number of laboratory tests ordered during outpatient visits are computed to determine the extent of laboratory tests for virtual care utilization. To improve the interpretability and clinical practicability, the number of laboratory orders during the study period are assigned to one of four categories: <11 orders, 11-20 orders, 21-30 orders, and 31+ orders.

The study also utilized an estimate of distance the patients' homes to their primary care clinic to account for any sensitivity to distance barrier. After the address of the patient's residence was geocoded using geographic information system (GIS) software (ArcGIS by Esri, Redlands, CA), the distance to the clinic was calculated in miles using the Euclidean method. To represent traveling time, the study further categorized the home-to-clinic distance into four levels: <5, 5-9, 10-14, and 15+ miles.

Moreover, patients' address is linked to a specific census tract area using the GIS application. Geographic areas developed by the United State Census Bureau, census tracts contain between 1,500 and 8,000 people. They are constructed to assess general population characteristics such as demographics and socioeconomic status. Census-based data have been used as proxy variables for patients' education and economic conditions in health services research because the socioeconomic information of individual patients is often not gathered and stored in EHRs. The current study includes several census-based socioeconomic indicators obtained from the 2013-2017 American Community Survey. The economic status was estimated using poverty rates representing the percentage of households whose total income was less than the official poverty threshold. The education status was estimated using the percentages of individuals who had education up to high school, completed some college or an associate degree, or had earned a bachelor degree or above. Internet access was estimated by examining internet subscription rates as representative of households with either broadband or dial-up subscriptions to Internet service providers.

3.4 Virtual Care Utilization Measure

The literature in patient portal and health IT adoption has shown that the extent to which virtual care is accessed and utilized can be measured through patient interviews (Giardina, Baldwin, Nystrom, Sittig, & Singh, 2018), self-assessment surveys (Dash, Haller, Sommer, &

Perron, 2016; Irizarry et al, 2017; McGrail et al., 2017), and billing codes (Gordon et al., 2017).

This study assesses the usage patterns of virtual care by evaluating access log data in EHR

systems. Utilizing EHRs as the data source can enable researchers to generate objective and

consistent measurements without relying on patients' memory, thus reducing the risk for

cognitive or recall bias. In essence, the virtual care use rate of a patient is measured as the

number of logins to a virtual care platform (e.g., patient portal, online apps) by the patient during

a specific time period. A login event is also referred to a session.

3.4.1 Principle for Measuring Use of Virtual Care

Although the frequency of logins is an intuitive measure regarding how often patients

access virtual care platforms, the usage rate does not always provide a precise estimate of the

true level of patients' virtual care usage. For instance, individuals can simply log onto their

virtual care platform multiple times and log off quickly. Hence, analyzing logging activities may

not be sufficient for researchers to gain a deeper understanding of the actual use of virtual care

platforms and their features. Prior studies also compute the number of web pages or online

modules that are clicked on or viewed in a session (Griffin, Skinner, Thornhill, & Weinberger,

2016; Redelmeier & Kraus, 2008). Knowing the number of views or clicks onto particular pages

or care features per session is important because it allows health systems to design better page

content to keep patients engaged and informed about their health conditions.

However, a greater number of page views per session does not necessarily mean better

virtual care utilization. People may quickly switch from one module to another without taking

time to comprehend the content or information presented to them. Therefore, to get a better

sense about whether people are actually reading or interacting with care content, this study

further assesses the duration of time spent on virtual care platforms and specific functional

features. In essence, longer sessions of time spent on a particular functional area indicates more engaged visits and greater amount of utilization.

3.4.2 Features Commonly Accessed in Virtual Care Platforms

Various communication functionalities and care features have been incorporated into modern virtual care platforms to facilitate appointment coordination, care consultation, and population health management. However, not all features in virtual care platforms receive the same amount of viewing attention or usage from patients. For instance, making appointments and viewing lab results are features frequently utilized in the patient portal, versus setting health goals and updating patient notes (Ramsey et al., 2018, Sakaguchi-Tang, Bosold, Choi, & Turner, 2017). As mentioned in Chapter 2, factors such as needs/advantages, ease of use, and trialability play important roles in influencing individuals' intention to engage or utilize certain features available through online or mobile health interfaces (Emani et al., 2018). People are more likely to take advantage of virtual care features that are relevant to their health needs and provide greater value and convenience.

Research in health-related portals has shown that virtual care interfaces enable users to view and manage a wide range of personal health information and care-related activities. Some features have a healthcare-specific focus, and others may involve insurance- and education-related functions. Table 5 summarizes a list of features commonly used by patients in virtual care platforms. These features often represent unique communication aspects, such as health record management, messaging, appointment management, visit summary, documentation, and educational resources (Elkind et al., 2017; Lafata et al., 2018; Ramsey et al., 2018).

Table 1. Commonly accessed features in health-related portals

Features	Feature Type
Record access and management	
Laboratory result [1,2,3]	Record access
Diagnostic test result [2]	Record access
Health summary	Record access
Current health issue [1,4]	Record access
Health summary [1,4]	Record access
Medical history [1,2]	Record access
Problem list [1,4]	Record access
Immunization history [1,3,4]	Record access
Medication	
History [1,2,4]	Record access
Request refill [2,4]	Record management
Allergies [1,2]	Record access
*Preventive care reminders [1,2]	Record access
Contraceptive visit reminders [3]	Record access
STD test reminders [3]	Record access
Appointment management	
Request or cancel [1,2,4]	Appointment scheduling
Reminders [1,2,3]	Appointment access
History log [2]	Appointment access
*Messaging	
View [1,2]	Messaging (general or medical) - View
Send to caregivers [1,2,3]	Messaging (general or medical) - Write
Patient note and goal	
Notes and biometric upload	Record management
Goal setting	Record management
Questionnaire	Record management
Referral	
Request	Record management
Summary	Visit summary
Visit/admission summaries [1]	Visit summary
*Educational materials and Web resources [2]	Resource
General health-related information [1]	Resource
*Document downloading or printing [1,2,4]	Documentation
Billing and insurance	
Insurance benefit	Insurance and payment - View
Billing statement	Insurance and payment - View
Pay online	Insurance and payment - Write
Provider and clinic information	Resource
Account management [4]	Excluded

* Stage 2 meaningful use requirements
[1] Lafata et al. (2018); [2] Elkind et al., (2017); [3] Ramsey et al. (2018); [4] Tsai et al. (2019)

This study classifies those common virtual care features into the following 13 feature types according to the functional and informational nature of each feature: health record access, health record management, visit summary, general messaging (view/write), medical messaging (view/write), appointment scheduling, appointment management, insurance and payment (view/write), documentation, and resource. The "health record access" type consists of user activities like viewing their medical history, test results, and general health conditions. The "health record management" type involves routine interactive activities for updating medical notes, setting health goals, and refilling medications. The "visit summary type" includes user viewing events specific to comments and summaries resulting from clinic visits or hospital admissions.

