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The Impact of Electronic Health Records on Healthcare Service Delivery, Patient Safety, and Quality

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THE IMPACT OF ELECTRONIC HEALTH RECORDS ON HEALTHCARE SERVICE DELIVERY, PATIENT SAFETY, AND QUALITY

by

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ABSTRACT

The HITECH Act has provided over $35 billion of support through the Meaningful Use program to implement Electronic Health Records (EHRs) with aims to improve healthcare service delivery, efficiency, quality, and patient safety. New healthcare models, such as pay-for-performance and value-based purchasing, were envisioned to aligning quality with reimbursement mediated with the use of EHRs. It is unclear of how EHRs and Meaningful Use have impacted health service delivery, patient safety, and quality of care. Thus, making it difficult to determine if the specific set of objectives for Meaningful Use have had a positive impact on outcomes, which ultimately is the goal of the program. The objective of this dissertation is to study the impact of EHRs on healthcare service delivery outcomes related to e-health services and productivity. Furthermore, the objectives are to study the impact of EHRs and Meaningful Use attestation on patient safety and inpatient quality of care.

The results demonstrate gains in efficiency may be achieved during patient-physician interaction time with the use of fully EHRs, where physicians saved 1.53 minutes per visit in time spent with the patient, or a 6.1% gain in efficiency. EHR use significantly improved the odds of providing e-billing, e-consults, and e-prescribing. We found that fully-implemented EHRs that did not attest to Meaningful Use had a significant positive impact on 3 patient safety outcomes, and hospitals that attested to Meaningful Use had a significant positive impact on 2 patient safety outcomes. However, there were no significant differences in patient safety composite scores. Last, there were significant differences in inpatient quality composite scores. Hospitals attesting to Meaningful Use had 18% improvements in mortality for selected conditions, and 8% improvements in mortality for selected procedures.

In conclusion, EHRs and the Meaningful Use program have had positive impacts on healthcare service delivery and inpatient quality of care. More efforts may be needed to improve patient safety with the use of EHRs, which may need to focus on EHR certification or Meaningful Use objectives. Future studies should determine specific EHR functionalities and Meaningful Use objectives that are associated with positive outcomes to further direct policy development.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

ACA	Affordable Care Act
AHA	American Hospital Association
AHRQ	Agency for Healthcare Research and Quality
AOR	Adjusted Odds Ratio
APR-DRG	All Patient Refined Diagnosis Related Groups
CHPL	Certified Health IT Product List
CI	Confidence Interval
CMS	Centers for Medicare and Medicaid Services
EHR	Electronic Health Record
GLM	Generalized Linear Model
HCUP	Healthcare Cost and Utilization Project
HHI	Herfindahl-Hirschman Index
HIT	Health Information Technology
HITECH	Health Information Technology for Economic and Clinical Health
IQI	Inpatient Quality Indicator
IQR	Hospital Inpatient Quality Reporting Program
MU	Meaningful Use
NAMCS	National Ambulatory Medical Care Survey
OLS	Ordinary least squares
ONC-ACB	Office of the National Coordinator Authorization Certification Body
ONC-HIT	Office of the National Coordinator for Health Information Technology
OR	Odds Ratio
PCMH	Patient Centered Medical Home
PR	Population Rate
PSI	Patient Safety Indicator
PSU	Primary Sampling Unit
RAR	Reliability Adjustment Ratio
RHQDAPU	Reporting Hospital Quality Data for Acute Payment Update program
SD	Standard Deviation
SID	State Inpatient Database
SVY	Survey Design
VBP	Value-Based Purchasing

CHAPTER 1: How are Electronic Health Records changing the way we offer healthcare services?

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ABSTRACT

Background: New healthcare models were envisioned to be mediated with the use of Electronic Health Records (EHRs), and aimed to deliver patient-centered care that increases patient access to their physicians by focusing on physician time spent with the patient, same-day scheduling, telephone consults, e-consults, and e-prescribing. These outcomes are aimed at improving patient satisfaction while aligning quality with reimbursement, through pay-for-performance and value-based payment. It is unclear of how these technologies have changed processes impacting patients during health service delivery, given the mixed results regarding EHR efficiency and productivity. Studying the impact of EHRs ability to transform healthcare services will be important to direct policy efforts.

Objective: The objective of this study was to determine the impact of EHR use on health service delivery outcomes, including providing set aside same day appointments, e-billing, e-consults, e-prescribing, and physician time spent with the patient, among a nationally representative sample of office-based physician population in the United States. Additionally, we provided subsample analyses stratified by physician specialty, group and solo practices, and rurality to determine the impact of EHR on health delivery outcomes.

Methods: We used a nationally representative sample of office-based physicians using 2012 National Ambulatory Medical Care Survey (NAMCS) survey data. There were a total of 3,583 physicians who participated in the study. The estimation model adjusted for solo or group practice (practice size), ownership of organization, percent of revenue from Medicaid patients (payer mix), rurality, region, physician-level patients' reason for visit, and physician specialty. An ordinary least squares (OLS) method was used to determine the effect between EHR use and average time spent with patients. A logit model was used to determine the effect of EHR on the other health service delivery outcomes, including set aside same day appointment, e-consults, e-prescribing, and e-billing. All analysis were adjusted with primary sampling unit (PSU), probability weight, and strata in survey design analysis (SVY) to provide nationally representative individual physician level estimates using Stata/IC v.14.1.

Results: In 2012, over half (54.3%) of physicians used fully EHRs in their practices, while 32.2% of physicians did not have EHRs, and 13.5% had partially EHR systems. Among health service delivery outcomes, the majority of the physician population in the United States had set time aside for same day appointments (61.2%). The total physician population spent an average of 24.3 minutes with their patients per visit. Only 13.2% of the physicians provided an e-consult with patients in the last week. Ninety-three percent of the physicians sent their order prescriptions electronically to the pharmacy (e-prescribing). Eighty-seven percent of physicians submit claims electronically (e-billing).

This study demonstrates that gains in efficiency may be achieved during patient and physician interaction time with the use of fully EHRs, where physicians saved 1.53 minutes per visit in time spent with the patient, or a 6.1% gain in efficiency. The odds of providing e-billing is consistently greater with the use of EHRs across our analyses.

There was a significant positive relationship between physician's use of fully EHRs and providing e-consults, where physicians using fully EHRs were 1.06 times more likely to provide e-consults than their counterparts without EHRs. There was a significant positive relationship in providing e-prescribing with physician's use fully EHRs, where physicians using fully EHRs were 1.38 times more likely to provide e-prescribing services compared to their counterparts without EHRs. Although, there was not a significant difference in our final model in offering set aside same day appointments between physicians with varied EHR use, in our stratified analyses we found that physicians that belong to group practices and rural areas were more likely to offer set aside same day appointments with the use of EHRs. Physicians that belonged to group practices with fully EHRs were 0.57 times more likely to offer set aside same day appointments compared to their counterparts without EHRs. Physicians that practiced in rural areas with fully EHRs were 1.14 times more likely to offer set aside same day appointments than their counterparts without EHRs. Rural providers have significantly greater odds of providing e-consults, e-billing and set aside same day appointments with the use of fully EHRs compared to rural physicians without the use of EHRs, and with a stronger effect than urban physicians with the use of EHRs. Although, urban physicians also had a significant gain in efficiency in time spent with the patient with use of fully EHRs, these gains were not observed among rural physicians. Primary care physicians with the use of fully EHRs have significantly greater odds of providing e-consults, e-billing, and e-prescribing compared to their counterparts without the use of EHRs. Providers in group practices with the use of fully EHRs have significantly greater odds of providing e-consults, e-prescribing, e-billing, and set aside same day appointments compared to providers that belong to group practice without the use of EHRs, and the effect was stronger than physicians that belong to solo practices. Medical specialties had the biggest gains in time efficiency for time spent with the patient with the use of fully EHRs, with a time savings of 3.16 minutes per visit.

Conclusion: Despite the significant financial, technical, and interoperability challenges in implementing and adopting EHR systems, we have seen significant progress in providing intended electronically mediated health service delivery among physicians utilizing fully EHR systems, even among early adoption in 2012. Despite the challenges rural providers have faced with EHR adoption and use, health service delivery has been significantly impacted with the use of EHRs among rural providers. Physicians that face higher degrees of uncertainty may be leveraging their EHR to provide healthcare services to maximize benefits to their practice, but may not see time efficiency gains. Additionally, among physicians with higher degrees of munificence may have the resources to see either time efficiency gains and deliver e-mediated healthcare services, depending on the nature of their work to meet the needs of their practice. Simply adopting and utilizing partially EHRs will not be enough to achieve the aims for our healthcare system to deliver electronic mediated healthcare services, including set aside same day appointments, providing e-consults, providing e-prescribing services, and efficiency in time spent with patients. Focusing Meaningful Use objectives on early successes may decrease the risk of penalties among lower resourced providers that are having difficulties adopting certain functionalities within EHR systems, such as interoperability.

INTRODUCTION

The goals set for the United States healthcare system by the Affordable Care Act (ACA) were envisioned to be Health Information Technology (HIT) mediated, with a $35 billion dollar investment provided through the Health Information Technology and Economic and Clinical Health (HITECH) Act. The HITECH Act was signed into law on February 17, 2009 with aims to promote the adoption and Meaningful Use of HITs in the United States healthcare systems, such as the adoption of EHRs. With the use of Electronic Health Records (EHRs), these goals were to achieve more affordable care at a higher quality, increase patient satisfaction, increase provider productivity and efficiency, and increase access to healthcare services for patients. Wide-scale adoption and implementation of EHRs across the healthcare system were aimed at achieving diverse efficiencies in healthcare service delivery by the ability to better record, store, and share information, including increased productivity, reduction in waste, reduced transcription costs, reduction in record storage and retrieval, reduction in medical errors, improved safety and quality, and provide a cost savings (Kumar and Bauer, 2011). However, it is currently unknown how EHRs have mediated changes in the United States healthcare service delivery to increase efficiency and improve access to care with electronic-mediated services.

Studying the impact of EHRs ability to transform healthcare services will be important to direct policy efforts in the future, especially where it has been identified as a top challenge for physicians in the United States to overcome the penalties if they are not able to meet the requirements of the federal Meaningful Use incentive program (Bendix et al., 2013). In order to receive Meaningful Use incentives, providers must demonstrate “Meaningful Use” with the use of their EHRs by meeting the criteria and objectives outlined in the different stages of the program. Stage 1 of the Meaningful Use program focuses on data capturing and sharing information between patients and providers. Objectives of the Meaningful Use of EHRs may need to be re-visited, and re-directed to focus on early successes in order to avoid penalizing physicians facing challenges in implementation and utilization. Stage 2 focus on advance clinical processes, such as health information exchange, increased requirements for e-prescribing and digitizing laboratory results, and incorporating patient controlled information. However in 2013, only 5.8 percent of hospitals met the criteria for Stage 2 Meaningful Use readiness with their EHR systems (Adler-Milstein et al, 2014). Due to the challenges in meeting Stage 2 Meaningful Use, further modifications to Meaningful Use were implemented in 2015 with the creation of "Modified Stage 2", making it a pivotal time to study the ability of EHRs to impact positive change in our healthcare system. Stage 3 will likely focus on improving outcomes by incorporating clinical decision support, patient data self-management tools, and comprehensive data available through health information exchanges.

EHRs have the ability to deliver information to diverse members of healthcare teams at different times during the workflow and decision making processes (Grossman, et al, 2011), where implementation also requires restructuring healthcare service processes to incorporate the use of information technologies during service delivery. It is unclear of how these technologies have changed processes impacting providers and patients during health service delivery, given the literature warrants mixed results regarding efficiency and productivity (Miller et al, 2004; Miller et al, 2005; Baron, et al, 2005; Miller and Newman, 2004; Miller et al, 2005). Implementing EHRs have not come without challenges, where physicians report dissatisfaction including poor usability, time-consuming data entry, interference with face-to-face patient care, inefficient and less fulfilling work content, inability to exchange health information, and degradation of clinical documentation (Friedberg et al, 2013). The literature has suggested mixed results regarding the benefits and costs of EHR systems (Baron, et al, 2005; Miller and Newman, 2004; Miller et al, 2005), and some studies suggest that EHRs may not be worth the high cost and disruptions (Verdon, 2014). Providers may have to extend, rather than reduce, their hours per patient visit when EHRs decreased the efficiency of service delivery to avoid financial losses in covering the cost of implementing EHRs (Miller, et al, 2005). Achieving the intended positive outcomes may be more complicated than first envisioned by the ACA and the HITECH Act. It is unclear if the national investment of EHRs have been effective in creating efficiencies in healthcare service delivery and increasing patient's access to physician services.

Offering patient-center care has been a focus of our healthcare system, and has led to the implementation of models such as the patient centered medical homes (PCMH) and pay for performance, which focuses on improving patient satisfaction through dimensions related to scheduling, access to care, e-health, and time spent with physicians (Lewis, 2009). These new healthcare models are mediated with the use of EHRs, and aimed to deliver patient-centered care that increases patient access to their physicians and patient satisfaction. Health service delivery practices that are critical to deliver patient-centered care include offering same-day scheduling, email consults, telephone consults, and e-prescribing. Same-day scheduling, email consults, telephone consults, and e-prescribing improve patient satisfaction while aligning quality with reimbursement, which are applied in pay-for-performance and value-based designs (Carrier et al., 2009). Additionally, moving toward a PCMH model was listed as one of the top ten challenges facing physicians in the United States in 2014 that focuses on outcomes in offering electronic mediated healthcare services, fully utilizing EHRs to improve workflow and processes, and offering set aside same day appointments as part of offering patient-center care (Bendix et al., 2013).

The literature suggests that providers lag behind in the ability to offer e-health resources and e-business tools (such as e-billing) to meet the consumers' needs, and researchers rarely study the efforts in providing these services to meet the patients' needs (Huang et al., 2012). There is considerable interest in finding digital solutions to enhance the quality, safety, and efficiency of care in healthcare (Black et al, 2011). Widely utilizing e-billing in the healthcare system through the use of EHRs will change the paradigm of outcomes research, making it possible to link billing claims with health outcomes and maybe even survey data (Zacker et al., 2010; Hogan, Mattison, 1993). Additionally, it will improve provider's productivity and financial outcomes by better documenting services provided to their patients (Miller & Sim, 2004). To our knowledge, there are no studies determining the impact of EHRs on improving the physicians' ability to provide e-billing services in the United States. Furthermore, e-consults are interactions between physicians and patients located outside of their practices mediated by electronic modes. E-consults significantly improve both the timeliness of and access to care as compared to traditional consultation processes, and is perceived as highly beneficial by providers and patients (Keely et al., 2013). Furthermore, e-prescribing is another electronic-mediated service that improves healthcare efficiency and increases medication safety (Weingart et al, 2009; Hollingworth, et al, 2007; Schade, et al, 2006). E-prescribing systems are used to enter, modify, review, and communicate pharmacy orders (Car et al, 2008). As EHR adoption has increased significantly across the United States, we should also determine its impact on e-billing, e-consults, and e-prescribing.

Lastly, it is unclear if the use of EHRs during the patient visit has translated into improving productivity for physicians during time spent with patients. One study reported that with the use of an EHR, physicians were able to see patients in less time, but the study was only conducted among 14 solo and small group practices (Miller et al, 2005). The ability to reduce the time to collect patient information during patients' visits improved physicians' productivity. One time-in-motion study found there were no significant differences in time spent with patient for direct care (time spent examining and talking to the patient) post-implementation of EHR systems (13.4 minutes vs. 13.6 minutes; $p=0.86$) (Pizziferri, et al., 2005). However, this study was based on a small sample size of only 20 physicians (Pizziferri, et al., 2005). Other studies suggest that efficiency may not be gained by increasing the reporting of quality measures and complexity of medical care standardization, but does not show the direct impact on time spent with patients (Casalino, et al., 2016). In fact, one recent study shows that physicians in the United States among four common specialties spend as much as 785 hours on average per physician each year and more than $15.4 billion dealing with the reporting of quality measures, due to both fragmentation of the healthcare system and poor standardization, functionality, and interoperability in EHRs (Casalino, et al., 2016). Therefore, it is unclear if the increased documentation during the visit actually increases time spent with patients resulting in decreased productivity. Given the current state of the literature, more research is warranted to determine the impact of EHRs on physicians' productivity with national physician samples. Nationally representative studies are needed to better understand the impact of EHRs on time spent with patients.

Are barriers to implementing and utilizing EHR systems out-weighing the benefits, thus making it difficult to move toward offering more efficient and productive healthcare service delivery methods, or have EHRs made a positive impact on how we deliver healthcare services? The objective of this study was to determine the impact of EHR use on health service delivery outcomes, including offering set aside same day appointments, providing e-billing, e-consults, e-prescribing, and physician time spent with patient, using a nationally representative office-based physician population in the United States. Additionally, we provided supplemental analyses to determine the impact of EHR use on these health service delivery outcomes by physician specialty, group and solo practices, and rurality.