The "general messaging" type includes communication events involving general health or care-related questions between patients and their health care providers, while the "medical messaging" type mainly involves specific medical advice that requires immediate attention from caregivers or care teams. To differentiate the level of engagement in relation to use of virtual care services, each messaging type is split additionally into two levels: view and write. The view level indicates patient access for viewing or reading responses sent by caregivers. The write level consists of interactive activities from patients sent to caregivers or care teams.

Similarly, events indicating users paying for medical bills or updating insurance status are assigned to the insurance and payment – write type. Patient access for viewing payment history or insurance records are classified as the insurance and payment – read type. All the user activities for making, changing, and cancelling appointments via online interfaces are

assigned to the appointment scheduling type. User activities related to viewing future or past appointments are attributed to the appointment management type.

Many virtual care platforms also include health education class schedules and wellness materials about prevention or healthy lifestyles to improve patient-centered care efforts. Events indicating patient access to educational resources or other health-related materials are assigned to the resource type. Patients may view scanned documents or download medical records from virtual care interfaces. This study assigns these activities to the documentation type.

Online activities related to account management are excluded from the current analysis because they are not health-related events. Examples of the account management events include updating user account information and changing passwords.

3.5 Outcomes of the Study

The previous section illustrates 13 feature types frequently accessed by patients in virtual care platforms. Each feature type represents specific information regarding how patients use virtual care services, but it can be challenging for healthcare system administrators and policymakers to evaluate each feature type or develop action plans for this many variables. Thus, developing a succinct framework to measure virtual care utilization can be an important step to improve the ability of health service researchers to assess the impact of virtual care services on overall care quality and outcomes.

The first hypothesis of the study postulates that, when accessing virtual care platforms, patients' utilization decisions are likely to be associated with more general functionality dimensions rather than in just the specific feature types. Those dimensions represent composites of unique feature types, which in term allow the dimensions to be interpreted and evaluated in broader and intuitive perspectives. This analysis characterizes the dimensions as feature domains.

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Because virtual care platforms encompass a broad range of care features and service functionalities, there could be multiple feature categories identified in the study outcome (see Figure 5). The amount of time spent on each feature category during the study period will serve as an outcome measure to assess the effects of the demographic, clinical, and system-related variables on the level of utilization for each virtual care feature category. A patient can have multiple outcome measures: one for each feature category.
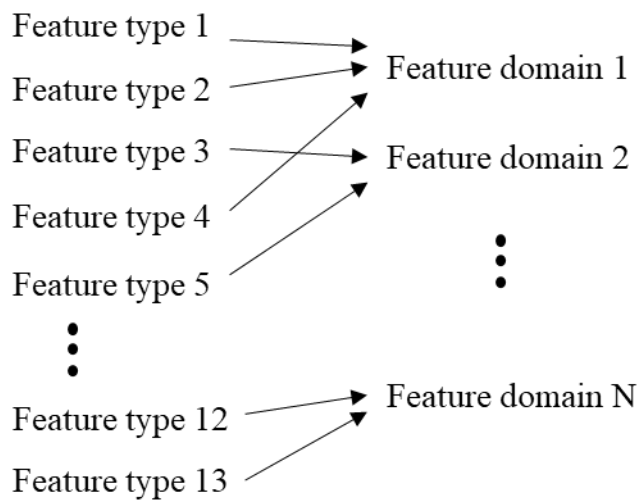
Figure 5. Anticipated relationships between virtual care feature types and feature domains

In essence, the amount of time spent by a patient on a virtual care feature domain is measured as the total number of seconds spent by the patient on accessing or interacting the care functionalities of the feature domain between January 2014 and December 2018. Yet, not all patients are medically homed at family medicine clinics during the entire 5-year study period. The actual duration of the PCP-patient relationship can vary by patient. To account for the time variation, an adjusted outcome measure for each feature domain is further computed as the total number of seconds prorated by the patient's total empanelment months over the study

period (see Figure 6). Empanelment months represent the number of months of the PCP-patient affiliation. The concept of the empanelment month is similar to the concept of the member month in an insurance plan. This analysis uses empanelment months to normalize the duration of a continuity relationship between patients and their PCP-led team and primary care clinics over the study period (Grambach & Olayiwola, 2015), so the effect sizes of the parameters of interest can be compared based on a consistent timeframe.

$$\text{The amount of time spent on a feature category} = \text{Total number of seconds accessing the feature category} \times \frac{60 \text{ months}}{\text{Total empanelment months}}$$

Figure 6. Outcome measure for the utilization level of the feature category

3.6 Statistical Analysis

3.6.1 Dimensionality Reduction

As described in Section 3.4.2, many care-related features are available in modern virtual care platforms. Commonly available virtual care features include online appointments, asynchronous consultations, lab result summaries, disease management, medication refills, and lifestyle coaching. The literature suggests that those features can be classified into 13 feature types, according to their functional and informational characteristics. They are health record access, health record management, visit summary, general messaging (view/write), medical messaging (view/write), appointment scheduling, appointment management, insurance and payment (view/write), documentation, and resource. Because some feature types share similar clinical or functional natures, the level of utilizations of those feature types can be correlated with each other. For instance, people frequently reading their health summary may also be

more likely to view visit summary information through virtual care interfaces. Thus, it may not be practical or effective to analyze the pattern of virtual care utilization by each feature type or by assessing all feature types in one model. Moreover, the use of virtual care will serve as explanatory variables to predict the level of continuity of care and other outcomes. Including a large number of variables in regression modeling may lead to multicollinearity or overfitting. That means that we may develop statistical models that fit extremely well, but they are not able to predict well in the long run.

One way to address this issue is to group the features types into a more interpretable and meaningful structure. The study applies factor analysis to explore the inter-relationships among the utilizations of those virtual care features by identifying a set of common underlying dimension or constructs. Essentially, with factor analysis the study can first identify the separate dimensions of feature types and then determine the extent to which a feature type is explained by each dimension. These dimensions become composites of specific feature types, which in turn allows the dimensions to be interpreted and described in broader aspects regarding how patients utilize virtual care platforms.

Because each feature type is measured by total time spent on a set of features in the feature type, the value range of a feature type may not be in a comparable scale from the value range of another feature type. Z-score transformation is performed to standardize the value of each feature type to a new value that has a standardized normal distribution with a mean of zero (0) and a standard deviation of one (1). The transformation approach will provide a consistent scale among all feature types.