THEORETICAL FRAMEWORK

Resource Dependence Theory central proposition is that organizations will alter their behaviors to manage their resource dependencies in order to achieve greater autonomy and reduce uncertainty in the flow of vital resources from the environment (Pfeffer and Salancik, 1978; Pfeffer and Salancik, 2003). EHRs were envisioned to create service efficiency and increase productivity for providers, allowing physicians to serve more patients with higher quality of care. However, it is costly to purchase and implement EHR systems which contribute to high fixed costs for providers. One study suggests that EHRs may not be worth the high cost and disruptions, since nearly 45% of physicians from the national survey report spending more than $100,000 on an EHR, and 77% of the largest practices spent nearly $200,000 on their systems (Verdon, 2014). EHRs may also contribute to variable costs, such as staff training or technical support required to implement the system and keep it functional for users.

Constructs of the RDT are uncertainty, munificence, and interdependence. Uncertainty refers “to the degree to which future states of the world cannot be anticipated and accurately predicted” (Pfeffer and Salancik, 1978). Munificence refers to the abundance of critical resources in the environment to support the organization’s survival. Through the adoption of EHRs, providers may be eligible to receive Meaningful Use incentives by meeting a set of objectives through the use of their EHRs. By receiving these incentives for the use of their EHRs, they are able to secure resources in their environment. EHRs have the ability to deliver information to diverse members of healthcare teams at different times during the workflow and decision making processes (Grossman, et al, 2011). We make the following hypotheses of the impact of EHRs on the following heath service delivery outcomes:

(H1) Physicians using EHRs are more likely to achieve better service delivery outcomes, including e-consults, e-billing, e-prescribing, and set aside same day appointments, as compared to their counterparts without EHR use.

(H2) Physicians using EHRs are more likely to achieve higher productivity by efficiency gains in time spent during patient visits, as compared to their counterparts without EHR use.

However, rurality may impose higher uncertainty and lower munificence to providers, as rural healthcare organizations face challenges in resource acquisition through serving a smaller population and operating in environments with less adequate resources. Incorporating concepts of RDT is appropriate in describing the relationship between EHR adoption and rurality of providers. Health care providers located in areas with a high degree of rurality, such as Critical Access Hospitals (CAH), may not have adequate and stable resources required to address challenges in implementing and maintaining HITs after purchasing. Sixty percent of Critical Access Hospitals (CAHs) reported financial challenges, while over half reported significant workflow or staffing challenges regarding HIT use and implementation (Gabriel, Jones, Samy, 2014).

RDT states “organizations are constrained and affected by their environments and that they act to attempt to manage resource dependencies” (Pfeffer and Salancik, 2003). Interdependence refers to organizations reliance on one another for the acquisition of resources. Rural health care providers may adopt EHRs to secure more resources provided through the Meaningful Use Incentive program. However, rural providers may incur more unexpected costs and have un-stabilized revenue as a result of EHR implementation. Therein, rural providers may not be receiving the adequate amount of incentives and support services required to help these lower resourced providers to use their EHRs to improve the service efficiency and productivity among providers, compared to their urban counterparts. One study reported that initial cost for EHRs among solo or small group practices averaged $44,000 per full-time-equivalent (FTE) provider with an average of $8,412 (19.5% of initial costs) of ongoing costs per year per provider (Miller et al, 2005). The study also reported that some providers experienced losses from reduced visits, but the losses were dependent on whether providers worked longer hours instead of reducing patient visits (Miller et al, 2005), suggesting that they did not see uniform gains in service efficiency or service productivity. In fact, practices vary in benefits and costs, with providers being able to pay back the cost of their EHRs ranging from 4 years to never being able to pay for their EHRs (Miller et al, 2005).

(H3) The effect of EHR use for physicians practicing in rural areas is smaller than physicians practicing in urban areas, when compared to their counterparts without EHRs.

(H4) Physicians practicing in rural areas using EHRs are less likely to achieve higher productivity by efficiency gains in time spent during patient visits than physicians practicing in urban areas, when compared to their counterparts without EHRs.

Physicians' characteristics are important factors when studying health service delivery outcomes. In a recent study which included 59 primary care providers, physician specialty impacts e-consult outcomes, where e-consults are delivered most commonly by physicians in dermatology (20%), endocrinology (13%), neurology (11%), internal medicine (10%), cardiology (10%) and hematology (9%) specialties. In our analysis, we also provided a subsample analyses to further explore the impact of EHRs on health service delivery outcomes between provider specialties. Furthermore, engagement in new delivery models may impact the ability to achieve outcomes related to service efficiency and productivity, such as set aside same day appointments, e-consults, telephone consults, and time spent with patients (Carrier et al., 2009). The physicians' perceived usefulness of the technology will also impact the outcomes of health information technology (Ketikidis et al, 2012), and may impact the way physicians interact and utilize their EHR systems.

Finally, practice size is another important organizational characteristics that influences the ability to adopt advanced technologies and impacts health service delivery outcomes (HSRA, 2010; MGMA, 2010; Casalino et al, 2004; Welch et al, 2013). Physicians have started to move toward belonging to group practices in the last decade in order to increase munificence and sharing of resources (Liebhaber, Grossman, 2007; Welch et al, 2013), which decreasing uncertainty for healthcare providers. Group practices have certain advantages over solo practices that would make it easier to achieve outcomes related to improved quality and healthcare service efficiency including greater access to capital to make technology investments, shared resources, greater ability to standardize processes, and the ability to accept more insurance risk (HSRA, 2010; MGMA, 2010; Casalino et al, 2004; Welch et al, 2013). The literature also reports that solo and small group practices can absorb significant financial risk when implementing EHR systems (Miller et al., 2005). Based on the constructs of the RDT, group practices may have greater munificence and face less uncertainty compared to solo practices. The resources provided from the Meaningful Use incentive program may have positively impacted outcomes among group practices compared to solo practices, where group practices are getting incentives awarded based on the number of providers utilizing EHR systems that meet "Meaningful Use". Therein, allowing group practice may have more resources (or munificence) to purchase EHR systems with advanced functionalities, higher usability, and seek more technical support, making it easier to transform their health service delivery patterns.

(H5) The effect of EHR use for solo providers is smaller than that for their counterparts practicing in group practices, when compared to their counterparts without EHRs.

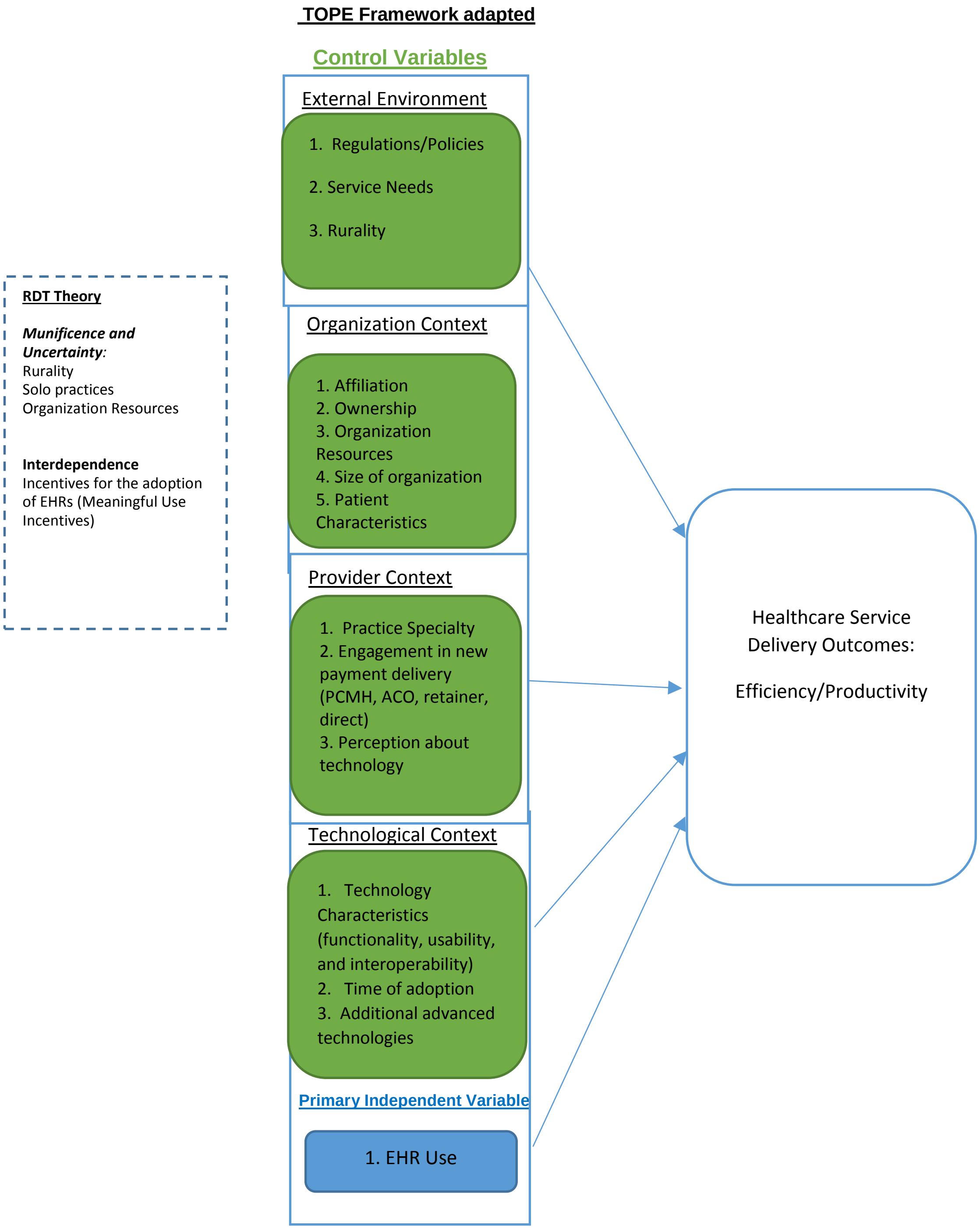
(H6) Physicians that belong to solo practices using EHRs are less likely to achieve higher productivity by efficiency gains in time spent during patient visits than physicians that belong to group practices, when compared to their counterparts without EHRs.

Furthermore, HIT adoption and use are influenced by institutional pressures/norms. Institutional theory declares that something identified at a higher level, such as organizational characteristics, can explain processes and outcomes at a lower level of analysis (Clemens and Cook 1999; Amenta 2005). An organization must conform to the rules, belief systems, and norms in the environment in order to gain organization legitimacy (Scott, 1995; Suchman, 1995). In fact, research shows that organizational factors appear to be more influential than market factors when it comes to information technology adoption and use (Zhang, et al, 2013). Furthermore, evidence suggests that there may be a relationship between intuitional factors and resource factors in the provision of services (Goodrick and Salancik, 1996), and the adoption and use of HITs vary by organizational characteristics (Zhang, et al, 2013). Ownership of the organizations may influence the adoption of certain health delivery services based on their institutional norms and values. Furthermore, the patient characteristics related types of conditions and payer mix may impact heath service delivery, where the literature states resource factors are important in the provision of services (Goodrick and Salancik, 1996)

Technology context must not be overlooked when researching HITs, including interoperability, functionality, and usability of EHR systems. Health information exchanges and health information sharing of patient records is an important means to improve care coordination across providers. It is widely cited that interoperability and information sharing will play a large role in improving the healthcare system (Cutler et al., 2006; Kvedar et al., 2014; Tan, 1999), but its design and implementation has been a challenge in the healthcare sector. Second, HITs highly vary in functionalities, especially when EHR systems are developed in different sectors of academia and industry. Next, users interact with HITs in different ways with different backgrounds and needs. Implementing HITs with high usability that are easy for providers with different backgrounds to use will be necessary to reduce waste. Furthermore, usability testing should direct future development efforts by focusing on measuring the technology's ability to meet the intended purpose. HIT usability evaluation has been overlooked widely during technology development, and has impacted the inability to accomplish system efficiency, effectiveness, and satisfaction (Minshall, 2013; Yen & Bakken, 2012), and needs to be controlled for when studying HIT adoption and utilization. HIT adoption can be highly complicated by marketing strategies, rather than be influenced by the true usability and functionality of the technologies. Transparency needs to be created among technological factors in order to effectively study HITs. In this study we could not determine the specific functionalities beyond partially electronic and fully EHR systems used by providers due to the lack of data. These EHRs in each group may vary by functionalities and usability. Future studies should incorporate these factors into their theoretical framework, as they impact outcomes of technology use.

The newly developed framework views the impact of technology adoption and utilization on health service delivery outcomes from an institutional and resource dependence perspective, and focuses on describing characteristics of providers that influence health service delivery outcomes with the use of EHR technologies. The constructs of the newly develop framework includes: (1) external environment, (2) organizational context, (3) provider characteristics, and (4) technological context (Figure 1).

Figure 1. A framework for HIT impact on healthcare service efficiency and productivity: Information Technology- Technology, Organizational, Provider, and Environmental (IT-TOPE)



METHODS

Data and Study Sample

We used a nationally representative sample of office-based physicians from the 2012 National Ambulatory Medical Care Survey (NAMCS) survey data. The NAMCS is conducted by the National Center for Health Statistics, Center for Disease Control and Prevention (CDC) annually. The sampling frame for the 2012 NAMCS includes all non-federally employed physicians listed in the files maintained by the American Medical Association (AMA) and the American Osteopathic Association (AOA) of physicians providing “office-based” patient care, which was sampled about 6 months prior to the beginning of the survey year. Physicians were included if they are: (1) not in specialties of anesthesiology, pathology, and radiology; and (2) younger than 85 years of age at the time of the survey.

Individuals that did not see any patients during the sample week were excluded from the study. Based on the number of full responders and those who saw no patients during their sample week, the unweighted response rate was 39.3 percent and the weighted response rate was 39.4 percent. Based on the total of full and minimal responders (those that submitted fewer than half of the expected number of patient record forms) including those who saw no patients during their reporting week, the weighted participation rate was 45.6 percent. There were a total of 3,583 physicians included in the study sample. NAMCS data is constructed of both patient-level and physician level data. Patient-level data was collected using information from the patient office-based visits. Physician-level responses were collected through the Physician Induction Interview. For the purposes of this study, we utilized physician-level responses and physician-level estimates were also computed using patient-level data for the physicians included in the study.

Dependent and Independent Variables

Outcome variables included in the study were healthcare service delivery variables related to service efficiency/productivity to mediate new healthcare delivery models, including e-consult, e-prescribing, e-billing, set aside same day appointments, and time spent with patients. These outcomes also associated with increased patient satisfaction by their ability to deliver timely care. E-consult, e-prescribing, and e-billing were answered by physicians if they used the service with patients during the last week of practice at the time of the survey, and were coded as dichotomous variables: “yes” (1) and “no” (0). Set aside same day appointments was also a dichotomous variable (yes=1; no=0) from the survey question, “Does your practice set aside for same day appointments?” Time spent with patients was calculated as a physician-level average from patient-level information for each unique physician included in the sample. The primary independent variable is EHR use based on the question “Does your practice use an electronic health record (EHR) or electronic medical record (EMR) system?” Responses were coded as “no EHR”, “Yes, part paper and part electronic” (partially EHR), and “Yes, all electronic” (fully EHR).

Other independent variables included: solo or group practice (practice size), ownership of organization, percent of revenue from Medicaid patients (payer mix), rurality, region, physician-level patients’ reason for visit, and physician specialty. Group and solo practice were self-reported by physicians, and used as a proxy for organization size. Physicians that belong to group practices may have greater resources and shared resources compared to physicians that belong to solo practices (HSRA, 2010; MGMA, 2010; Casalino et al, 2004; Welch et al, 2013). Ownership of the organization were self-reported by physicians from the survey question “Who owns this practice at the visit location?” Responses were recoded by NAMCS into the following categories: (1)

physician or physicians group; (2) medical/academic health center and other hospital; and (3) insurance company, company, health plan, HMO, other health care corporation, and other. Percent of revenue from Medicaid patients was used as a proxy for payer mix to describe the patient population for each physician. Physicians were asked in the survey, "Roughly, what percent of your patient care revenue comes from Medicaid?" Metropolitan statistical area (MSA) and geographic region were used to determine the location characteristics of the physician's practice. Patient-level data was used to determine patients' reason for visit for each physician. The distribution of patients' characteristics regarding major reason for visit were calculated for each physicians including: new problem (<3 months onset), chronic problem (routine and flare-up), chronic problem, pre-/post-surgical care, and preventive care (e.g. routine prenatal, well-baby, screening, insurance, general exams). Physician specialty was included as a provider characteristic that influences health service delivery outcomes based on the nature of their work, and categorized as medical, surgical, and primary care specialties internally by NAMCS. See Appendix A for more information of AMA specialties that were regrouped into medical, surgical, and primary care specialties.

Statistical Analysis

First, we produced data summary statistics and performed bivariate analysis to examine the difference in outcome variables and explanatory variables by EHR use level. Then, we conducted multivariate regression analyses to examine the association of EHR use and outcome variables. An ordinary least squares (OLS) method was used to determine the effect between EHR use and physician's average time spent with patients. A logit model was used to determine the effect of EHR on the probability of having other health service delivery outcomes, including set aside same day appointment, e-consults, e-prescribing, and e-billing. Model selection was determined by forward selection. We first adjusted for basic practice and location characteristics of the providers, including solo or group practice (practice size), ownership of organization, percent of Medicaid revenue (payer mix), and region. The final model adjusted for solo or group practice (practice size), ownership of organization, percent of Medicaid revenue (payer mix), rurality, region, physician-level patients' reason for visit, and physician specialty. All analysis were adjusted with primary sampling unit (PSU), probability weight for physician, and strata in survey design analysis (SVY) to estimate nationally representative physician level estimates using Stata/IC v.14.1.

RESULTS

A. Descriptive Statistics

Over half (54.3%) of physicians used fully EHRs in their practices, while 32.2% of physicians did not have EHRs, and 13.5% had partially EHR systems. The majority of the physician practices were owned by physician or physician groups (82.2%), were group practices (63.3%), located in the south region of the United States (35.2%), and were located in metropolitan statistical areas (92.2%). The majority of physicians had a payer mix of 0 to 25 percent of revenue from Medicaid patients (82.8%), and the majority of their patients sought care for chronic care (41.9%, mean). The majority of physicians specialties were primary care (46.9%), followed by medical (33.0%) and surgical (20.1%). See Appendix A for AMA physician specialties regrouped into primary care, surgical, and medical specialties.

Table 1 shows the characteristics of the sample by EHR use. There were significant differences in ownership, solo or group practice, region, patients' reason for visit, and physician specialty among physicians with different EHR use levels. Physicians with fully EHRs had a higher percentage of ownership by insurance companies, health plans, and HMOs (12%), and medical/academic health centers and community health centers (9.8%) compared to the other two EHR groups (p<0.001). The majority of physicians without an EHR belong to solo group practices (55.1%), compared to the majority of physicians with partially EHRs (58.8%) and fully EHRs (75.5%) belong to group practices (p<0.001). There were also significant differences (p=0.003) in geographic region between EHR groups, where the majority of physicians without EHRs were from the South and Northeast regions, physicians with partial EHRs from the South and Northeast regions, and physicians with full EHRs from the South and West regions. There were no significant differences in rurality between the EHR groups. Physicians without EHRs saw 44.6% for chronic care, compared to 47.0% for physicians with partially EHRs, and 39.6% for physicians with fully EHRs (p<0.001). There were no significant differences in percent of revenue from Medicaid patients between EHR groups (p=0.164). Over half of the physicians that have fully EHRs (51.2%) belong to primary care specialty, compared to 44.1% of physicians with partially EHRs and 41.0% of physicians without an EHR (p=0.003).

Table 1. Weighted percent of physician, patient, and organizational characteristics by EHR Use Level among the physician population in the United States in 2012.

Variables	Total sample	**No EHR**	**Partial EHR**	**Full EHR**	P-value
Organization Characteristics					
Ownership					<0.001
Physician/physicians group	82.2%	88.3%	86.6%	77.4%	
Medical/academic health center; CHC	7.6%	4.3%	6.0%	9.8%	
Insurance company, health plan, HMO	10.2%	7.4%	7.5%	12.8%	
Solo practice					<0.001
Solo	36.7%	55.1%	41.2%	24.5%	
Group	63.3%	44.9%	58.8%	75.5%	
Region					0.003
Northeast	21.5%	26.4%	25.9%	17.6%	
Midwest	18.9%	18.6%	15.6%	20.0%	
South	35.2%	31.7%	36.3%	36.9%	
West	24.4%	23.3%	22.2%	25.4%	
Rurality					0.859
MSA	92.2%	91.9%	92.6%	92.3%	
Non-MSA	7.8%	8.1%	7.4%	7.7%	
Patient characteristics (practice-level mean)					
Reason for visit (% of patients)					<0.001
New problem	28.5%	29.6%	27.8%	34.3%	
Chronic care	42.6%	44.6%	47.0%	39.6%	
Pre-/Post-surgical care	8.3%	7.9%	8.6%	6.6%	
Preventative care	20.6%	18.0%	16.6%	19.6%	
Payer mix					0.164
Percent of Patients on Medicaid					
0- 25%	82.8%	82.1%	79.6%	84.0%	
26-50%	11.0%	10.3%	12.7%	11.2%	
51%-75%	4.0%	5.6%	4.9%	2.7%	
76%-100%	2.2%	2.1%	2.8%	2.1%	
Physician characteristics					0.003
Specialty					
Primary care	46.9%	41.0%	44.1%	51.2%	
Surgical care	20.1%	23.3%	19.1%	18.4%	
Medical care	33.0%	35.7%	36.8%	30.4%	

Notes: Percent reported were adjusted with PSU, probability weight, and strata in svy design analysis to represent national estimates.
Columns add up to 100%

Heath service delivery outcomes are described by EHR use level among the physician population in Table 2. Among health service delivery outcomes, the majority of the physician population in the United States has set time aside for same day appointments (61.2%). There were significant differences in the percentage of setting time aside for same day appointments among physicians with different levels of EHR use, where 64.1% of physicians that used fully EHRs and 61.5% of physicians using partially EHRs did set time aside for same day appointments, respectively, but only 55.9% of physicians that did not use an EHR system set aside same day appointments.

The total physician population spent an average of 24.3 minutes with their patients per visit. There were significant differences in the average time spent with patients among physicians with different levels of EHR use, where the average time spent with patient decreased to 23.6 minutes in physicians using a fully EHR from 25.5 minutes in physicians that did not use an EHR (Table 2). Only 13.2% of the physicians provided an e-consult with patients in the last week. There were significant differences in the percentage of e-consults among physicians with different levels of EHR use, where 17.0% of physicians with fully EHRs provided e-consults, followed by 10.4% with partially EHRs, and only 8.3% with no EHR systems. Ninety-three percent of the physicians sent their prescription orders electronically to the pharmacy (e-prescribing). There were significant differences in the percentage of e-prescribing among physicians with different levels of EHR use, where 95.7% of physicians with fully EHRs and 87.9% with no EHR systems provided e-prescribing, respectively, but only 85.1% of physicians with partially EHRs provided e-prescribing services. Eighty-seven percent of physicians submit claims electronically (e-billing). There were significant differences in the percentage of e-billing among physicians with different levels of EHR use, where 94.4% of physicians with fully EHRs provided e-billing, followed by 91.9% with partially EHRs, and only 73.8% with no EHR systems.

Table 2. Weighted percent of health service delivery outcomes by EHR use among the physician population in the United States

Outcomes	Overall	**No EHR**	**Partial EHR**	**Full EHR**	P-value
Healthcare service delivery					
Set aside same day appointment					0.007
Yes	61.2%	55.9%	61.5%	64.1%	
No	38.8%	44.1%	38.5%	35.9%	
Average time spent with patient (physician-level average in minutes)	24.3	25.5	24.5	23.6	<0.001
E-consult (email/internet)					<0.001
Yes	13.2%	8.3%	10.4%	17.0%	
No	86.8%	91.7%	89.6%	83.0%	
E-prescribing					<0.001
Yes	93.2%	87.9%	85.1%	95.7%	
No	6.5%	12.1%	13.4%	4.0%	
Yes, but not used	0.4%	0.0%	1.5%	0.3%	
E-billing					<0.001
Yes	87.4%	73.8%	91.9%	94.4%	
No	12.7%	26.2%	8.1%	5.6%	

Notes: Percent reported were adjusted with PSU, probability weight, and strata in svy design analysis to represent national estimates
Significant at *P*-value < 0.05
Columns add up to 100%

B. Effect of EHR on Health Service Delivery Outcomes

Table 3 reports the unadjusted odds ratios and the adjusted odds ratio depicting the effect of EHR use on health service delivery outcomes. After adjusting for practice size, ownership, payer mix, rurality, region, reason for visit, and physician specialty in the final model, there were significant differences in providing e-consults between physicians using fully EHRs and their counterparts with no EHRs. Physicians using fully EHRs were1.06 times more likely to offer e-consults, as compared to the physicians with no EHRs (p<0.001). Furthermore, there were significant differences in providing e-billing services between physicians using EHRs and their counterparts with no EHRs. Physicians using partially EHRs were 2.45 more likely to offer e-billing (p<0.001), and physicians with fully EHRs were 3.13 times more likely to offer e-billing (p<0.001), as compared to the physicians with no EHRs. Lastly, physicians using fully EHRs were 1.38 times more likely to offer to offer e-prescribing, compared to the physicians with no

EHRs (p=0.01). There were no significant difference in providing e-consults and e-prescribing between physicians using partially EHRs compared to physicians with no EHR systems. Furthermore, there were no significant differences in offering set aside same day appointments between physicians using either partially EHRs or fully EHRs compared to physicians with no EHRs.

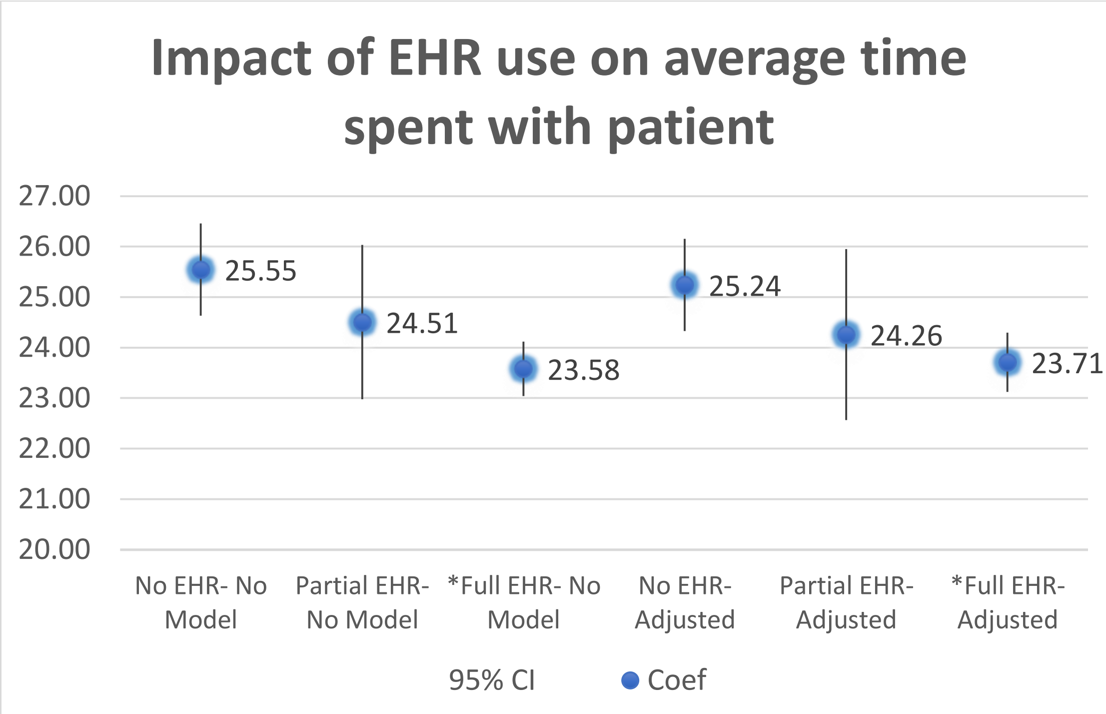
Table 3. Adjusted odds ratios of EHR use on health service delivery outcomes

	No Model			Model 1			Model 2		
	OR	**(95% CI)**	**P-value**	**AOR**	**(95% CI)**	**P-value**	**AOR**	**(95% CI)**	**P-value**
E-consult									
No EHR	Ref			Ref			Ref		
Partial	1.24	(0.66 to 2.33)	0.50	1.38	(0.72 to 2.66)	0.33	1.40	(0.73 to 2.67)	0.31
Full EHR	2.28	(1.58 to 3.28)	<0.001	2.11	(1.42 to 3.13)	<0.001	2.06	(1.39 to 3.06)	<0.001
E-billing									
No EHR	Ref			Ref			Ref		
Partial	3.92	(2.31 to 6.67)	<0.001	3.38	(1.93 to 5.91)	<0.001	3.45	(2.00 to 5.93)	<0.001
Full EHR	5.95	(4.01 to 8.83)	<0.001	4.21	(2.72 to 6.52)	<0.001	4.13	(2.65 to 6.42)	<0.001
***E-prescribing**									
No EHR	Ref			Ref			Ref		
Partial	0.77	(0.37 to 1.61)	0.49	0.69	(0.32 to 1.51)	0.36	0.78	(0.39 to 1.59)	0.50
Full EHR	3.08	(1.73 to 5.49)	<0.001	2.32	(1.20 to 4.47)	0.01	2.38	(1.23 to 4.62)	0.01
Offer set aside same day appointments									
No EHR	Ref			Ref			Ref		
Partial	1.27	(0.92 to 1.77)	0.15	1.30	(0.92 to 1.85)	0.13	1.29	(0.89 to 1.89)	0.18
Full EHR	1.41	(1.15 to 1.74)	<0.001	1.43	(1.14 to 1.81)	0.002	1.21	(0.95 to 1.55)	0.13
Average Time Spent with Patient (minutes)	**Coef**	**(95% CI)**	**P-value**	**Adj Coef**	**(95% CI)**	**P-value**	**Adj Coef**	**(95% CI)**	**P-value**
No EHR	Ref			Ref			Ref		
Partial	-1.04	(-2.84 to 0.76)	0.26	-0.81	(-2.77 to 1.14)	0.41	-0.98	(-2.91 to 0.95)	0.32
Full EHR	-1.97	(-3.03 to -0.90)	<0.001	-1.84	(-2.94 to -0.71)	0.001	-1.53	(-2.64 to -0.42)	0.007

Notes: OR= Odds Ratio; Ref= Reference; AOR= Adjusted Odds Ratio; Adj Coef= Adjusted Coefficient
No Model are unadjusted odds ratios
Model 1 adjusts for practice size, ownership, payer mix, and region
Model 2 adjusts for practice size, ownership, payer mix, rurality, region, reason for visit, and physician specialty.
For e-prescribing we combined "Yes, but do not use" with "No". After preforming a sensitivity analysis, this does not significantly impact the results.

Figure 2 shows the relationship between the average time spent with patient per visit and EHR use. Without adjusting for other factors, there were significant differences in average time spent with patients for physicians between physicians using a fully EHR compared physicians without an EHRs (p<0.001). Physicians' using fully EHRs had a decrease in average time spent with patients by 1.97 minutes compared to those physicians not using an EHR, which is a 7.7% gain in efficiency per visit with patient when compared to the average of 25.5 minutes with no EHR. There were no significant differences in average time spent with patients between those physicians using partially EHRs compared to physicians without an EHR (p=0.26). We used forward model selection by first adjusting for basic organization and location characteristics in model 1, including practice size, ownership, payer mix, and region (Table 3). In model 1, there were significant differences in average time spent with patients for physicians between physicians using a fully EHR compared physicians without an EHRs (p<0.001), where physicians using fully EHRs had a decrease in average time spent with patients by 1.84 minutes compared to those physicians not using an EHR. After adjusting for practice size, ownership, payer mix, rurality, region, reason for visit, and physician specialty in the final model, there were significant differences in average time spent with patients between physicians using a fully EHR compared to physicians without an EHR (p=0.01). Physicians using a fully EHRs had a decrease in average time spent with patients by 1.53 minutes compared to those physicians no using an EHR, which is a 6.1% gain in efficiency. There were no significant differences in average time spent with patients between those physicians using partially EHRs compared to no EHRs in the final model (p=0.32).

Figure 2. Average unadjusted and adjusted number of minutes spent with patients stratified by EHR use



Notes: Reference= No EHR; CI= Confidence Interval
No Model are unadjusted number of minutes spent with patients
* *P*-value < 0.05
Model adjusts for practice size, ownership, payer mix, rurality, region, reason for visit, and physician specialty.

C. The Impact of EHR use on Physician Service Outcomes by Physician Specialty

Table 4 reports the adjusted odds ratio after adjusting for practice size, ownership, payer mix, rurality, region, reason for visit, and physician specialty in the final model on the impact of EHR use on health service delivery outcomes for physicians with primary care, surgical, and medical specialties. There were significant differences in providing e-consults for physicians with primary care and surgical specialties using fully EHRs compared to physicians without EHRs, with 1.47 and 1.62 times more likely to provide e-consults compared to physicians without the use of EHRs, respectively. There were significant increases in providing e-billing between EHR use among physicians for all specialties. Primary care physicians using partially EHRs were 7.37 time more likely to offer e-billing, and physicians using fully EHRs were 3.5 times more likely to offer e-billing compared to physicians without the use of EHRs. Among primary care physicians, physicians using a fully EHRs were 3.56 times more likely to offer e-prescribing compared to physicians without EHRs. However, there were no significant differences in providing e-prescribing between EHR use among surgical and medical specialties. Additionally, there were no significant differences in offering set aside same day appointments between EHR use across the three specialties.