The factor analysis is computed using principal components method with varimax rotation to determine underlying constructs in the data pattern. The cumulative percentage of

variance is estimated to determine the total amount of variance extracted by the factor solution. The factor loading of each variable on each factor is also estimated to indicate the variance accounted for each variable on a corresponding factor. In essence, the factor loading indicates the degree of correspondence between variables and a factor, with a higher loading making the variable more representative of the factor.

The number of factors is determined using latent root criterion and scree test criterion (Johnson & Wichern, 2008). According to the latent root criterion, only factors having eigenvalues greater than one (1) are considered significant. The scree test criterion is used to identify the optimum number of factors that can be extracted before the amount of unique variance begins to dominate the common variable structure. The test is often derived by plotting the latent roots against the number of factors in their order of extraction, and the shape of the resulting curve is used to evaluate the cutoff point. The point at which the curve first begins to straighten out is considered to indicate the maximum number of factors to extract. Thus, the scree test is also referred to as the elbow rule.

Using the dimensionality reduction approach allows the study to identify a smaller, more manageable set of constructs from the 13 virtual care feature types. Each construct does not only provide a meaningful and concise measure, but also results in better statistical representation and improved predictions for further analyses.

3.6.2 Generalized Linear Models

To assess patients' utilization level of the core virtual care features, a summary measure is created for each virtual care feature category that is deduced in the dimensionality reduction method. Essentially, based on the correlations of time spent on each virtual care feature, the dimensionality reduction analysis is used to identify a set of underlying feature domains (i.e.,

latent factors) and systematically assign those commonly used virtual care features into one of

the feature domains. Each virtual care feature domain may consist of a certain number of virtual

care feature types. A summary measure for each feature domain is generated by aggregating the

total amount of time spent by patients on viewing or responding to those feature types that are

attributed to the corresponding feature domain. The measure will represent the overall utilization

level of the virtual care feature domain in the following analysis.

The study will apply the generalized liner modeling method to estimate the likelihood of

patients to access and interact with the virtual care feature category, controlled for patient, PCP,

and clinic characteristics. Because the patients' usage of virtual care platforms seems sparse and

content-driven (Turner et al., 2015), the value of the virtual care feature category measure is

expected to be positively skewed with a large proportion of zeros and a long right tail. This

means that the measure of the virtual care category will not be normally distributed, thus

affecting the accuracy of the results using regression model when using the traditional ordinary

least squares (OLS) method.

To ensure data meet modeling assumptions for generalized linear modeling, the study

will apply either Poisson regression or negative binomial regression to address the over-

dispersed nature of the virtual care feature category data. Although both regression approaches

are useful for over-dispersed non-negative count data, negative binomial regression can be a

better option when the conditional variance exceeds the conditional mean (Ver Hoef & Boveng,

2007). The generalized linear model will be computed using the Maximum Likelihood

Estimation method, which will provide regression coefficients, standard errors, Wald 95%

confidence intervals for the coefficients, Chi-square tests, and p-values for each of the model

variables. The deviance and Pearson goodness-of-fit are computed to assess the overall fit of the

model. A backward reduction process will be applied to eliminate variables with the least impact on the overall fit of the model, until the most parsimonious model is identified. Contrast analysis will also be performed to calculate relative risks (or risk ratios) and 95% confidence intervals of the model variable to predict the likelihood that patients will use the virtual care feature category. All statistical analyses were performed using PROC GENMOD procedure (Version 9.4 SAS Institute Inc., Carey, NC).

CHAPTER IV

ARTICLE MANUSCRIPT

INTRODUCTION

Advances in health information technology have quickly made virtualized medicine and asynchronous care a popular care-delivery option in modern healthcare systems (Dorsey & Topol, 2016). Since 2017, nearly all hospitals in the U.S. have offered online portal access or apps enabling patients to view and download their health information, exchange care messages with medical providers, or transmit biometric data back to electronic health record systems (Henry, Barker, & Kachay, 2019). Virtual care platforms and patient portals provide healthcare organizations with innovative ways to coordinate and deliver primary care services remotely through online communications and other store-and-forward features so that clinicians can remain in frequent contact with their patients and quickly respond to any emergency needs (Sorondo, Allen, Fathima, Bayleran, & Sabbagh, 2016). The literature has shown that improving access to online portals has contributed to better population health management, patient experience, quality of care, and cost control in the rapidly evolving healthcare environment (Nagykaldi, Aspy, Chou, & Mold, 2012; Ramsey, Lanzo, Huston-Paterson, Tomaszewski, & Trent, 2018). As more of the nation's health systems are transforming to patient-centered care models, virtual care platforms have played a vital role in helping patients become better informed, engaged, and involved in their care.

However, adoption of virtualized care is complicated for both patients and providers. Primary care clinicians struggle with the challenges of integrating new information technology into their day-to-day practice (Kash, Baek, Davis, Champagne-Langabeer, & Langabeer, 2017). Despite federal government incentive programs and value-based reimbursement models to

stimulate the development of patient portals (Adler-Milstein et al., 2017), the lack of interoperability and intuitive user interfaces have prevented both clinicians and patients from taking a full advantage of the virtual health technology (Neuner, Fedders, Caravella, Bradford, & Schapira, 2015).

Learning about usability and acceptability of online patient portals in real-world practice is a critical first step to gain insight into behavioral and communication factors that impede or enable patients' virtual care adoption. Yet, little is known about how people use patient portals and other online applications (Griffin, Skinner, Thornhill, & Weinberger, 2016; Lafata et al., 2018). Prior research in health information technology adoption examined the extent to which a virtual care feature is utilized through patient interviews (Giardina, Baldwin, Nystrom, Sittig, & Singh, 2018), self-assessment surveys (Irizarry et al, 2017; McGrail et al., 2017), and billing codes (Gordon et al., 2017). However, because they rely on patient memory and personal perceptions, these measures are subject to recall or social desirability bias, or in the case of billing data, may lack granular information.

The goal of this study was to elucidate current patient portal behaviors by examining the pattern of time and service type use of patients, via data provided by access logs within electronic health records (EHR). The first objective was to identify common virtual care features that can serve as core measures for tracking use of online patient portals. The second objective was to evaluate the effects of patient, provider, and system characteristics on patients' decisions to use online portals. We hope that the study will provide additional insights into ongoing nationwide efforts to increase communication and care coordination through online healthcare portals.