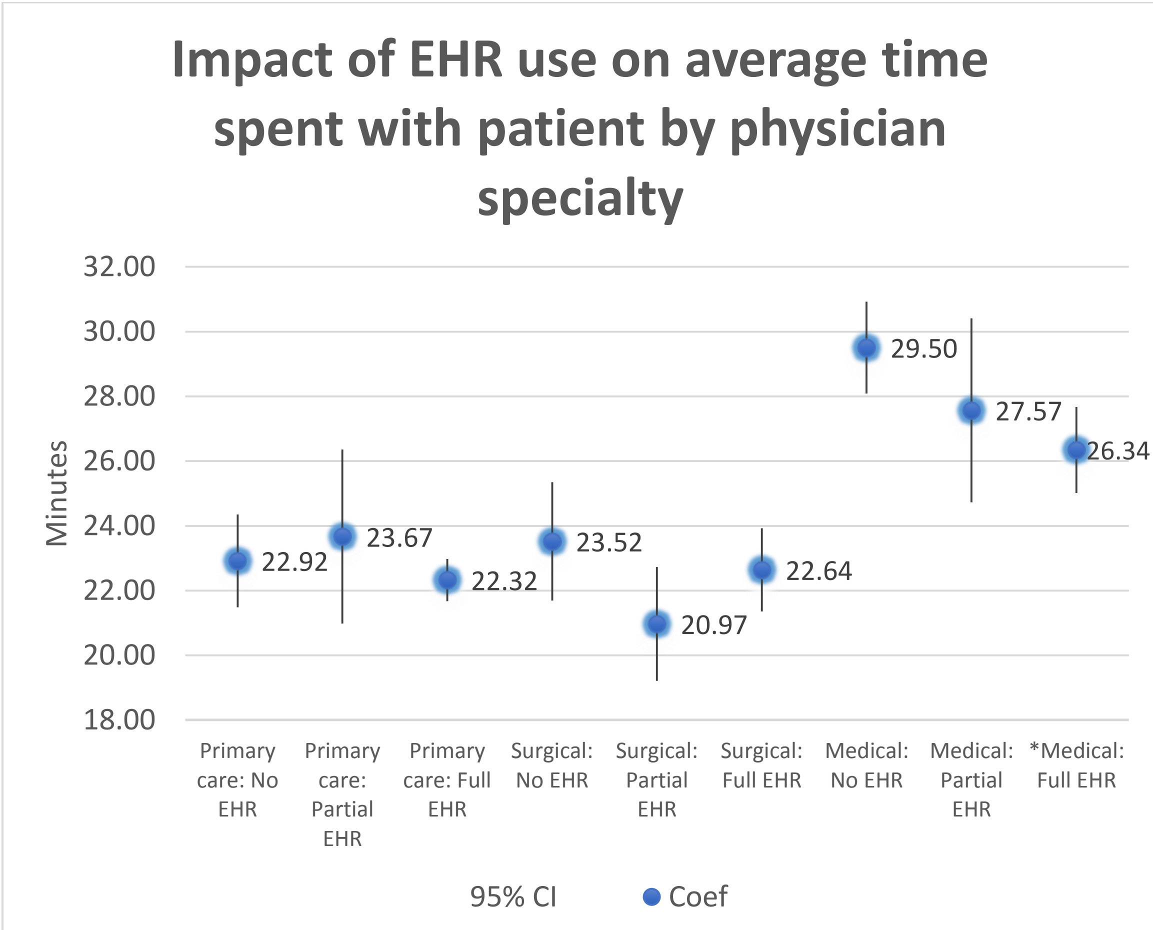
Table 4. Adjusted odds ratios of EHR use on health service delivery outcomes for physicians with primary care, surgical, and medical specialties

	Physician Specialty, Primary care			Physician Specialty, Surgical			Physician Specialty, Medical		
	AOR	**95% CI**	**P-value**	**AOR**	**95% CI**	**P-value**	**AOR**	**95% CI**	**P-value**
E-consult									
No EHR	Ref			Ref			Ref		
Partial EHR	1.81	(0.60 to 5.44)	0.29	2.13	(0.73 to 6.18)	0.17	0.75	(0.33 to 1.72)	0.50
Full EHR	2.47	(1.33 to 4.59)	0.004	2.62	(1.08 to 6.37)	0.03	1.52	(0.81 to 2.83)	0.19
E-billing									
No EHR	Ref			Ref			Ref		
Partial EHR	8.37	(2.62 to 26.70)	<0.001	3.32	(0.86 to 12.88)	0.08	1.88	(0.92 to 3.85)	0.08
Full EHR	4.5	(2.23 to 9.10)	<0.001	3.31	(1.35 to 8.09)	0.009	4.46	(2.39 to 8.34)	<0.001
E-Prescribing									
No EHR	Ref			Ref			Ref		
Partial EHR	1.25	(0.44 to 3.53)	0.68	0.32	(0.07 to 1.47)	0.14	1.07	(0.34to 3.33)	0.91
Full EHR	4.56	(1.77 to 11.69)	0.002	0.6	(0.15 to 2.34)	0.46	3.04	(0.93 to 9.92)	0.07
Set aside Same Day Appointments									
No EHR	Ref			Ref			Ref		
Partial EHR	1.35	(0.61 to 3.00)	0.46	1.05	(0.57 to 1.96)	0.87	1.44	(0.82 to 2.51)	0.2
Full EHR	1.19	(0.78 to 1.82)	0.41	1.03	(0.65 to 1.63)	0.90	1.5	(1.00 to 2.24)	0.049
Average Time Spent with Patient (minutes)	**Adj Coef**	**(95% CI)**	**P-value**	**Adj Coef**	**(95% CI)**	**P-value**	**Adj Coef**	**(95% CI)**	**P-value**
No EHR	Ref			Ref			Ref		Ref
Partial	0.74	(-2.31 to 3.80)	0.63	-2.55	(-5.06 to -0.04)	0.047	-1.94	(-5.20 to 1.33)	0.25
Full EHR	-0.60	(-2.17 to 0.98)	0.46	-0.88	(-3.13 to 1.36)	0.44	-3.16	(-5.22 to -1.10)	0.003

Notes: Ref= Reference; AOR= Adjusted Odds Ratio; Adj Coef= Adjusted Coefficient
Model adjusts for practice size, ownership, payer mix, rurality, region, and reason for visit.
See Appendix A for primary care, surgical, and medical specialty groups

Figure 3 shows the relationship in average time spent with patients between physicians with varied EHR use for physicians with primary care, surgical and medical specialties. After adjusting for practice size, ownership, payer mix, rurality, region, and reason for visit in the final model, there were significant differences in average time spent with patients between physicians with fully EHRs that belong to the medical specialties compared to physicians with medical specialties that did not use EHRs (p=0.003). Physicians' with medical specialties using a fully EHR had a decrease in average time spent with patients by 3.16 minutes as compared to their counterparts without EHRs, which is a 10.7% gain in efficiency per visit compared to the average time spent with patient for physicians without an EHR. There were no significant differences in time spent with patents for physicians with primary care or surgical specialties between EHRs use in the final model.

Figure 3. Average adjusted number of minutes spent with patients stratified by EHR use among physician specialties



Notes: Reference= No EHR; CI= Confidence Interval
See Appendix A for primary care, surgical, and medical specialty groups
* *P*-value < 0.05
Model adjusts for practice size, ownership, payer mix, rurality, region, and reason for visit.

D. The Impact of EHR use on Physician Service Outcomes by Solo and Group Practice

After stratifying by solo and group practices, there were significant differences in offering set aside same day appointments, e-consults, e-billing, and e-prescribing between EHR use for group practices after adjusting for ownership, payer mix, rurality, region, reason for visit, and physician specialty. Table 5 reports the adjusted odds ratio in the final model on the impact of EHR use on health service delivery outcomes for physicians that belong to solo and group practices.

Among physicians that belong to group practices, there were significant differences in providing e-consults for physicians between using fully EHRs compared to no EHRs, where they were 1.68 times more likely to provide e-consults compared to physicians without the use of EHRs. Furthermore, among physicians that belong to group practices using fully EHRs were 3.81 times more likely to provide e-prescribing than physicians that belong to group practices without EHRs. Among physicians that belong to group practices, there were significant differences in offering set aside same day appointments between physicians with varied EHR use, but the same impact was not observed for solo practices. Physicians that belong to group practices using partially EHRs were 0.64 times more likely to offer set aside same day appointments compared to their counterparts without the use of EHRs, although with marginal significance (p=0.04). There were significant differences in offering set aside same day appointments between physicians with the use of fully EHRs that belong to group practices, where they were 0.57 times more likely to offer set aside same day appointments compared their counterparts without the use of EHRs.

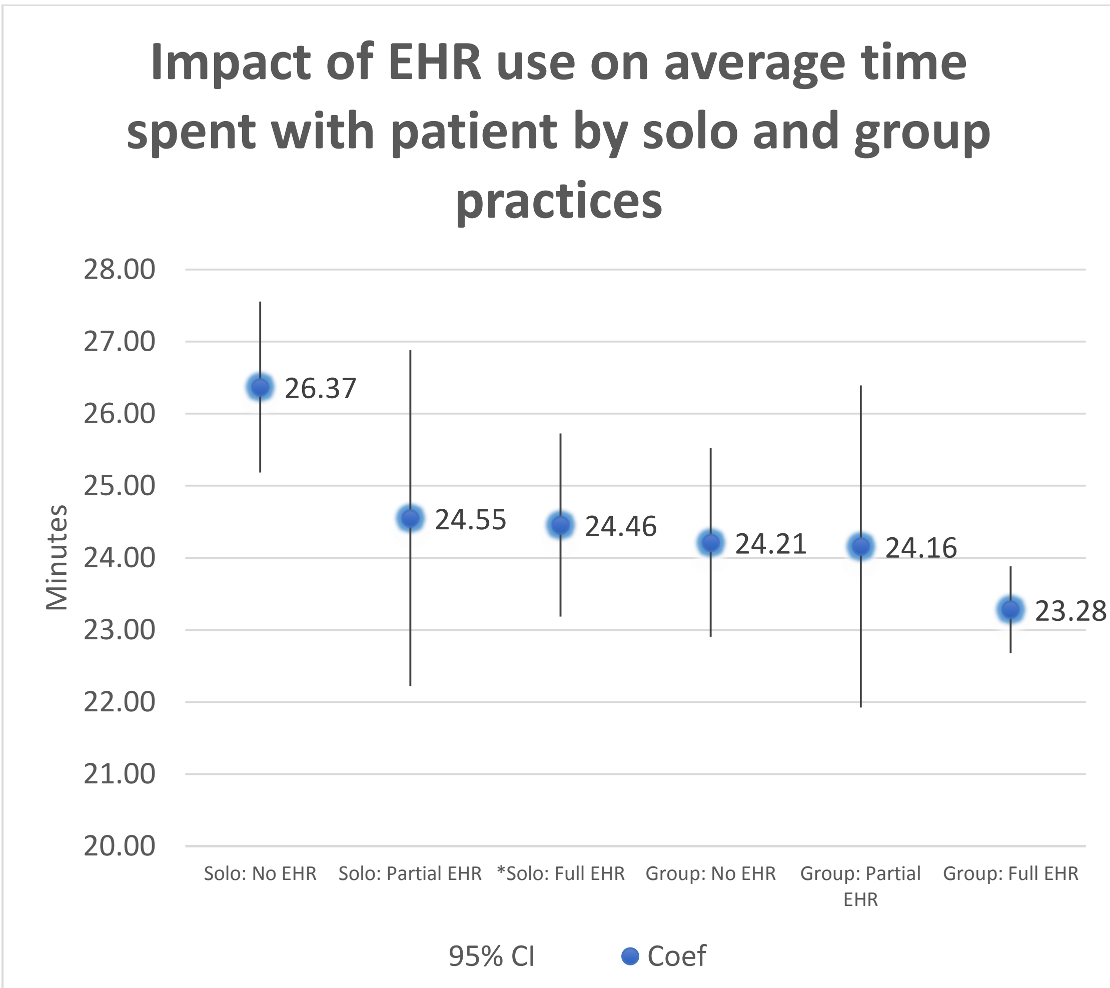
Table 5. Adjusted odds ratios of EHR use on health service delivery outcomes for physicians that belong to solo and group practices

	Solo Practice			Group Practice		
	AOR	**95% CI**	**P-value**	**AOR**	**95% CI**	**P-value**
E-consult						
No EHR	Ref			Ref		
Partial EHR	1.06	(0.35 to 3.14)	0.923	1.84	(0.82 to 4.11)	0.14
Full EHR	1.62	(0.91 to 2.89)	0.101	2.68	(1.49 to 4.81)	0.001
E-billing						
No EHR	Ref			Ref		
Partial EHR	2.68	(1.38 to 5.22)	0.004	5.69	(2.39 to 13.52)	<0.001
Full EHR	3.64	(1.89 to 7.00)	<0.001	5.09	(2.93 to 8.84)	<0.001
E-Prescribing						
No EHR	Ref			Ref		
Partial EHR	0.75	(0.24 to 2.36)	0.62	1.03	(0.41 to 2.59)	0.94
Full EHR	1.21	(0.48 to 3.05)	0.69	4.81	(1.93 to 11.96)	0.001
Set aside same day appointments						
No EHR	Ref			Ref		
Partial EHR	1.08	(0.59 to 2.01)	0.80	1.64	(1.02 to 2.62)	0.04
Full EHR	0.88	(0.59 to 1.31)	0.53	1.57	(1.15 to 2.14)	0.005
Average Time Spent with Patient (minutes)	**Adj Coef**	**(95% CI)**	**P-value**	**Adj Coef**	**(95% CI)**	**P-value**
No EHR	Ref			Ref		
Partial	-1.82	(-4.48 to 0.84)	0.18	-0.06	(-2.66 to 2.55)	0.97
Full EHR	-1.91	(-3.67 to -0.15)	0.03	-0.93	(-2.35 to 0.49)	0.20

Notes: Ref= Reference; AOR= Adjusted Odds Ratio; Adj Coef= Adjusted Coefficient
Model adjusts for ownership, payer mix, rurality, region, reason for visit, and physician specialty

Figure 4 show the relationship in average time spent with patients between EHR use for physicians from solo and group practices. After adjusting for ownership, payer mix, rurality, region, reason for visit, and physician specialty in the final model, there were significant differences in average time spent with patients between EHR use for physicians belonging to solo practices using fully EHRs compared to no EHRs (p=0.003). Physicians' belonging to solo practices using a fully EHR had a decrease in average time spent with patients by 1.91 minutes compared to those physicians no using an EHR, which is a 7.2% gain in efficiency per visit compared to the average time spent with patient for physicians without an EHR. There were no significant differences for physicians that belong to group practices between time spent with the patient and EHRs use in the final model.

Figure 4. Average adjusted number of minutes spent with patients stratified by EHR use among solo and group practices



Notes: Reference= No EHR; CI= Confidence Interval
* *P*-value < 0.05
Model adjusts for ownership, payer mix, rurality, region, reason for visit, and physician specialty.

E. The Impact of EHR use on Physician Service Outcomes by Rurality

After stratifying by physicians located in urban and rural practices, there were significant differences in offering set aside same day appointments, e-consults, and e-billing between EHR use after adjusting for practice size, ownership, payer mix, rurality, region, reasons for visit, and physician specialty. We could not determine the impact of EHR use on e-prescribe by rurality, because convergence was not achieved in the model due to the small sample size. Table 6 reports the adjusted odds ratio in the final model on the impact of EHR use on health service delivery outcomes for physicians that were located in urban and rural areas.

Among physicians that were located in both urban and rural areas, there were significant differences in providing e-consults between physicians with fully EHRs compared to physicians without EHRs. However, the effect in providing e-consults was larger for physicians located in rural areas than their urban counterparts. Physicians located in rural areas with the use of fully EHRs are 2.82 times more likely to provide e-consults than their counterparts without EHRs compared to 0.99 times more likely for physicians located in urban areas, respectively. There were no significant differences in providing e-consults between physicians with the use of partially EHRs their counterparts without EHRs. Similarly, the same effect was observed in providing e-billing, where odds of offering e-billing nearly doubled for rural physicians with partially and fully EHRs compared to physicians located in urban areas. Among physicians located in rural areas, there were significant differences in offering set aside same day appointments between EHR use for physicians, but the same effect was not observed for physicians located in urban areas. Physicians in rural areas using partially EHRs were 1.44 times more likely to offer set aside same day appointments than their counterparts without EHRs, although with marginal significance (p=0.046). Additionally, physicians located in rural areas using fully EHRs were 1.14 times more likely to offer set aside same day appointments than their counterparts without EHRs. However, due to the small sample size of rural physicians included in the sample, the confidence intervals for the rural physician analyses are wide compared to the analyses of the urban physician sample.