METHODS

This retrospective study examined patient use of an online portal at 18 family medicine clinics in a large mid-western academic healthcare center from January 2014 through December 2018. The clinics consisted of over 170 primary care providers (PCP) serving more than 150,000 patients. The healthcare system's online portal was available to patients who received care in any primary care or specialty clinic. Patients could activate their online account by using access codes or enroll in the portal through EHR interfaces at clinics. User instructions, video clips, and podcasts were available to help patients familiarize the functionality of the online portal.

To be included in the study, patients had to be on a PCP panel for at least 12 months during the study period, had at least one office visit and at least one non-face-to-face encounter to ensure that patients were actively managed by a PCP in the context of ongoing care. Patients who died, stayed in long-term care facilities, or lived outside the state were excluded from the analysis. Clinical encounter and patient data for the study were extracted from an enterprise electronic health medical record (EHR) database. This research was approved by the medical school's Health Sciences Institutional Review Board.

Patient Portal Features

Various care and communication functionalities have been incorporated into modern virtual care platforms and patient portals to facilitate appointment coordination, care consultation, and population health management. Some features have care-specific focuses and others may involve insurance or educational functions. The literature indicates that online portals typically have one or more of the 13 feature types designed for various care or information services (Table 1) (Elkind et al., 2017; Lafata et al., 2018; Ramsey et al., 2018).

We chose to group portal features types into a small set of domains to ensure a more interpretable and meaningful structure. We did this for several reasons. Some feature types offer care or business functionalities in similar service areas so use of those feature types often correlated with each other. For instance, individuals who read their health summary on the patient portal may be more likely to view their visit summary information, making it difficult to understand use patterns by analyzing individual feature type or by assessing all feature types in one model. In addition, including a large number of variables in regression modeling may lead to multicollinearity or overfitting that can reduce the generalizability of the model.

Table 1. Commonly-accessed Features in Patient Online Portals

Feature	Feature Type
Record access and management	
Laboratory result [a,b,c]	Record access
Diagnostic test result [b]	Record access
Health summary	Record access
Current health issue [a,d]	Record access
Health summary [a,d]	Record access
Medical history [a,b]	Record access
Problem list [a,d]	Record access
Immunization history [a,c,d]	Record access
Medication	
History [a,b,d]	Record access
Request refill [b,d]	Record management
Allergies [a,b]	Record access
Preventive care reminders [a,b]	Record access
Contraceptive visit reminders [c]	Record access
STD test reminders [c]	Record access
Appointment management	
Request or cancel [a,b,d]	Appointment scheduling
Reminders [a,b,c]	Appointment access
History log [b]	Appointment access
Messaging	
View [a,b]	Messaging (general or medical) - View
Send to caregivers [a,b,c]	Messaging (general or medical) - Write
Patient note and goal	
Notes and biometric upload	Record management
Goal setting	Record management
Questionnaire	Record management
Referral	
Request	Record management
Summary	Visit summary
Visit/admission summaries [a]	Visit summary
Educational materials and Web resources [b]	Resource
General health-related information [a]	Resource
Document downloading or printing [a,b,d]	Documentation
Billing and insurance	
Insurance benefit	Insurance and payment - View
Billing statement	Insurance and payment - View
Pay online	Insurance and payment - Write
Provider and clinic information	Resource
Account management [d]	Excluded

[a] Lafata et al. (2018); [b] Elkind et al., 2017; [c] Ramsey et al. (2018); [d] Tsai et al. (2019)

Utilization Measure

Investigators in previous studies have used numbers of logins and web pages that are clicked on or viewed to evaluate patients' online portal access (Griffin, Skinner, Thornhill, & Weinberger, 2016; Redelmeier & Kraus, 2008). Although frequency of logins and clicks is an intuitive measure regarding online portal usage, the access rate does not always provide accurate usage of the online portal because people often quickly switch from one webpage to another without taking time to comprehend content or information presented to them.

To better quantify online portal use, we measured the amount of time spent by patients on virtual care platforms using the time stamp of the access log record. A longer time spent on a particular functional area was interpreted as being a more engaged visit and represented a greater amount of utilization. Patients were disconnected from the online portal when their sessions became inactive or idle for 15 minutes.

Practice, Physician and Patient Characteristics

Practice-level characteristics included site proximity to a densely-populated urban area and whether a clinic was a residency training site. A clinic proximity variable was created based on geo-population distribution. Clinics located within 0-5 miles of a highly populated urban area were considered urban clinics. Clinics located within 6-10 miles in a number of clustered residential areas were considered suburban clinics. Clinics located 11+ miles in rural townships were considered rural clinics.

To account for potential clinician influences on patient portal use, the study included family physician-specific characteristics of clinician status (faculty versus resident physicians) and years of practice. Physician practice experience was measured by the years of practice in four categories: <5 years, 5-14 years, 15-24 years, and 25+ years.

Patient demographic characteristics included sex, age, race/ethnicity, insurance type, PCP-patient duration, overall health complexity, and the numbers of prescriptions and laboratory tests during the study period. The PCP-patient duration was estimated based on the total empanelment months of the patient during the study period. Patient's health complexity was assessed by applying the Elixhauser comorbidity method using a set of 29 medical, psychiatric, and lifestyle-related health conditions (Elixhauser, Steiner, Harris, & Coffey, 1998; AHRQ, 2018). The Elixhauser comorbidity measure has demonstrated great predictive performance for associations between individual medical conditions, healthcare utilization, and health outcomes in population health analysis (Baldwin et al., 2006; Ou, 2012). The study used the number of diseases in the Elixhauser measure to represent patient complexity because the simple count measurement of unique medical conditions is a reliable predictor of healthcare utilization similar to other complex comorbidity indices (Farley, Harley, & Devine, 2006). We also linked patients' addresses to census tract areas using ArcGIS software (ESRI) to account for a sensitivity to potential socioeconomic barriers, such as the percentage of the population that is below the poverty level, has Internet access, and graduates from either high school or college.

Statistical Analyses

To identify the common underlying construct of a large set of feature types, the study began with a dimensionality reduction approach using factor analysis based on the principal component method with varimax rotation. Z-score transformation was performed to scale the value of each feature type to a standardized normal distribution. Then, the eigenvalue and the cumulative percentage of variance was estimated for each latent factor to determine the total amount of variance extracted by the factor solution. Moreover, the loading of the feature type

on each latent factor was estimated to indicate the variance accounted for each feature type on a corresponding domain. Latent root criterion and scree test criterion were used to determine the optimal number of latent factors in the analysis. Each latent factor was classified as a feature domain that could consist of one or more feature types. Feature types with the rotated factor loading of at least ±0.45 on a feature domain were included in that feature domain. A feature domain was also assigned a name representing the common nature of the feature types in the feature domain.

Time spent on each feature domain was measured by computing the total amount of time spent by patients on viewing or responding to all feature types attributed to the domain. Essentially, the amount of time spent by a patient on a portal feature domain was measured as the total number of seconds spent by the patient on accessing or interacting the care functionalities of the feature domain during the study period. To better characterize the usage of the online portal, we further applied generalized linear modeling to assess the effects of patient, PCP, and practice characteristics on time spent for each feature domain. Because portal use could be sparse and content-driven (Turner et al., 2015), the distribution of the time estimate is expected to be positively skewed with a long right tail. Thus, due to a non-normal distribution, regression analysis using the traditional ordinary least squares (OLS) method would not generate reliable model estimates. Poisson and negative binomial regression approaches are better alternatives to address the over-dispersed nature of time measures. Although both regression approaches are useful for over-dispersed count data, negative binomial regression is a better option when the conditional variance exceeds the conditional mean (Ver Hoef & Boveng, 2007). The overall fit of the model was assessed by the deviance and Pearson goodness-of-fit statistics. Regression model analysis was computed using the

Maximum Likelihood Estimation method. All statistical analyses were performed using the

PROC GENMOD procedure (Version 9.4 SAS Institute Inc., Cary, NC).

RESULTS

There were 102,342 adult patients who met inclusion criteria at the 18 family medicine

clinics between 2014 and 2018. Of those patients, 73% had online portal accounts. The

average time on a PCP's panel of the online portal user was 47.3 months over the 5-year study

period, compared to 46.3 months for those without online portal access. Table 2 shows that the

percentage of patients with online portal accounts was higher in non-residency clinics and urban

clinics. A greater percentage of online accounts was also found among patients whose PCP was

clinical faculty or had been in the middle phase of their career practice. In general, individuals

with portal accounts were likely to be female, younger, non-Hispanic white, chronically-ill, and

have commercial insurance. They also had more medication and laboratory tests, compared to

patients without online portal accounts.

Table 2. Characteristics of the Patient Population

Characteristics	With Online Portal Account		Without Online Portal Account		Chi-square Statistics
	N	%	N	%	
Total population	74,147	72.5	28,195	27.5	
Practice-Level					
Residency Clinic	17,256	23.3	7,970	28.3	274.4[**]
Clinic Location					505.0[**]
Urban	44,856	60.5	15,225	54.0	
Suburban	13,766	18.6	5,290	18.8	
Rural	15,525	20.9	7,680	27.2	
PCP-Level					
Faculty	68,980	93.0	24,959	88.5	551.0[**]
Years of Practice					
< 5	5,482	7.4	3,313	11.8	1045.7[**]
5-14	26,152	35.3	7,757	27.5	
15-24	22,856	30.8	8,173	29.0	
25+	19,657	26.5	8,952	31.8	
Patient-Level					
Female	43,739	59.0	12,823	45.5	1508.1[**]
Age Group					1528.0[**]
18-39	25,377	34.2	8,262	29.3	
40-64	19,758	26.6	8,082	28.7	
65+	5,743	7.7	4,325	15.3	
Hispanic	2,119	2.9	2,275	8.1	1358.4[**]
Race					1400.9[**]
White	68,209	92.0	23981	85.1	
Black	2,128	2.9	2085	7.4	
Asian	1,899	2.6	836	3.0	
Other	1,911	2.6	1293	4.6	
Payer Category					5285.8[**]
Commercial	62372	84.1	17964	63.7	
Medicaid	3564	4.8	3601	12.8	
Medicare	7501	10.1	5648	20.0	
Uninsured	710	1.0	982	3.5	
Comorbidity	58653	79.1	21964	77.9	17.7[**]
Prescriptions					444.3[**]
0-10	22,246	30.0	10,356	36.7	
11-20	14,644	19.7	5,038	17.9	
21-30	9,744	13.1	3,096	11.0	
31+	27,513	37.1	9,705	34.4	
Lab Tests					1788.2[**]
0-10	19,843	26.8	11,326	40.2	
11-20	16,571	22.3	5,681	20.1	
21-30	11,586	15.6	3,430	12.2	
31+	26,147	35.3	7,758	27.5	

[*]$p<0.05$; [**]$p<0.01$

Overall Time Spent by Patient on the Portal

Of the 74,147 patients with online portal accounts, 70,981 patients (95.7%) had logged onto the online portal to view or interact with virtual care features during the study period, which consisted of 4,518,017 sessions and 310,098 use hours in total. The median and mean time spent per session was 5.1 and 4.7 minutes, with a standard deviation of 8.6 minutes. Despite the high accessing rate from patients with online portal accounts, 25.9% of users accounted for over 70% of the total portal accessing time during the study period.

Table 3 shows that 90% of patient portal users viewed their personal health data and general messages through the online portal, accounting for 50.6% of total time spent in the virtual care platform. More than 80% of patients viewed their visit summary, searched for appointment schedules, downloaded documentation, and reviewed insurance information. These activities accounted for over 30% of total time spent on the virtual care platform. Despite 84% of patients viewing documentation pages, the overall percentage of time spent on documentation-related information was relatively small. Only a small portion of patients used the online portal for scheduling appointments, paying bills, searching for resource information, and uploading personal data back to the EHR system.

Table 3. Dimensionality Reduction Analysis in Feature Types

| Feature Type | Patient | | Time on Portal | | Feature Domain[a] | | | |
	N	%	Hours	%	Messaging	Health Info Management	Billing/ Insurance	Resource/ Education
Messaging - View	64,050	90.2	66,011	21.2	0.789	0.373	0.096	0.021
Messaging - Write	50,747	71.5	9,546	3.1	0.851	0.139	0.073	0.142
Messaging - View medical	47,846	67.4	38,930	12.5	0.833	0.302	0.059	0.007
Messaging - Write medical	43,898	61.8	10,994	3.5	0.197	0.224	0.088	-0.034
Appointment access	58,177	81.9	22,229	7.1	0.188	0.740	0.164	0.253
Appointment scheduling	39,908	56.2	2,639	0.8	0.269	0.574	0.146	0.092
Record access	69,543	97.9	92,048	29.4	0.105	0.688	0.075	0.045
Record management	26,607	37.5	928	0.3	0.188	0.510	0.078	-0.366
Visit Summary	61,822	87.1	34,919	11.2	0.102	0.783	0.103	0.118
Insurance and payment - View	57,163	80.5	22,964	7.4	0.083	0.349	0.675	0.035
Insurance and payment - Write	22,691	32.0	1,490	0.5	0.196	0.001	0.893	-0.007
Documentation	59,468	83.8	7,401	2.4	0.197	0.472	-0.005	0.501
Resource	24,300	34.2	1,808	0.6	0.104	0.142	0.036	0.889
Sums of squares (Eigenvalue)					4.88	1.42	1.06	1.01
Percent of trace					37.5	10.9	8.2	7.8

[a] Numbers are rotated factor loadings which are correlations between feature types and feature domains.