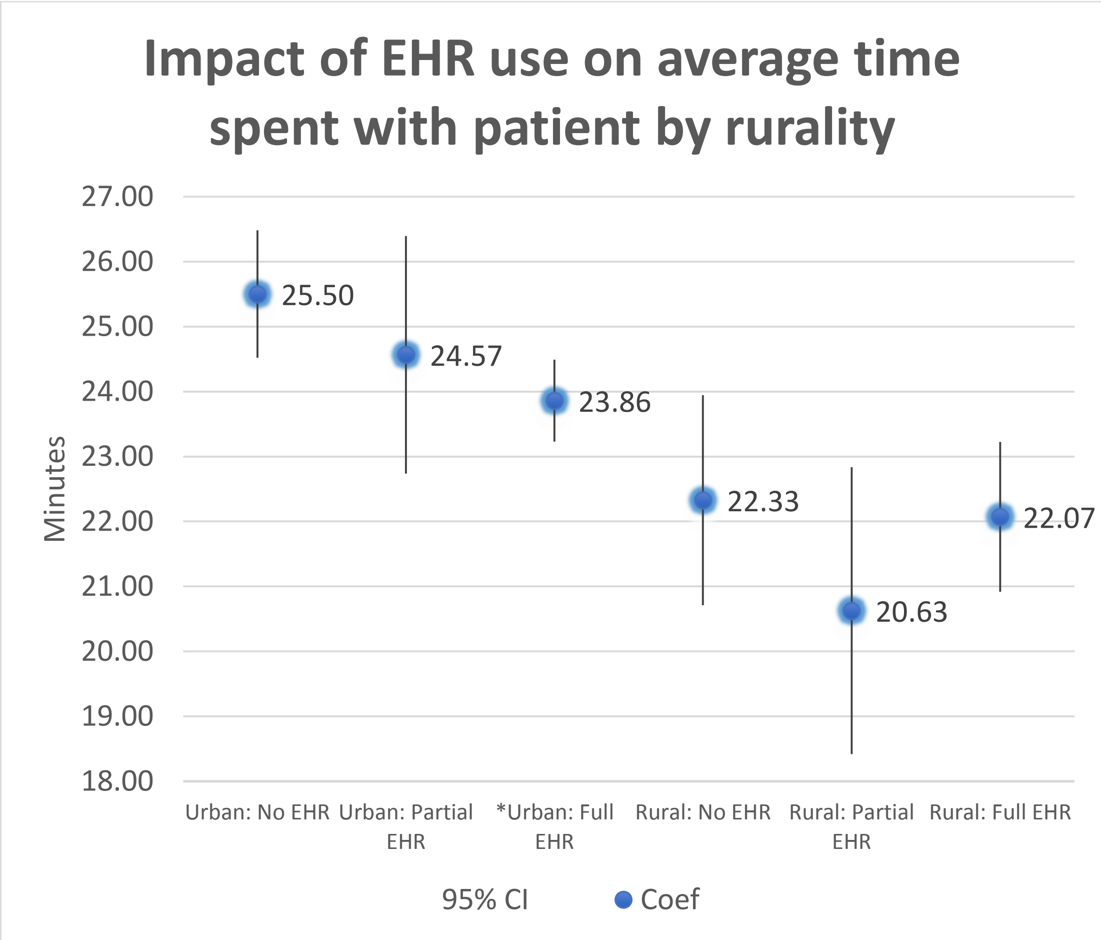
Table 6. Adjusted odds ratios of EHR use on health service delivery outcomes for physicians are located in urban and rural areas

	Urban			Rural		
	AOR	**95% CI**	**P-value**	**AOR**	**95% CI**	**P-value**
E-consult						
No EHR	Ref			Ref		
Partial EHR	1.40	(0.71 to 2.74)	0.33	1.62	(0.26 to 10.23)	0.61
Full EHR	1.99	(1.31 to 3.00)	0.001	3.82	(1.09 to 13.46)	0.04
E-billing						
No EHR	Ref			Ref		
Partial EHR	3.28	(1.86 to 5.77)	<0.001	6.99	(1.60 to 30.56)	0.01
Full EHR	3.93	(2.46 to 6.26)	<0.001	7.19	(2.56 to 20.14)	<0.001
Set aside same day appointments						
No EHR	Ref			Ref		
Partial EHR	1.23	(0.83 to 1.84)	0.31	2.44	(1.02 to 5.86)	0.046
Full EHR	1.15	(0.89 to 1.50)	0.29	2.14	(1.14 to 4.03)	0.02
Average Time Spent with Patient (minutes)	**Coef**	**(95% CI)**	**P-value**	**Adj Coef**	**(95% CI)**	**P-value**
No EHR	Ref			Ref		
Partial	-0.93	(-3.01 to 1.14)	0.38	-1.70	(-4.53 to 1.13)	0.24
Full EHR	-1.64	(-2.84 to -0.45)	0.007	-0.26	(-2.21 to 1.70)	0.80

Notes: Ref= Reference; AOR= Adjusted Odds Ratio; Adj Coef= Adjusted Coefficient
Model adjusts for practice size, ownership, payer mix, region, reason for visit, and physician specialty

Figure 5 show the relationship in average time spent with patients between EHR use for physicians from urban and rural areas. After adjusting for practice size, ownership, payer mix, region, reason for visit, and physician specialty in the final model, there were significant differences in average time spent with patients between EHR use for physicians from urban areas using fully EHRs compared to no EHRs (p=0.007), but not a significant difference among physicians from rural areas (p=0.80). Physicians' located in urban areas using a fully EHR average time spent with patients decreased by 1.64 minutes compared to those physicians no using an EHR, which is a 6.4% gain in efficiency per visit compared to the average time spent with patient for physicians without an EHR. There were no significant differences for physicians that belong to group practices between time spent with patient and EHRs use in the final model.

Figure 5. Average adjusted number of minutes spent with patients stratified by EHR use among physicians practicing in urban and rural areas



Notes: Reference= No EHR; CI= Confidence Interval
* *P*-value < 0.05
Model adjusts for practice size, ownership, payer mix, region, reason for visit, and physician specialty

DISCUSSION

This study demonstrates gains in efficiency may be achieved during patient and physician interaction time with the use of fully EHRs, where physicians saved 1.53 minutes per visit in time spent with the patient, or a 6% gain in efficiency. The odds of providing e-billing is consistently greater with the use of EHRs across our analyses, with both partial and fully EHR systems. There was a significant positive relationship between the physicians that use fully EHRs and providing e-consults, e-billing, and e-prescribing compared to those physicians without the use of an EHR system. One strength of this study is that the providers were asked if they provided the service in the past week, not only if they were capable of providing the service. Physicians may have EHR systems that contain the ability or functionality to improve the mediation of delivering certain services, but that does not mean that physicians are utilizing the system to its capacity. In our study physicians are asked if they have utilized the electronic-consult health service delivery outcomes in the survey one week prior to completing the survey. Therein, the study is representative of providers that are utilizing the electronic health service delivery methods, and not just capable of providing the service.

Our results suggest that physicians using partially EHRs do not widely impact the majority of health service delivery outcomes in this study compared to fully EHRs, such as providing e-consults, e-prescribing, set aside same day appointments, and time spent with patients. Partially EHR systems may have limited amount of viewable data and limited functionalities available in their electronic systems, as compared to fully EHRs. Quality benefits depend on the amount of viewable clinical data (Miller & Sim, 2004), which is more limited in partially EHRs. Partially EHRs require part paper-based health records and part electronic health records that still requires staff time spent finding, pulling, and filing charts and physician time spent locating information (Miller & Sim, 2004). Partially EHRs may not offer enough functionality to experience gains in efficiency, and offer electronically mediated services to move toward new healthcare models that focus on patient-center care and electronic-mediated healthcare service delivery.

Providing e-consults, e-prescribing, and referrals are all outcomes related to the continuity of care, and a priority under the National Committee for Quality Assurance (Carrier, et al, 2009). It is reported that it would be difficult to achieve these outcomes without the use of EHRs, but, to our knowledge, there have been no national studies that determine the ability of EHRs to achieve these outcomes. We conducted an analysis between EHRs use and providing referrals that is not reported in this analyses, but found no significant differences. There was a significant positive relationship in providing e-consults between the physicians that use fully EHRs compared to their counterparts without EHRs, where physicians were 1.06 times more likely to provide e-consults respectively. However, more efforts will be needed for physicians to offer e-consults, where only 13.2% of physician provided e-consults in our study sample. There was a significant positive relationship in providing e-prescribing between the physicians that use fully EHRs compared their counterparts without EHRs, where physicians were 1.38 times more likely to offer e-prescribing services respectively. This is consistent with one study that found that e-prescribing with the use of EHRs had significantly increased from 2008 to 2012 using data from one e-prescribing network, but did not determine the differences among those physicians with no EHR or partially EHRs (Hufstader, Swain, Furukawa, 2012). We found that only fully EHRs have a significant impact on providing e-prescribing, but there were no significant impact with the use of partially EHRs.

E-prescribing systems are used to enter, modify, review, and communicate orders (Car et al, 2008). Just like e-billing, e-prescribing can be integrated into EHRs, but can also be submitted through stand-alone systems. In fact, the majority of e-prescribing in the United States is facilitated through the use Surescripts-certified software to rout prescriptions, where approximately 95 percent of all community pharmacies utilize the e-prescription network (Hufstader, Swain, Furukawa, 2012). It is unknown the number of e-prescribing systems that are integrated into EHR systems in this study. It was previously unclear of the impact of EHRs to improve the use of e-prescribing, as EHRs may integrate e-prescribing systems but may not necessarily be utilized by providers.

Movement toward the medical home would require considerable shift in daily routine, where the National Committee for Quality Assurance outlines principles that focus on increasing same-day appointments and expanded hours (Carrier, et al, 2009). We analyzed the relationship between EHR use and offering evening or weekend appointments that is not reported in this analysis, but found no significant differences. We found that more efforts are also needed for providers to have the ability to offer set aside same day appointments. After adjusting for confounding factors, there was not a significant relationship between the physicians that use EHRs and offering set aside same day appointments. Set aside same day appointments are an important outcome in offering patient-centered care and increase patient satisfaction (Carrier et al., 2009). There are several factors that may impact the ability of providers to offer set aside same day appointments. First, EHR architecture may need to be strengthened to support offering these services. EHR functionalities that support the ability of physicians to offer patient-center healthcare services can be incorporated into the Office of the National Coordinator for Health Information Technology (ONC) Health IT Certification Program, which oversees the certification criteria and associated standards of EHRs. Furthermore, literature reports that process improvement strategies are needed with the use of EHR system to repair suboptimal workflows (Zaroukian and Sierra, 2006). Process improvement workflow strategies regarding scheduling may need to be implemented in order to effectively utilize EHR systems to offer set aside same day appointments.

The odds of providing e-billing is consistently greater with the use of EHR across our analyses for physicians using both partially and fully EHRs. Integration of billing software and EHR software can produce additional financial benefits through better documentation of services provided, better documentation for Medicare coding at higher levels, and reductions in data-entry staff (Miller & Sim, 2004), suggesting it may be a priority when implementing EHR systems. To increase financial incentives, focusing on integration of e-billing may be a priority for physicians with partially EHRs. It is unknown whether these e-billing systems are incorporated into a comprehensive EHR system or are stand-alone e-billing software, which may or may not be integrated into their EHR software. To our knowledge, this is the first study to determine the impact of EHRs on the utilization of e-billing among a nationally representative office-based physician population. Future studies should determine the distribution of e-billing that is a part of comprehensive EHR systems and stand-alone e-billing software, and its impact on financial and productivity outcomes.

This study demonstrates that with the use of EHRs, slight gains in efficiency may be gained during patient and physician interaction time. It is likely that this time may be saved in information gathering, where EHRs can immediately retrieve data about the patients' medical history and conditions. In the final model we found that physicians saved 1.53 minutes per visit in time spent with patient, or a 6.1% gain in efficiency when compared to the average time spent with patient for physicians without an EHR. Because it was a slight change, it is not likely the result spending less time with the patients. Rather, it is possible the results suggest that EHRs may act as an efficient way for physician's to review and retrieve data and information about their patient's case or medical history during the time spent with patients. Other savings outside of the face-to-face time spent with patient may be gained with the use of EHRs, where financial savings accrued from less staff time spent finding, pulling, and filing charts and less physician time spent locating information (Miller & Sim, 2004). It is unclear of the impact on the quality of time spent with the patient during the interaction, as EHRs decreases in average time spent with patients. However, it is reported in the literature that EHRs have the ability to achieve improved healthcare quality benefits depending on the amount of viewable clinical data (Miller & Sim, 2004). Future studies need to determine how this decrease in time spent with patient impacts the quality of these interactions between patients and their providers.

Stratified Analyses

We conducted several stratified analyses based on significant factors that may impact the relationship between EHR utilization and health service delivery outcomes. First, we stratified by physician specialty. In the field of consumer health informatics and the field of human–computer interaction, the literature states that diverse users interact with HITs in different ways to meet their needs (ISO/IEC, 2008; ISO/IEC, 2010; Mayhew, 1999; Stone et al, 2005; Rosson and Carroll, 2002). Therein, physicians with different specialties may interact with EHRs in different ways to meet their service needs. Second, we stratified by group and solo practice. Physicians are incentivized per physician from the Meaningful Use program, suggesting that group physicians have more financial resources to adopt and implement EHR systems. Physicians that belong to group practices may have greater munificence and less uncertainty than solo practices, based on the constructs of the RDT. Third, we performed a stratified analysis among physicians in urban and rural areas, because the literature consistently states that rural providers continuously fall behind in EHR adoption and use compared to their urban counterparts (DesRoches et al., 2012; Tietze MF, Williams J, Galimbertti, 2009; Boon, 2007; Memel et al., 2001). Rural providers face lower munificence and a higher degree of uncertainty, based on the constructs of the RDT.

After our stratified analyses, consistent with the un-stratified model results above, we found that physicians using partially and fully EHR systems increases the odds of providing e-billing services from both group and solo practices, as well as physicians from rural and urban areas. However, the effect is stronger for physicians that belong to group practices compared to solo practices. From this study we know that physicians using partially EHRs in group practices were more than two times more likely to provide e-billing than solo practices. Physicians that belong to group practices were 4.69 times more likely to provide e-billing verses 1.68 times more likely for physicians that belong to solo practices, compared to their counterparts without EHRs respectively. In addition, physicians using fully EHRs that belong to group practices were 4.09 times more likely to provide e-billing verses 2.64 times more likely for physicians that belong to solo practices, compared to their counterparts without EHRs respectively. Furthermore, we found a stronger effect in providing e-billing for physicians located in rural areas than urban areas with the use of EHRs. Physicians using partially and fully EHR systems located in rural areas have seen significant gains for providing e-billing compared to their counterparts without the use of EHR systems. Physicians located in rural areas have odds that were 2 times greater than their urban counterparts in providing e-billing with the use of EHRs. For example, we found that physicians located in rural areas using partially EHRs were 5.99 times more likely to provide e-billing verses physicians located in urban areas using partially EHRs were 2.28 times more likely to provide e-billing, compared to their counterparts without EHRs. These results suggest that rural providers maybe focusing on using their EHR systems to increase the use of e-billing, even though rural providers face lower munificence and a higher degree of uncertainty. In order to meet the needs of rural providers with lower resources, they may be leveraging their EHRs to focus on improve accuracy in documentation related to billing in order to improve revenue with their EHR systems. More studies are needed to determine if rural physicians are receiving the same financial benefits as their urban counterparts with the use of e-billing technologies. Our stratified analyses suggests that even partially EHRs are able to improve outcomes in offering e-billing, but especially for physicians with primary care specialties, physicians part of group practices, and physicians located in rural areas.

Additionally, we found that physicians with primary care specialties, and physicians that belong to group practices were more likely to provide e-prescribing services that use fully EHRs compared to no EHR system, with large effects. Physicians with primary care specialties using fully EHRs were 3.56 times more likely to offer e-prescribing compared to primary care physicians without EHRs. Physicians that belong to group practices with fully EHRs were 4.81 times greater than the odds to provide e-prescribing than physicians that belonged to group practices without EHRs. However, we were not able to determine the impact of rurality on e-prescribing because we were not able to meet model convergence due to the small rural physician sample size. In the final model there was not a significant relationship between the physicians that use EHRs and offering set aside same day appointments. However, after our stratified analyses we found that with the use of EHRs, physicians that belong to group practices and rural areas were more likely to offer set aside same day appointments. For physicians that belonged to group practices with partially EHRs were 0.64 times more likely to offer set aside same day appointments, and physicians that belong to group practices with fully EHRs were 0.57 times more likely to offer set aside same day appointments than their counterparts without EHRs respectively.

Increasingly over the past decade, physicians have started to move toward group practices (Liebhaber, Grossman, 2007; Welch et al, 2013), which results in increasing munificence and sharing of resources while decreasing uncertainty. Our analyses shows that it may be easier for group practices to achieve the outcomes with the use of EHRs in healthcare service delivery, which is consistent with the evidence suggested within the literature. Our results show that providers in group practices provide significantly greater odds of providing e-consults, e-prescribing, e-billing, and set aside same day appointments with the use of fully EHRs compared to group practices without the use of EHRs. The only significant outcomes among solo practices was e-billing, but at a lower effect than group practices. From the RDT, group practices may have greater munificence and less uncertainty than solo practices. The resources provided from the Meaningful Use incentive program may have positively impacted outcomes among group practices compared to solo practices, where group practices are getting incentives awarded based on the number of providers utilizing EHR systems. Group practices have certain advantages over solo practices that would make it easier to achieve outcomes related to improved quality and healthcare service efficiency including greater access to capital to make technology investments, shared resources, greater ability to standardize processes, and the ability to accept more insurance risk (HSRA, 2010; MGMA, 2010; Casalino et al, 2004; Welch et al, 2013). These providers belonging to group practice may have more resources (or munificence) to purchase systems with more functionalities with better usability than providers that belong to solo practices, making it easier to transform their health service delivery patterns. One study found that solo and small group practices can absorb significant financial risk when implementing EHR systems (Miller et al., 2005). However, there is no comparative literature for solo and group practices in achieving outcomes with the use of EHRs. Additionally, group practices may have the ability to seek more technical support due to the sharing of resources, and increased information sharing between providers regarding improving workflow processes with the use of EHR systems. Evidence also suggests that physicians may find it is easier to achieve greater care coordination and increased accountability for care delivery to improve the quality of care when they are organized into group practices rather than when they are in solo practices (Ketcham, et al, 2007; Welch et al, 2013). Group practices may be facing an increased accountability to adopt efficient health service delivery methods that accompany the use of EHRs, such as electronic mediated services, after the costly investment.

There were significant differences among health service delivery outcomes with the use of EHRs among physician specialties. Primary care physicians provide significantly greater odds of providing e-consults, e-billing, and e-prescribing with the use of fully EHRs than primary care physicians without the use of EHRs. We found that primary care physicians with fully EHRs were 1.47 times more likely to provide e-consults than their counterparts without EHRs. Additionally, physicians with surgical specialties using fully EHRs were 1.62 times more likely to provide e-consults than their counterparts without EHRs. There were no significant results among physicians with medical specialties regarding e-consults and the use of EHRs. With the use of an EHR system, the literature reports that Kaiser Permanente specialty care physicians can e-consult with primary care physicians and coordinate treatment plans much more quickly and effectively than traditional referral-based models of care (Chen et al., 2009). In the study of consumer health informatics and the field of human–computer interaction, physicians may interact with EHRs in different ways to meet their needs (ISO/IEC, 2008; ISO/IEC, 2010; Mayhew, 1999; Stone et al, 2005; Rosson and Carroll, 2002). Due to the nature of primary care and surgical cases, the need to consult with specialists may be higher than other specialties. In conjunction with the use of their EHR systems, this may imply that primary care physicians are seeking e-consults more frequently as compared to medical specialties to meet the needs in delivering efficient and timely care to their patients. However, medical specialties had the biggest gains in time efficiency for average time spent with patient with the use of fully EHRs, with a time savings of 3.16 minutes per visit. This may be achieved efficiency in gaining access to patient health information and provider documentation that is contained in EHR systems, such as e-prescribing. Medical specialties were 2.04 times more likely to provide e-prescribing than their counterparts without the use of EHRs. More research is needed to determine the factors attributable to efficiency gains in time spent with patients among medical care specialties.

A large body of literature demonstrates that rural providers continuously fall behind in EHR adoption and use compared to their urban counterparts (DesRoches et al., 2012; Tietze MF, Williams J, Galimbertti, 2009; Boon, 2007; Memel et al., 2001). Based on our central hypothesis from the RDT, our results support that rural physicians may not be achieving the same gains in efficiency compared to their urban counterparts. Our results show only urban physicians utilizing fully EHR systems had significant efficiency gains in time spent with patients compared physicians with no EHR use (1.64 minute decrease per visit), but the effect was not observed among physicians and EHR use in rural areas. Urban physicians that used fully EHRs had significantly greater odds of providing e-consult and e-billing services than urban physicians without the use of an EHR. More evidence is required to identify the effect of EHRs in rural areas in achieving diverse healthcare service efficiency outcomes. The literature reports that rural hospitals experience significant workflow, staffing, and technical challenges with EHR use (Gabriel et al, 2014), which may make it difficult to gain the additional resources to overcome these challenges to achieve efficiency outcomes of their urban counterparts.

Providers with higher degrees of uncertainty may be leveraging their EHR systems to offer services that benefit their practices. Rural office-based physicians have significantly greater odds of providing e-consults, e-billing, and set aside same day appointments compared to physicians with no EHR, with greater effects than urban physicians with the use of EHRs. For physicians in rural areas using partially EHRs were 1.44 times more likely in offering set aside same day appointments, and physicians in rural areas using fully EHRs are 1.14 times more likely in offering set aside same day appointments, compared to their counterparts without EHRs respectively. Although there is little evidence provided in the literature about rural hospitals ability to set aside same day appointments, past studies have reported that generalist physicians were significantly more likely to offer same day appointments than specialty physicians (Hing and Schappert, 2012). The same mechanism may be acting with rural providers due to the variability (uncertainty) of their day-to-day cases in rural areas. From the constructs of the RDT, rural hospitals may face greater uncertainty regarding patient cases and the number of same day appointments that will be needed. Under a higher degree of uncertainty, physicians may utilize their EHR systems in different ways to improve financial viability. In the study of consumer health informatics and the field of human–computer interaction, the literature states that diverse users interact with HITs in different ways to meet their needs (ISO/IEC, 2008; ISO/IEC, 2010; Mayhew, 1999; Stone et al, 2005; Rosson and Carroll, 2002). It may be a priority for rural providers to focus on providing same day appointments with the use of their EHR systems given their geographic isolation of their patient population for urgent cases, and the pressures faced by agreeing to treat patient that receives government reimbursement. Rural providers patient population may consist of a higher proportion of lower income patients that are part of state and government programs (such as Children's Health Insurance Program), which require providers to offer same day appointments and urgent care (DPHHS, 2015).

Even though the literature reports that it will be a challenge for small and rural hospitals to meet stage 2 meaningful use criteria, as they continue to lag behind their better-resourced urban counterparts (Alder-Milstein et al., 2014), rural providers are making changes in their health service delivery with the use of EHRs. Providers with higher degrees of uncertainty may be leveraging their EHR systems to offer services that benefit their practices. Our results suggests that rural providers were providing e-billing, e-consults, e-billing, and set aside same day appointments with odds ratios that were nearly doubled that of their urban counterparts with the use of EHRs, although with large confidence intervals due to the small sample size. Again, the results show that they are providing these health care services, but it is unknown if they are able to achieve efficiency of their urban counterparts that are utilizing the same electronic mediated services. Future studies need to increase the sample size of physicians located in rural areas. Due to the cross-sectional design of the study we were not able to determine the causality, but the results suggest a significant impact of EHRs among rural physicians in delivering electronic-mediated healthcare services delivery outcomes that support productivity.

Limitations

First, due to the secondary data source we were limited to adjust for factors that are included in the dataset. There may be unobserved effects that were not accounted for in our model, including the perception about technology, engagement in new delivery models (such as patient center medical homes or pay-for-performance), and the organization's financial resources. However, every effort was made to include significant factors in the final model that were included in the NAMCS survey dataset. Second, it is unknown whether there is an unobserved clustering effect if more than one physician was sampled belonging to the same organization or clinic.

Third, there was a small sample size of physicians practicing in rural areas, producing large confidence intervals in our analysis stratified by rurality. More studies are needed with a larger sample of rural physician that are nationally representative, although this study provides insight of the interaction between EHR use of rural physicians and health service delivery outcomes.

Another limitation is that e-consult were representative of services provided in the past week before they completed the survey, and may not represent their full healthcare service delivery patterns or frequency of utilization. The results may be underestimated by those physicians that may utilize these services, but did not prior to the week of survey. However, the results appear to have a consistent relationship between increasing healthcare service delivery outcomes (such as e-consult, e-billing, and e-prescribing) with increasing functionality of partial and fully EHR use. Future studies are needed to determine patterns of engagement in these healthcare service delivery outcomes.

Furthermore, we were not able to identify specific functionalities included among partially or fully EHRs. Variability may exist in the functionalities offered in partially and fully EHRs, making it difficult to identify the specific functionalities and their association with the identified outcomes. However, the study offers insight into a nationally representative sample of physicians with partially electronic and fully EHRs in the year 2012.

Due to the temporality of the data the results may be underestimated, as 2012 was early adoption of EHR use in receiving Meaningful Use incentives. However, we used the most recent NAMCS data that was available at the time of analysis. Since 2012, Meaningful Use criteria and objectives have been modified to better align with EHR use, and require the use of certified EHRs by an ONC Authorized Certification Body (ONC-ACB). EHR certification was developed to improve EHRs transparency for purchasers for EHRs that meet federal requirements for technological capability, functionality, usability, and security requirement (Federal Register, 2015). Widely adopting EHRs that are more highly functional and easier to use would increase the effectiveness to utilize healthcare service delivery that is mediated with the use of EHRs. More recent studies are needed to determine how widely these healthcare service delivery outcomes are utilized among the United States healthcare system among hospitals utilizing certified EHRs, and the impact on physicians' time spent with patients.

Lastly, based on the cross-sectional survey data, we were not able to establish causality between EHR use and the impact of healthcare service delivery outcomes included in this study. Longitudinal, prospective studies are needed to establish causality on the impact of EHR use on healthcare service delivery outcomes.

CONCLUSION

Despite the significant financial, technical, and interoperability challenges in implementing and adopting EHR systems, we have seen significant changes in health service delivery among physicians utilizing fully EHR systems even among early adoption in 2012. Physicians who face higher degrees of uncertainty may be leveraging their EHR to provide healthcare services to maximize benefits to their practice, but do not see time efficiency gains. Rural physicians face greater uncertainty in their geographic isolation with lower munificence. Our results found that rural providers with the use of fully EHRs have significantly greater odds of providing e-consults, e-billing, and set aside same day appointments than rural providers without EHR use, and the effect was stronger for rural providers than for their urban counterparts. Furthermore, primary care physicians have higher uncertainty about cases they will see compared to other specialties. Primary care physicians with the use of fully EHRs have significantly greater odds of providing e-consults, e-billing, and e-prescribing compared to primary care physicians without the use of EHRs, and the effect was stronger for primary care provider than for other specialties. Both groups with higher uncertainty did not have significant time efficiency gains with time spent with patients. Furthermore, among physicians with higher degrees of munificence and low degrees of uncertainty (such as group practices, urban physicians, and medical specialties) may have the resources to see either time efficiency gains or to deliver e-mediated healthcare services, depending on the nature of their work. Providers in group practices provide significantly more e-consults, e-prescribing, e-billing, and set aside same day appointments with the use of fully EHRs compared to physicians without the use of EHRs, and with strong effect than physicians that belong to solo practices. Furthermore, physicians that belong to urban practices had significant efficiency gains in time spent with patients, and significantly greater odds of providing e-consult and e-billing services than urban physicians without the use of EHRs. Medical specialties had the biggest gains in time efficiency for time spent with the patient with the use of fully EHRs, with a time savings of 3.16 minutes per visit.

Simply adopting and utilizing partially EHRs will not be enough to achieve the aims for our healthcare system to deliver electronic mediated healthcare services, including set aside same day appointments, providing e-consults, providing e-prescribing services, and efficiency in time spent with patients. Meaningful Use objectives should be tailored around early EHR successes in order to motivate efforts, and develop more uniform health service delivery reform across the providers in the United States, such as providing e-billing, e-consults, and e-prescribing services. Focusing on early successes that may be easier to achieve will decrease the risk of Meaningful Use penalties among lower resourced providers that are having difficulties adopting certain functionalities within EHR systems, such as interoperability. More efforts may be needed for providers to have the ability to set aside same day appointments to achieve this outcome that impacts patient satisfaction, and EHR architecture may need to be strengthened within EHR systems to support offering this service.

CHAPTER 2: Does attesting to Meaningful Use with Electronic Health Records Improve Hospital Patient Safety?

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ABSTRACT

Background: Providers and healthcare organizations may be eligible to receive financial incentives for demonstrating “meaningful use” with their EHR systems by meeting a set of objectives and criteria specified by Medicare and Medicaid Services, aimed to improve patient safety and care outcomes. The impact of Meaningful Use attestation with the use of EHRs on patient safety has been understudied, making it difficult to determine if the specific set of Meaningful Use objectives and the government benchmark set for EHR use has had a positive impact on patient safety outcomes.

Objective: The objective of this study is to determine the impact of hospitals attesting to Meaningful Use with the use of their Electronic Health Records (EHRs) on patient safety outcomes.

Methods: We used three data sources to study the impact of EHRs on patient safety outcomes. Inpatient hospitalization information was used from Healthcare Cost and Utilization Project (HCUP) 2013 State Inpatient Databases (SID) of Florida, Nebraska, New York, and Washington. We used the AHRQ PSI software version 5.0 and SAS version 9.4 statistical software to determine the hospital-level risk-adjusted standardized rates for eight patient safety indicators, and the PSI 90 composite score. Additionally, we used 2013 American Hospital Association (AHA) annual survey data and CMS Meaningful Use attestation records to gather information regarding hospital characteristics and the use of EHR systems in 2013. Our final sample included 349

hospitals from Florida, Nebraska, New York, and Washington that provided information about their EHR systems.

Data summary statistics and bivariate analysis were performed to examine the difference in outcome variables and explanatory variables by EHR use. Then, we performed multivariate regression analysis using generalized linear model (GLM) method with log link function and gamma family distribution to examine the impact of EHR use on the individual PSIs and the PSI 90 composite score. In the final model, we adjusted for minor teaching hospital status, major teaching hospital status, for profit status, nurse to staffed bed ratio, state, and staffed beds.

Results: The majority of hospitals in the study sample attested to Meaningful Use Stage 1 with the use of their EHR systems (82.2%), followed by having partially-implemented or no EHR system (9.2%) and having a fully-implemented EHR system that does not attest to Meaningful Use (8.6%). The majority of hospitals had 100-299 beds (38.7%), had non-profit status (91.4%), were not teaching hospitals (57.0%), located in a metropolitan area (74.8%), from New York (37.3%), and had an average nurse to bed ratio of 1.73.

After adjusting for other factors in our model, fully-implemented EHRs that did not attest to Meaningful Use had a significant positive impact on 3 patient safety outcomes, and EHRs that attested to Meaningful Use had a significant positive impact on 2 patient safety outcomes. Fully-implemented EHRs that did not attest to Meaningful Use had a significant positive impact on death rate in low-mortality DRGs, postoperative physiologic and metabolic derangement rate, and wounds split open after surgery compared to hospitals with a partially-implemented or no EHR. Furthermore, EHRs that attested to Meaningful Use had a significant positive impact on postoperative physiologic and metabolic derangement rate, and perioperative pulmonary embolism or deep vein thrombosis rate (serious blood clots after surgery) compared to hospitals with a partially-implemented or no EHR. However, there was no significant impact of attesting to Meaningful Use or having a fully-implemented EHR that did not attest to Meaningful Use on the PSI 90 composite score compared to hospitals with partially-implemented or no EHR.

Conclusion: Our study demonstrates that hospitals attesting to Meaningful Use with their EHR systems improved 2 patient safety outcomes. More research needs to be conducted to determine which functionality or set of functionalities that contribute to these increases in patient safety to direct future of the Meaningful Use program, as fully-implemented EHRs that did not attest to Meaningful Use had greater effects on patient safety among some indicators. However, EHR use did not have a significant impact on PSI composite scores in 2013. The evidence suggests that hospitals will not see significant differences in their PSI 90 composite scores with the adoption and use of EHR systems as they move toward pay-for-performance models that incorporate the PSI 90 in the total performance score (TPS). Policy makers may want to focus on specific patient safety indicators that are highly preventable in payment models to avoid penalizing hospitals through reimbursement, rather than incorporating the PSI 90 composite score.

INTRODUCTION

The United States has made a significant investment on the adoption and use of Health Information Technology (HIT) in the healthcare system, providing over 35 billion dollars of support through the Health Information Technology for Economic and Clinical Health (HITECH) Act. Into the 21st century, the Affordable Care Act (ACA) aimed to improve the efficiency, quality, patient safety, and health outcomes of health service delivery by using of Electronic Health Records (EHRs) to establish better care coordination across providers, standardization across health data, and develop clinical decision support systems. Providers and healthcare organizations may be eligible to receive financial incentives for demonstrating "meaningful use" with their EHR systems by meeting a set of objectives and criteria specified by Medicare and Medicaid Services, aimed to improve patient safety and care outcomes. Many studies show that EHRs have improved patient satisfaction, quality, clinical outcomes, risk management, and decision support (Jamoom et al., 2012; Duffy et al., 2010; Kern et al., 2012; Bell et al., 2011; Holt et al., 2010; Barlow, Johnson, & Steck, 2003). However, recent literature has provided mixed empirical evidence regarding the impact of EHRs on achieving other outcomes, including patient safety, quality, and cost-efficiency (Jones et al., 2014; Verdon, 2014; Adler-Milstein, Salzberg, Franz, Orav, & Bates, 2013). It will be important to study the impact of Meaningful Use attestation on the ability to achieve intended outcomes envisioned by the ACA and the HITECH Act to direct policy and implementation efforts, such as the ability of EHRs to achieve patient safety.