Dimensionality Reduction

Results of the dimensionality reduction analysis suggest that the 13 feature types could be captured by four latent domains whose eigenvalues were greater than or equal to one and together accounted for 63.9% of the total variance (Table 3). Essentially, the "messaging" domain consisted of four message-specific feature types representing communication activities for exchanging general and medical messages among patients and their healthcare teams. The "health information management" domain included health- and visit-related feature types designed to help patients access their health/medical data and help patients manage clinic visits. The "billing and insurance" domain included health plan and payment-related features that allow patients to update insurance information and check billing processes. The "resource and education" domain included online functions designed to help patients download/upload authorized documents for treatment purposes or search for health education and general clinic resource information.

Impacts on Time Usage by Feature Domain

Table 4 summarizes results from the negative binomial regression analysis of the association between characteristics on the amount of time spent on each feature category. The overall goodness of fit showed that the negative binomial models fit well (deviance: 1.29 to 1.42) with almost no over-dispersion (Pearson χ^2: 0.69 to 0.82). Individuals who had a longer empanelment period with their PCP were likely to spend more time viewing and interacting with materials on the virtual care platform. Compared to patients at non-residency clinics, patients at residency clinics showed almost 13% greater tendency to use features in the messaging domain (OR=1.127, 95% CI, 1.089-1.167), but they were 7.5% less likely to use the

billing/insurance domain (OR=0.925, 95% CI, 0.883-0.968). Patients at the urban and suburban

clinics were 1.19-1.60 time more likely to use the online portal than those in the rural area.

Patients at the urban and suburban clinics were more likely than patients in the rural area to use

messaging (OR=1.29-1.60), health information management (OR=1.19-1.23), billing/insurance

(OR=1.27-1.36), and resource/education features (OR=1.22-1.25).

There was a 20% increase in odds of the use of the resource/education features for

patients managed by non-resident PCPs than patients managed by resident PCPs; however, their

time differences in the other feature domains were small and not statistically significant. The

effect of the PCP's years of practice varied by feature domain. Patients with PCPs in their mid-

career phase spent significantly more time using features in the messaging and health

information management domains than patients with PCPs whose years of practice were less

than 5 years or greater than 25 years. Patients with PCPs in the early and middle career phase

generally showed a 7-21% greater of odds of using online features in the billing/insurance

domain and the resource/education domain, compared to patients whose PCP had more than 25

years of practice. In general, patients with PCP who had fewer practice years were more likely

to use billing/insurance and resource/education features.

Table 4. Results of Negative Binomial Regression on Time Spent by Feature Domain

Characteristics	Messaging Estimate	Odds Ratio	Health Info Management Estimate	Odds Ratio	Billing/Insurance Estimate	Odds Ratio	Resource/Education Estimate	Odds Ratio
Panel Months	0.007	1.007**	0.009	1.010**	0.003	1.003**	0.004	1.004**
Residency Clinic	0.120	1.127**	0.015	1.015	-0.078	0.925**	0.036	1.036*
Clinic Location (ref: rural)								
Urban	0.469	1.599**	0.209	1.232**	0.310	1.363**	0.225	1.252**
Suburban	0.257	1.293**	0.172	1.188**	0.237	1.267**	0.198	1.219**
Faculty	0.114	1.121	-0.035	0.966	0.169	1.184	0.186	1.204*
Years of Practice (ref: 25+)								
< 5	0.057	1.058	0.019	1.019	0.192	1.211*	0.196	1.217**
5-14	0.233	1.263**	0.141	1.152**	0.168	1.182**	0.084	1.088**
15-24	0.114	1.121**	0.064	1.066**	0.068	1.071**	0.026	1.026
Female	0.135	1.145**	0.100	1.105**	0.091	1.095**	0.282	1.326**
Age in years (ref: 65+)								
18-39	0.044	1.045*	-0.015	0.985	-0.017	0.983	-0.069	0.933**
40-64	0.113	1.119**	-0.039	0.962**	-0.036	0.965	-0.119	0.888**
Hispanic	-0.343	0.710**	-0.082	0.921**	-0.037	0.964	0.083	1.087*
Race (ref: white)								
Black	-0.754	0.471**	-0.243	0.784**	-0.470	0.625**	0.034	1.035
Asian	-0.268	0.765**	0.086	1.090**	0.116	1.123*	-0.025	0.975
Other	-0.173	0.841**	-0.05	0.951	-0.089	0.915	-0.033	0.968
Payer Category (ref: commercial)								
Medicare	-0.082	0.921**	0.053	1.055**	-0.745	0.475**	-0.252	0.777**
Medicaid	-0.267	0.765**	-0.12	0.887**	-1.184	0.306**	0.037	1.037
Uninsured/Self-pay	-0.143	0.867*	-0.077	0.926	-0.226	0.798*	0.264	1.302**
Comorbidity	0.039	1.040**	0.053	1.055**	0.015	1.016**	0.037	1.037**
# Prescriptions (ref: ≤10)								
11-20	0.406	1.501**	0.100	1.105**	0.141	1.151**	0.182	1.200**
21-30	0.596	1.815**	0.129	1.138**	0.176	1.192**	0.219	1.245**
>30	1.002	2.722**	0.304	1.355**	0.296	1.345**	0.442	1.556**
# Lab tests (ref: ≤10)								
11-20	0.413	1.512**	0.492	1.635**	0.329	1.389**	0.218	1.244**

21-30	0.633	1.884**	0.736	2.087**	0.57	1.769**	0.326	1.385**
>30	1.035	2.814**	1.174	3.235**	0.824	2.280**	0.536	1.708**
% Internet Access	0.006	1.006**	0.002	1.002	0.002	1.002	-0.001	0.999
% HS Degree	0.014	1.014**	0.004	1.004	-0.003	0.997	0.005	1.005
% Some College and AA Degree	0.016	1.016**	0.006	1.006**	0.006	1.006	0.005	1.005
% Bachelor Degree	0.018	1.019**	0.008	1.008**	0.004	1.004	0.004	1.004
% Below Poverty	0.001	1.001	0.003	1.003**	0.004	1.004*	0.002	1.002
Scaled Deviance	1.40		1.29		1.52		1.42	
Scaled Pearson Chi-square	0.82		0.69		0.67		0.77	

*$p<0.05$; **$p<0.01$

Female patients were more likely than their male counterparts to use online care features, especially the resource/education domain (OR=1.326, 95% CI, 1.292-1.360). Compared to patients aged ≥ 65, younger patients showed greater tendency to use most of the online features, except for the resource/education domain. Individuals aged 40-64 were 11% less likely than the older group to use resource/education features (OR=0.888, 95% CI, 0.861-0.914). The online usage of patients with Hispanic heritage tended to be less than their non-Hispanic counterparts, though their differences in the resource/education domain were not statistically significant. In general, minority patients were less likely than white patients to use online features in both the messaging domain and the health information management domain. Furthermore, compared to white patients, black patients showed a 37.5% lower of odds of using the billing/insurance domain (OR=0.625, 95% CI, 0.564-0.692) and Asian patients were 12.3% more likely to use the billing/insurance domain (OR=1.123, 95% CI, 0.761-0.904).