The current state of literature warrants that more attention should focus on studying the impact of use of EHRs on patient safety, given the mix results. One study found that EHRs and HITs had little to no association with hospital readmission rates (Himmelstein et. al, 2010). A study by Jones and colleagues found Stage 1 Meaningful

Use electronic medication ordering will not likely have a significant impact on hospital deaths with only 1.2 percent fewer deaths from medication errors, suggesting that Meaningful Use will need to be held at a higher standard using electronic orders to have a significant reduction in medication errors (Jones, et al., 2011a). The study suggested that Meaningful Use threshold set for hospitals is likely too low to have a significant impact on deaths related to heart failure and heart attacks, where Stage 1 requires electronic orders for at least 30 percent of eligible patients (Jones, et al., 2011a). The majority of studies that demonstrated a positive impact of EHRs on patient safety only focus on specific functionalities with the use of EHRs, such as clinical decision support or computerized provider order entry (Jones et al., 2014). Only one study has investigated the impact of Stage 1 Meaningful Use capable EHR systems on patient safety, where they found Stage 1 Meaningful Use capable EHR systems were associated with improvements on 3 of 8 patient safety measures with 7% to 11% lower rates of adverse events (Appari et al., 2014). However, the limitation of this study is that Stage 1 Meaningful Use was determined by classifying functionalities that could potential meet Stage 1 Meaningful Use, but not actually attesting to Meaningful Use. There remains a significant gap in the literature in studying the impact of Meaningful Use attestation with EHR use on patient safety outcomes. To the best of our knowledge, there has not been a study determining the impact of hospital Meaningful Use attestation with their EHR systems on patient safety.

Achieving positive patient safety outcomes will become increasingly important as Centers for Medicare and Medicaid Services (CMS) are moving toward value-based purchasing models by linking quality scores to Medicare payments. In value-based purchasing, a percentage (from 1.00% in 2013 to 2.00% in 2018) of the total payment is taken-out and then paid back based on the total performance score (TPS) of the provider. Patient Safety Indicator (PSI) 90 composite score is a component of TPS in the value based purchasing model in the safety domain, where safety accounts for 20% in 2017 and 25% in 2018 of the TPS for value-based purchasing. Patient Safety Indicators (PSIs) developed by Agency for Healthcare Research and Quality (AHRQ) are a set of indicators providing information on patient potential in hospital complications and adverse events following surgeries and procedures. Patient safety and Meaningful Use attestation have been understudied. It is difficult to determine if the specific set of Meaningful Use objectives chosen by CMS have had a positive impact on outcomes.

To our knowledge, only one study has examined the impact of Meaningful use on patient safety by classifying EHRs functionalities that could potentially meet Meaningful Use Stage 1 (Appari et al., 2014). However, the classification is not actually attesting to Meaningful Use. Furthermore, information regarding the EHR systems were collected from 2007 data, but classified by 2011 Meaningful Use functionalities with patient safety estimates between 2008 to 2010. This kind of gap could misclassify many hospitals that adopted the Stage 1 functionalities for Meaningful Use after 2007, which is likely because of the steep increase in EHR adoption that took place in 2009 and after with the implementation of the Affordable Care Act (DesRoches, et al., 2013). The objective of this study is to determine the impact of hospital Meaningful Use attestation with the use of their EHRs on patient safety outcomes.

THEORETICAL FRAMEWORK

Technology, Organizational, and Environment (TOE) framework adapted

The framework used in this study is a modification of Tornatzky and Fleischer (1990) technology, organizational, and environment (TOE) innovation adoption framework. TOE framework incorporates three contexts that impact the adoption of technological innovations, including: (1) environmental context, (2) organizational context, and (3) technology context. Environmental context is defined by the organization's environment to conduct business, which includes its industry, competitors, and governmental factors (Tornatzky and Fleischer 1990). The organizational context provides information about the size, scope of organization, managerial structures, and other descriptives about the organization. Technological context takes into account both the internal and external technologies relevant to the organization. TOE framework has been highly utilized and supported by results of previous research to explain technology adoption across organizations (Brancheau and Wetherbe, 1990; Baker, 2012; Fichman, 1992; Bretschneider, 1990; Cooper and Zmud, 1990). TOE framework provides elements that are important in studying outcomes of technology use, as it accounts for technology, organizational, and environmental factors. TOE framework can be modified and applied to include important factors when studying the impact of EHRs on care outcomes. We have expanded this framework to incorporated important factors that impact patient safety in the literature to study the impact of EHRs on patient safety outcomes.

Organizational characteristics have a significant impact on patient safety and care outcomes (Armstrong et al., 2009; Donabedian, 2003; Lehrman et al., 2010). Studies have shown that organization support of nurses may affect patient outcomes (Aiken et al., 2002; Rivard et al., 2010). Nurse-to-bed ratio has been used in previous literature to adjust for the effect of nurse support within the organization (Appari et al., 2014). Furthermore, engagement in safety/quality metrics that is linked to compensation may have an impact on patient safety at the facility-level (Appari, et al., 2014). There has been inconsistent findings of adverse effects with hospital size (Iezzoni et al., 1994; Slonim et al., 2007; Smith et al., 2007). However, the inconsistency in findings may be due to inadequate risk adjustment (Sax and Pittet, 2002; Rivard et al., 2010), but have not yet been determined. Other organizational characteristics that could have a significant impact on quality and safety outcomes include for-profit status, teaching hospital status, and academic hospital status (Appari et al., 2014).

HITs were envisioned to improve patient safety and quality. Furthermore, there are several important factors that impact the use of HITs, including interoperability, functionality, and usability of systems. It is widely cited that interoperability and information sharing will play a large role in improving the healthcare system and health outcomes (Cutler et al., 2006; Kvedar et al., 2014; Tan, 1999), but has been a challenge to achieve in system design in the healthcare sector. It is a goal of the Meaningful Use program to achieve information sharing and interoperability in the later stages of the program. EHRs may vary by functionalities and usability. In this study, we aim to determine the impact of EHRs on patient safety by focusing on a set of functionalities in order to attest to Meaningful Use, which represents the government standard for EHR adoption and use. In 2013, eligible hospitals for Stage 1 Meaningful Use had to have met all 12 core objectives of Meaningful Use, choose 5 of 10 menu objectives (at least 1 public health measure), and report all 15 clinical quality measures (CQMs). The 12 core objectives included: (1) Use computerized provider order entry (CPOE) for medication orders directly entered by any licensed healthcare professional who can enter orders into the medical record per state, local and professional guidelines; (2) Implement drug-drug and drug-allergy interaction checks; (3) Maintain an up-to-date problem list of current and active diagnoses; (4) Maintain active medication list; (5) Maintain active medication allergy list; (6) Record all of the following demographics: preferred language, gender, race, ethnicity, date of birth, and date and preliminary cause of death in the event of mortality in the eligible hospital or CAH; (7) Record and chart changes in vital signs: height, weight, blood pressure, calculate and display body mass index (BMI), plot and display growth charts for children 2-20 years, including BMI; (8) Record smoking status for patients 13 years or older; (9) Implement one clinical decision support rule related to a high priority hospital condition with the ability to track compliance with that rule; (10) Provide patients with an electronic copy of their health information (including diagnostic test results, problem list, medication lists, medication allergies, discharge summary, procedures), upon request; (11) Provide patients with an electronic copy of their discharge instructions at the time of discharge, upon request; and (12) Protect electronic health information created or maintained by the certified EHR technology through the implementation of appropriate technical capabilities. It is unclear if the specific set of objectives chosen for the Meaningful Use program have had a positive impact on outcomes.

In addition, users with different backgrounds and needs interact with HITs in different ways. Implementing HITs with high usability are necessary to reduce waste and direct development through focusing on measuring the technology's ability to meet the intended purpose. HIT usability evaluation has been overlooked widely during technology development, which has negatively impacted the ability to accomplish system's efficiency, effectiveness, and satisfaction (Minshall, 2013; Yen & Bakken, 2012), and needs to be controlled for when studying HIT adoption and utilization. However, the Office of the National Coordinator for Health Information Technology (ONC-HIT) created a Certified Health IT Product List (CHPL). The purpose of certifying EHRs was to implement systems with higher functionality, interoperability, and usability. In order to receive EHR incentives in 2016, providers and hospitals must use a CMS certified EHR by ONC Authorized Certification Body (ONC-ACB). Study the impact of the national certification of EHRs will help better predict the impact on the system design thresholds set by ONC. Therein, ONC certified EHR systems may have higher levels of functionality, interoperability, and usability, impacting the ability of the hospital to achieve intended outcomes. Studying the EHR certification into the future will provide an opportunity to study the standards set by the ONC. Future studies should incorporate these factors into their theoretical framework, as they impact outcomes of technology use.

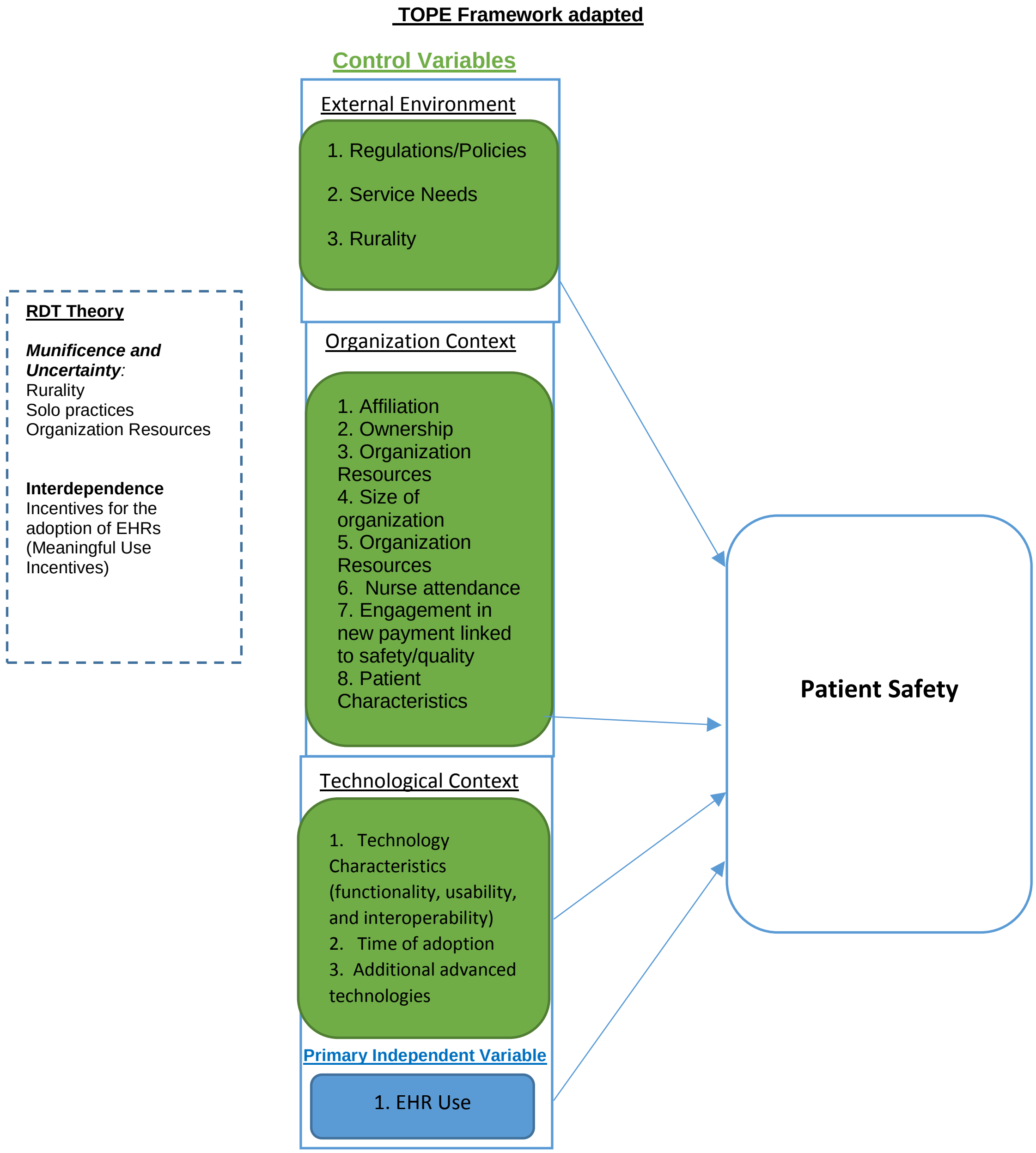
In this study, we apply the RDT to hypothesize the effect of Meaningful Use attestation and rurality on the impact of EHR use on patient safety outcomes. Resource Dependence Theory (RDT) central proposition is that organizations will alter their behaviors to manage their resource dependencies in order to achieve greater autonomy and reduce uncertainty in the flow of vital resources from the environment (Pfeffer and Salancik, 1978; Pfeffer and Salancik, 2003). Constructs of the RDT are uncertainty, munificence, and interdependence. Uncertainty refers “to the degree to which future states of the world cannot be anticipated and accurately predicted” (Pfeffer and Salancik, 1978). Munificence refers to the abundance of critical resources in the environment to support the organizations survival. Interdependence refers to organizations reliance on one another for the acquisition of resources.

Hospitals may be adopting and implementing EHRs to attest to Meaningful Use in order to secure resources “to achieve greater autonomy and reduce uncertainty in the flow of vital resources from the environment,” as stated in the RDT. Securing these resources may be the driving factor in adopting Meaningful Use capable EHR systems. Other resources hospitals may secure by adopting Meaningful Use capable EHR systems include coverage by insurance networks and increased revenue through patient satisfaction, while avoiding financial penalties in Medicare reimbursement. In contrast, those hospitals that have fully-implemented EHR systems that are not receiving incentives through the Meaningful Use program may face more pressure to improve outcomes to receive the financial benefits from their EHR system.

H1.*Hospitals that attest to Meaningful Use and receive incentives for their EHR systems will have greater gains in patient safety outcomes than hospitals that have fully-implemented EHR systems that do not receive Meaningful Use incentives, when compared to their counterparts with partially-implemented or no EHRs.*

The newly developed framework views the utilization of advanced information technology's impact on patient safety from an institutional and resource dependence perspective, and focuses on describing the organizational, environmental, and external characteristics of hospitals that influence patient safety with the use of EHR technologies. The constructs of the newly develop framework includes: (1) external environment, (2) organizational context, and (3) technological context (Figure 6).

Figure 6. A framework for HIT impact on patient safety: Information Technology-Technology, Organizational, Provider, and Environmental (IT-TOPE)



METHODS

Data and Study Sample

We used three data sources in this study to examine the impact of EHRs on patient safety outcomes. Inpatient hospitalization information was used from Healthcare Cost and Utilization Project (HCUP) 2013 State Inpatient Databases (SID) of Florida, Nebraska, New York, and Washington. One state was chosen from each of the census regions to be more geographically representative to a national sample. Additionally, we used 2013 American Hospital Association (AHA) annual survey data and CMS Meaningful Use attestation records to gather hospital characteristics and information regarding their EHR systems. Our final sample included 349 hospitals from Florida, Nebraska, New York, and Washington that provided information about their EHR systems.

Data Elements

Outcomes variables

We used the Agency for Healthcare Research and Quality (AHRQ) PSI software version 5.0 and SAS version 9.4 statistical software to determine the hospital-level risk-adjusted standardized rates for 8 patient safety indicators (PSIs), and the PSI 90 composite score. PSIs developed by AHRQ are a set of indicators providing information on patient's potential hospital complications and adverse events following surgeries and procedures. Risk-adjustment using the AHRQ software includes a complex algorithm to adjust for patient characteristics (age, gender), severity of illness, and 25 comorbidities as covariates (Geppert, Rhoda, & Morara, 2013). The 2013 population file was used in the software to produce risk-adjusted rates based on the general population at risk during the year 2013. Death related PSIs included in the study were: death rate in low-mortality diagnosis related groups (DRGs), and death rate among surgical inpatients with serious treatable complications. Non-death related PSIs included: iatrogenic pneumothorax rate (collapsed lung due to medical treatment), postoperative physiologic and metabolic derangement rate, postoperative respiratory failure rate (breathing failure after surgery), perioperative pulmonary embolism or deep vein thrombosis rate (serious blood clots after surgery), postoperative sepsis rate, and postoperative wound dehiscence rate (wounds split open after surgery). Rates were transformed to represent rates per 1,000 patients.