Individuals living in a community with greater Internet access were more likely to use the messaging features of the online portal (OR=1.006, 95% CI, 1.002-1.010), while Internet availability did not affect time spent in the other feature domains. Patients living in areas with higher graduation rates in high school and college were more likely to use the messaging domain (OR=1.014-1.019). Small increasing usage in the health information management domain was associated with patients with higher college graduation rates living in the area (OR=1.006-1.008). The education attainment level did not affect patient usage in the billing/insurance and resource/education domains. Individuals living in the area with greater percentage of households below the federal poverty level tended to spend more time viewing and using the health information management domain (OR=1.003, 95% CI, 1.001-1.005) or

billing/insurance domains (OR=1.004, 95% CI, 1.001-1.007), whereas the poverty percentage did not affect the usage of the messing or resource/education domains.

DISCUSSION

This study provides an innovative approach to examine factors influencing patient use of virtual care platforms by measuring the amount of time patients spent on online portals through the access log records in the EHR system. We found that patients accessed a wide range of communication- and care-related features in the online portal, and most portal utilization was related to viewing personal health information and care summaries. This finding is consistent with the previous literature confirming the growing adoption of patients in using EHRs to track personal health information and manage care activities (Adler-Milstein et al., 2017; Patel & Johnson, 2018). Online patient portals not only help patients become more informed about their health conditions, but also make healthcare more convenient and accessible. However, our data analysis revealed that only a fraction of patients took advantage of the portal's interactive communication features designed to facilitate patient self-management, such as messaging for medical advices or tracking health goals. Patients may not use these features because they feel hesitant to use too much clinician time, worried about sending inappropriate messages, and find using the interfaces difficult (Hefner, MacEwan, Biltz, & Sieck, 2019; Lafata et al., 2018). Those challenges prevent patients from communicating with their care teams effectively through virtual care platforms.

Overall Portal Usage Pattern

In general, the analysis shows that patients with more chronic conditions, prescriptions, and laboratory tests spend more time using various features of the online portal. These patients tend to have higher healthcare utilization and often require more efforts to maintain their health

conditions outside of traditional medical settings. Prior research also indicates that, because of

the constant availability of virtual care platforms, individuals who are chronically-ill or have

greater healthcare needs have shown higher frequency in utilizing patient portals to manage and

monitor their care activities (Otte-Trojel, Rundall, de Bont, van de Klundert, & Reed, 2015;

McGrail, Ahuja, & Leaver, 2017). As new functionalities continue to be incorporated into

patient portals to facilitate information exchange and care coordination, patient portals have

gradually become an extension of care services for primary care clinicians to monitor

physiologic and laboratory data remotely, or delegate staff on a care team to engage in proactive

e-mails and other asynchronous communications to replace an office visit or avert emergency

room care (McGrail, Ahuja, & Leaver, 2017).

Nonetheless, the literature has shown very few patients who have regularly used online

portals (Patel & Johnson, 2018), despite a large increase in patient portal enrollment in the past

decade. The use of online portals is unevenly distributed among population groups with

different demographic and economic backgrounds. Our analysis shows that male, elderly, and

minority patients have less tendency to use the online portal. Individuals in rural areas also

have lower online portal usage than those in the urban and suburban areas. The pattern reflects

the digital divide phenomena in prior health services research (Graetz, Gordon, Fung, Hamity,

& Reed, 2016; Perzynski, 2016). The phenomena theorizes that quality and outcome of care

can be affected by the distribution of individuals' access to or use of online technology. The

digital divide raises concerns that certain patient populations are less likely to adopt and benefit

from virtual care platforms. Those individuals often experience economic hardships and social

constraints throughout their life, including long working hours, poor health literacy, negative

perceptions toward new technology, privacy and security concerns, inadequate social support, and limited access to computers and the Internet (Choi & DiNitto, 2013; Sarkar et al., 2011).

Moreover, a mission of the federal government's meaningful use requirements is to offer patients the ability to view and access their health information via online portals or secure e-mail exchanges. Yet, getting patients to sign up for an online portal does not guarantee a patient will use the portal to manage their health. Recent statistics reveal that more than half of the patient population in the U.S. had access to various online portal platforms, but only a fraction of those patients viewed their health records online (Patel & Johnson, 2018). Thus, while healthcare communities continue to promote the use of virtual health tools to keep their patients connected to their caregivers, primary care clinicians should be sensitive to technological, economic, and cultural barriers faced by individuals (Anthony, Campos-Castillo, & Lim, 2018).

Domain-Specific Usage

Modern patient portals enable users to view and manage a wide range of personal health information and care-related features, such as messaging, appointments, lab results, disease management, and lifestyle coaching. Researchers in virtual care functionality often looked for ways to help patients utilize online features during care processes. Because many portal features share similar clinical or functional natures, the level of utilization of those feature categories can be correlated with each other. For instance, people frequently reading their personal health information may also be more likely to view visit summary information through virtual care interfaces. Thus, it is not practical or effective to analyze the pattern of virtual care utilization by each feature type or by assessing all feature types in one model. The present study used dimensionality reduction methods to group online portal features into four domains: messaging, health information management, billing/insurance, and resource/education. These

dimensions became composites of specific feature types, which in turn allowed the dimensions to be analyzed and interpreted in broader categories representing how patients utilized virtual care platforms.

This study showed that the influence of the practice and patient characteristics on the degree of portal usage could vary by the feature domain. In essence, we observed large differences in use of electronic messages across most patient, clinic, and community characteristics. The discrepancy may occur because features in the messaging domain often involve more complex designs and interactivities that require patients with a greater level of technology proficiency and health literacy to learn to use messaging interfaces. Thus, patients' intention to use messaging features can be very sensitive to the knowledge, experience, and self-efficacy of the patients regarding health information technology. To reduce gaps in messaging utilization, the literature suggests that health systems can offer patients training on the use of messaging features and enhance interface designs to provide clearer guidance and rules in helping patients determine appropriate message types and contents to meet their healthcare needs (Sieck et al., 2017; Hefner, MacEwan, Biltz, & Sieck, 2019).

Education and Health Insurance

Our analysis also revealed that patients living in the neighborhoods with a greater percentage of the college-educated population were more likely to view or interact with features in the health information domain. This finding again demonstrates that education plays an important role in helping individuals become more engaged in navigating healthcare services and managing their health conditions (Davis, Osborn, Kripalani, Goggins, & Jackson, 2015). Individuals living in neighborhoods with higher education levels could have greater socioeconomic conditions, and likely have other important resources and support facilitating

patient portal use. Education also shows positive correlations with features in the

billing/insurance and resource/education domains, though its impact is not evident. It is

probably because the payment and resource designs of these domains provide patients similar

experiences to typical consumer retail websites. Thus, tendency to use these features is not

affected by their knowledge in health and healthcare.

Health insurance was also identified as an important predictor for patient portal usage in

the study. Prior health service research indicates that individuals who are uninsured or on

public health insurance are less likely to sign up or use patient portals, due to sociodemographic

and economic barriers (Anthony, Campos-Castillo, & Lim, 2018; Lafata et al., 2018). While

our study consistently showed that a greater percentage of uninsured and public insured patients

did not have online portal accounts than patients with commercial health insurance, the analysis

found mixed results in portal usage across different feature domains among portal users.

Essentially, patients with commercial health plans had greater usage of most of portal features

than individuals who were uninsured or on public insurance. Yet, Medicare patients were more

likely to use features in the health information domain; possibly to meet increasing needs in

managing appointments and care outcomes due to chronic and aging-related health conditions.

Medicaid and uninsured patients were also more likely to use online portals to view health

education and other resource information. This is possibly because individuals who are

uninsured or on public health insurance may lack resources or social support to find needed

healthcare information. Online portals may become an accessible tool for them to find

treatment information and track their health plan enrollment status. This finding is consistent

with recent studies showing that underserved patient populations seem more willing to accept

and use online portals, even though they tend to face challenges in enrolling in virtual care platforms (Ancker et al., 2011; Wallace et al., 2016).

Internet Access

In our study, we also found that having Internet access only slightly affected the use of features related to the messaging domain, but not in other feature domains. Access to the Internet has rapidly increased in the past two decades. In 2016, eight in ten of U.S. adults had online access through either home computers or smartphones (Ryan, 2017), and over 90% of Americans are expected to have Internet access by the year 2020. Hence, simply having online access may no longer be a reliable predictor for the intention to use patient portals. Interestingly, patients living in less affluent neighborhoods show slightly greater tendency to use the online portal to look up personal health and billing information. This finding seems counterintuitive to general beliefs that lower portal usage occurs among people who have lower income or lack of online access. The paradox may be explained by the rapid growth of smartphone ownership among vulnerable or underserved population (Anderson & Kumar, 2019; Vangeepuram et al., 2018). A recent survey by the Pew Research Center (2019) indicates that a growing number of lower-income Americans use smartphones to access online information. Over one quarter of adults living in households whose annual income is less than $30,000 solely rely on smartphones to access the internet (Anderson & Kumar, 2019). Increasing ownership in smartphones has made internet more accessible to individuals who traditionally did not previously have computer-based internet connection.

Study Limitations

Our study included several limitations. First, despite a large sample size, the study population was mainly based on a single regional academic healthcare center, limiting the

findings' generalizability. Second, the time tracking process was terminated after a portal

session became idle for 15 minutes. Because there was no way to ascertain when patients

stopped viewing or interacting with the portal, the time estimate could be imprecise for sessions

that were timed out. Third, because the internet access and socioeconomic variables are not

available in the individual level of the EHR data, the study uses census tract statistics driven

from patients' home location as proxies for these characteristics. Census tract data are

aggregated statistics that summarize the overall sociodemographic nature of a small

neighborhood area. This data may not capture all the variation in an individual, possibly

diluting predictive power (Geronimus & Bound, 1998). Fourth, although most of virtual care

features examined in the study are offered across different EHR systems, the patient intention to

use these features can be limited to their experience regarding how these portal features are

implemented and used specially in the EHR platform of the study. Fifth, the study did not

examine the patterns of the portal usage of young and proxy users who could have different

functional needs from their adult counterparts in using patient portals. Sixth, social

psychological effects are not assessed in the analysis that could also influence patient adoption

of online portals (Giardina, Baldwin, Nystrom, Sittig, & Singh, 2018). Similarly to how

consumers make online purchasing decisions, the use of online portals can be affected by

patients' attitudes and beliefs toward online technology, such as privacy concern, dissatisfaction

from previous online experiences, and preferring to speak to a clinician (Anthony, Campos-

Castillo, & Lim, 2018). Thus, assessment on socio-psychological characteristics could provide

a more comprehensive picture on patients' motivation and acceptance in using online portals.

CONCLUSIONS

The widespread adoption of virtual care platforms has enabled patients to receive a broad range of medical support outside of brick-and-mortar medical settings. The goal of this research was to bridge gaps in the knowledge of type and amount of use of online portals in primary care practices by analyzing the amount of time spent by patients viewing and interacting with various portal features. Through this study, we identified the use of patient portal by four feature domains: messaging, health information management, billing/insurance, and resource/education. Each domain represents the unique care and communication aspects of the portal functionality that can either spur or hamper patient engagement in the use of online portals. Analyzing data by each feature domain can help health systems gain more useful insight into how patients leverage different virtual health features to improve access and self-care. The overall results of the study resonate with findings in prior health service research that patients having more chronic conditions, lab tests or prescriptions have greater patient portal usage. Patients who are male, elderly, in minority groups, or living in rural areas persistently have lower portal usage, in addition to already lower patient portal enrollment rates for these population groups. Contrary to popular beliefs, individuals who have public health insurance or reside in underserved neighborhoods seem more likely to use certain portal features or do not show significant differences, compared to their counterparts. Thus, while promoting the use of virtual health tools as part of patient-center care delivery model, primary care clinicians need to be aware of technological, socioeconomic, and cultural challenges faced by their patients. It is essential for primary care practitioners to understand the pattern of virtual care utilization to enhance patient engagement and care experience and to achieve better continuity of care. Failure to do so could potentially harm the healthcare organization's overall care quality and financial stability in the long run (Neuner, Fedders, Caravella, Bradford, & Schapira, 2015).

We hope that this study will help primary care practitioners formulate more effective strategies to integrate virtual care platforms into continuity care practices, and thus, improve population health management.

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