Additionally, the PSI 90 composite scores were calculated by the AHRQ PSI software to determine the overall impact on patient safety. PSI 90 composite scores are the weighted average of the reliability-adjusted observed-to-expected ratios. Each of the PSI components are weighted by component weights and reliability-adjusted ratios (RARs) among 11 PSI component indicators, including PSI #03 Decubitus Ulcer, PSI #06 Iatrogenic Pneumothorax, PSI #11 Postoperative Respiratory Failure, PSI #07 Selected Infection Due to Medical Care, PSI #08 Postoperative Hip Fracture, PSI #09 Postop Hemorrhage or Hematoma, PSI #10 Postoperative Physiologic and Metabolic Derangements, PSI #12 Postoperative Pulmonary Embolism or Deep Vein Thrombosis, PSI #13 Postoperative Sepsis, PSI #14 Postoperative Wound Dehiscence, PSI #15 Accidental Puncture or Laceration. First, the component weights are numerator weights, which is determined by the relative frequency of the numerators for the component indicators in the reference population. Therein, the weighting of the individual component indicators is based on only volume weights (numerator weights), calculated in the software on the number of safety-related events for the component indicators in the all-payer reference population. Second, the reliability-adjusted ratios are determined empirically. The reliability-adjusted weights are the signal-to-noise ratio, where the signal variance is estimated from the reference population, and the noise variance is estimated from the dataset and is unique to each provider in the dataset. Each weighted reliability-adjusted ratio for each indicator is summed to determine the composite score (AHRQ, 2015).

Composite = [indicator1 RAR × weight1] + [indicator2 RAR × weight2] + . . . + [indicatorN RAR × weightN]

The component measures are expressed as a ratio to the reference population rate, where a provider will have a composite rate of 1 if the risk adjusted ratio component score that are the same as the reference population. Composite scores that include 1 represent the same quality as the national average.

Primary Independent Variable

The primary independent variable was determined by combining the Meaningful Use attestation records and the AHA annual survey question about EHR use. Meaningful Use attestation is process for healthcare providers and organizations to secure financial incentives by CMS for demonstrating "meaningful use" of their EHR. Meaningful Use attestation was determined from the CMS attestation records which identifies the stage of Meaningful Use attested to by the hospital, the incentives they received, and the years they attested. The CMS attestation records provided information on the providers who received incentives and attested to Meaningful Use in 2013. The 2013 American Hospital Association (AHA) annual survey data was used to identify information regarding the use of an EHR system. The AHA survey provided the option for providers to report either using no EHR, a partially-implemented EHR, or fully-implemented EHR. Hospitals were categorized into three group for this study: (1)

attesting to Meaningful Use with the use of their EHRs, (2) having a fully-implemented EHR but have not attested to Meaningful Use, and (3) having partially-implemented EHR or no EHR system. This categorization has never been compared in the literature, but provides the opportunity to study outcomes among hospitals that attest to Meaningful Use with the use of their EHRs (the government standard for EHR functionality) and those that have fully-implemented EHR systems that do not attest to Meaningful Use. Our sample included in the study had 90.8% of hospitals had an EHR system, either that attested to Meaningful Use or fully implemented. This is fairly consistent with the national sample where about 94% of hospitals reported having a certified EHR in 2013 (Henry, et al., 2016).

Other Independent Variables

The 2013 American Hospital Association (AHA) annual survey data was used to identify hospital characteristics, such as number of staffed beds, ownership, teaching hospital status, rurality of facility, and nurse-to-staffed bed ratio. Total facility staffed beds were reported as set up and staffed at the end of reporting period in the AHA annual survey. Teaching hospital status was coded as a categorical variable including major teaching hospital, minor teaching hospital, and non-teaching hospital. Hospitals that reported having Council of Teaching Hospitals designation of the Association of American Medical Colleges were categorized as major teaching hospital. Hospitals were categorized as minor teaching hospitals if they reported any one or more of the following: (1) approval to participate in residency and/or internship training by the Accreditation Council for Graduate Medical Education (ACGME), (2) medical school affiliation reported to the American Medical Association (AMA), (3) Internship approved by American Osteopathic Association, and/or (4) residency approved by American Osteopathic Association. Ownership status was categorized by for-profit and non-profit/government. Nurse to bed ratio was defined as a continuous variable determined by number of full time equivalent (FTE) registered nurses (RN) and licensed practical nurses (LPN) to the number of staffed beds.

Statistical Analysis

First, we produced data summary statistics and performed a bivariate analysis to examine the difference in outcome variables and explanatory variables by EHR use. Analysis of variance (ANOVA) and chi squared tests were used during our bivariate analysis, among continuous and categorical variables respectively. Then, we performed multivariate regression analyses using generalized linear model (GLM) method with log link function and gamma family distribution to examine the impact of EHR use on the individual PSIs and the PSI 90 composite score. Safety-related adverse events, if measured using with a Poisson parameter (ex. mean rate for patients) across each facility, should be considered gamma distributed (Appari et al., 2014; Singer et al., 2009; Gardner, Mulvey, and Shaw, 1995). This is consistent with the previous literature where PSI measures are rate variables, and each PSI was modeled as a nonlinear regression model with a log link function and gamma distribution using a GLM model (Appari et al., 2014). The model coefficient represents the semi-elasticity, where the dependent variable changes by 100*(coefficient) percent for a one unit increase in the independent variable while all other variable in the model are held constant. In the final model, we adjusted for minor teaching hospital status, major teaching hospital status, for profit status, nurse-to-staffed bed ratio, state, and staffed beds. Rurality was excluded from the model because of its strong correlation with teaching hospital status, where teaching hospitals are primarily located in metropolitan areas compared to rural areas. All analysis conducted using Stata/IC v.14.1.

RESULTS

The majority of the hospitals attested to Meaningful Use Stage 1 with the use of their EHR systems (82.2%), followed by having partially-implemented or no EHR system (9.2%) and having a fully-implemented EHR system that does not attest to Meaningful Use (8.6%). The majority of hospitals had 100-299 beds (38.7%), had non-profit status (91.4%), were not teaching hospitals (57.0%), located in a metropolitan area (74.8%), from New York (37.3%), and had an average nurse to bed ratio of 1.73.

There were not many significant differences in hospital characteristics across EHR use groups, except for the number of staffed hospital beds and the state where hospitals were located (Table 7). The majority of hospitals with partially-implemented or no EHR (46.9%) and with fully-implemented EHRs not attesting to Meaningful Use (56.7%) had less than 100 staffed beds in their facilities, compared to the majority of hospitals that attested to Meaningful Use with their EHRs (40.8%) had 100-299 staffed beds in their facilities ($p=0.002$). The majority of hospitals with partially-implemented or no EHR were from Nebraska (31.3%) and New York (34.4%), compared to fully-implemented EHRs that don't attest to Meaningful Use were from Florida (30%) and Washington (33.3%) ($p<0.001$). The majority of hospitals attesting to Meaningful Use were located in Florida (37.3%) and New York (39.7%).

Table 7. Description of EHR use and Hospital Characteristics

	Total sample n(%) **(N=349)**	**Partially-implemented or No EHR** n(%) **(n=32)**	**Full-EHR without MU** n(%) **(n=30)**	**EHR that attests to MU** n(%) **(n=287)**	**P-value**
Hospital Characteristics					
Number of staffed beds *Mean (SD)*	292.2 (17.2)	237.8 (73.5)	217.8 (79.2)	306.1 (17.4)	0.218
<100	97 (27.8)	15 (46.9)		65 (22.7)	
100-299	135 (38.7)	11 (34.4)	17 (56.7)	117 (40.8)	0.002
300-399	36 (10.3)	2 (6.25)	7 (23.3)	31 (10.8)	
400-499	20 (5.7)	0	3 (10.0)	19 (6.6)	
500 & greater	60 (17.5)	4 (12.5)	1 (3.3)	55 (19.2)	
			2 (6.7)		
N (%) for profit	30 (8.6)	4 (12.5)	2 (6.7)	24 (8.4)	0.676
Teaching status					
Non-teaching	199 (57.0)	21 (65.6)	19 (63.3)	159 (55.4)	
Minor teaching	110 (31.5)	8 (25.0)	7 (23.3)	95 (33.1)	0.687
Major teaching	40 (11.5)	3 (9.4)	4 (13.3)	33 (11.5)	
Location					
State					
Florida	122 (35.0)	6 (18.8)	9 (30.0)	107 (37.3)	
Nebraska	38 (10.9)	10 (31.3)	6 (20.0)	22 (7.7)	<0.001
New York	130 (37.3)	11 (34.4)	5 (16.7)	114 (39.7)	
Washington	59 (16.9)	5 (15.6)	10 (33.3)	44 (15.3)	
Rurality					
Rural	88 (25.2)	12 (37.5)	9 (30.0)	67 (23.3)	
Metropolitan	261 (74.8)	20 (62.5)	21 (70.0)	220 (76.7)	0.177
Nurse attendance					
Nurse to bed ratio *Mean (SD)*	1.73 (0.03)	2.02 (0.38)	1.84 (0.22)	1.81 (0.05)	0.577

Notes: p-values were derived with ANOVA and Chi-squared tests; MU=Meaningful Use

Impact of EHR Use on Patient Safety

Among EHR use groups, there were significant differences in 7 patient safety outcomes, including: the death rate in low-mortality diagnosis related groups (DRGs), the death rate among surgical inpatients with serious treatable complications, postoperative physiologic and metabolic derangement rate, postoperative respiratory failure rate (breathing failure after surgery), perioperative pulmonary embolism or deep vein thrombosis rate (serious blood clots after surgery), postoperative sepsis rate, and postoperative wound dehiscence rate (wounds split open after surgery) (Table 8). Partially-implemented or no EHR had a higher mean incidence for the following patient safety outcomes: low-mortality diagnosis related groups (DRGs) with a mean death rate of 1.04 deaths per 1,000 patients (p=0.022); postoperative physiologic and metabolic derangement rate with a mean incidence of 2.20 incidence per 1,000 patients (p=0.004); serious blood clots after surgery with a mean incidence of 9.21 incidence per 1,000 patients (p=0.007); and wounds split open after surgery with a mean incidence rate of 5.90 incidence per 1,000 patients (p=0.006).

Furthermore, fully-implemented EHRs that did not attest to Meaningful Use had the highest mean incidence rate of postoperative sepsis with a mean of 19.34 incidence per 1,000 patients, and breathing failure after surgery with a mean incidence of 9.25 incidence per 1,000 patients (p=0.004). Although not significantly different, EHRs that attested to Meaningful Use had the highest mean death rate among surgical inpatients with serious treatable complications with a mean of 124.83 deaths per 1,000 patients (p=0.222). There were no significant differences among EHR groups and collapsed lung due to medical treatment (p=0.897) and the PSI 90 composite score (p=0.407).

Table 8. Summary Statistics of Patient Safety among EHR use

	Partially-implemented or No EHR *Mean (SD)*	**Full-EHR not receiving MU** *Mean (SD)*	**EHR that attests to MU** *Mean (SD)*	**P-value**
Death Related PSI				
Death Rate in Low-Mortality Diagnosis Related Groups (DRGs)	1.04 (0.82)	0.10 (0.06)	0.34 (0.04)	0.022
Death Rate among Surgical Inpatients with Serious Treatable Complications	89.21 (15.65)	109.43 (16.42)	124.83 (5.64)	0.222
Non-Death Related PSI				
Iatrogenic Pneumothorax Rate (collapsed lung due to medical treatment)	0.28 (0.16)	0.19 (0.05)	8.69 (8.40)	0.897
Postoperative Physiologic and Metabolic Derangement Rate	2.20 (1.84)	0.10 (0.04)	0.49 (0.06)	0.004
Postoperative Respiratory Failure Rate (breathing failure after surgery)	7.54 (4.12)	9.25 (3.48)	8.21 (0.39)	0.810
Perioperative Pulmonary Embolism or Deep Vein Thrombosis Rate (serious blood clots after surgery)	9.21 (4.84)	7.52 (4.03)	4.11 (0.19)	0.007
Postoperative Sepsis Rate	9.44 (3.06)	19.34 (6.97)	8.70 (0.71)	0.004
Postoperative Wound Dehiscence Rate (wounds split open after surgery)	5.90 (4.74)	0.59 (0.24)	1.45 (0.22)	0.006
PSI 90 Composite Score*	0.99 (0.03)	0.99 (0.03)	0.95 (0.01)	0.407

Notes: Rates are per 1,000 population; MU=Meaningful Use
*PSI 90 is a composite score, and not a rate

Table 9 shows that after adjusting for minor teaching hospital, major teaching hospital, for-profit status, state, nurse-to-staffed bed ratio, and staffed beds in our model, fully-implemented EHRs that did not attest to Meaningful Use had a significant decrease in adverse events on 3 patient safety outcomes, and EHRs that attested to Meaningful Use had a significant decrease in adverse events on 2 patient safety outcomes. EHRs that attested to Meaningful Use had a significant decrease in adverse events on postoperative physiologic and metabolic derangement rate and in perioperative pulmonary embolism or deep vein thrombosis rate (serious blood clots after surgery). However, there was no significant impact of attesting to Meaningful Use or having a fully-implemented EHR not attesting to Meaningful Use on the PSI 90 composite score compared partially-implemented or no EHR systems.

The effect of fully-implemented EHRs that did not attest to Meaningful Use were larger than those EHRs that attested to Meaningful Use. The death rate in low-mortality DRGs decreased by 291% for those hospitals with a fully-implemented EHR system that did not attest to Meaningful Use compared to hospitals with a partially-implemented or no EHR, indicating a positive impact ($p<0.001$). The effect was less among hospitals attesting to Meaningful Use, decreasing by 93% compared to hospitals with a partially-implemented or no EHR, although not statistically significant ($p=0.086$). This same effect between groups was observed among postoperative physiologic and metabolic derangement rate, and wounds split open after surgery. Postoperative physiologic and metabolic derangement rate decreased by 242% for those hospitals with a fully-implemented EHR system that did not attest to Meaningful Use compared to hospitals with a partially-implemented or no EHR ($p=0.014$). Among hospitals attesting to Meaningful Use postoperative physiologic and metabolic derangement rate decreased by 119% compared to hospitals with a partially-implemented or no EHR ($p=0.002$). Postoperative wound dehiscence rate (wounds split open after surgery) decreased by

193% for those hospitals with a fully-implemented EHR system that did not attest to Meaningful Use compared to hospitals with a partially-implemented or no EHR (p=0.011). Among hospitals attesting to Meaningful Use, there were not significant differences in postoperative wound dehiscence rate compared to hospitals with a partially-implemented or no EHR (p=0.152).

However, Meaningful Use attestation did have a significant decrease in perioperative pulmonary embolism or deep vein thrombosis rate (serious blood clots after surgery). Among hospitals attesting to Meaningful Use perioperative pulmonary embolism or deep vein thrombosis rate decreased by 89% compared to hospitals with a partially-implemented or no EHR (p=0.001). Although, there was not a significant impact observed among fully-implemented EHRs that did not attest to Meaningful Use compared to partially-implemented or no EHR system (p=0.744).

There were not significant differences in death rate among surgical inpatients with serious treatable conditions, iatrogenic pneumothorax rate, postoperative respiratory failure rate, and postoperative sepsis rate between EHR groups.

Table 9. The impact of EHR use on Patient Safety Outcomes

	Coefficient	Confidence Interval	P-value
Death Related PSI			
Death Rate in Low-Mortality DRGs			
Full-EHR not receiving MU	-2.91	-4.31 to -1.51	<0.001
EHR that attests to MU	-0.93	-2.00 to 0.13	0.086
Death Rate among Surgical Inpatients with Serious Treatable Complications			
Full-EHR not receiving MU	0.12	-0.37 to 0.60	0.641
EHR that attests to MU	0.16	-0.22 to 0.53	0.410
Non-Death Related PSI			
Iatrogenic Pneumothorax Rate (collapsed lung due to medical treatment)			
Full-EHR not receiving MU	-0.42	-2.29 to 1.44	0.658
EHR that attests to MU	-0.33	-1.72 to 1.07	0.647
Postoperative Physiologic and Metabolic Derangement Rate			
Full-EHR not receiving MU	-2.42	-4.35 to -0.49	0.014
EHR that attests to MU	-1.99	-3.27 to -0.71	0.002
Postoperative Respiratory Failure Rate (breathing failure after surgery)			
Full-EHR not receiving MU	0.68	-0.01 to 1.31	0.053
EHR that attests to MU	0.47	-0.05 to 0.99	0.077
Perioperative Pulmonary Embolism or Deep Vein Thrombosis Rate (serious blood clots after surgery)			
Full-EHR not receiving MU	-0.13	-0.91 to 0.65	0.744
EHR that attests to MU	-0.89	-1.44 to -0.34	0.001
Postoperative Sepsis Rate			
Full-EHR not receiving MU	0.63	-0.31 to 1.56	0.188
EHR that attests to MU	-0.17	-0.86 to 0.52	0.634
Postoperative Wound Dehiscence Rate (wounds split open after surgery)			
Full-EHR not receiving MU	-1.93	-3.43 to -0.43	0.011
EHR that attests to MU	-0.86	-2.02 to 0.31	0.152
PSI 90 Composite Score			
Full-EHR not receiving MU	-0.02	-0.15 to 0.10	0.701
EHR that attests to MU	-0.07	-0.16 to 0.02	0.122

Notes: Reference= No EHR or Partially-implemented EHR; MU=Meaningful Use
Coefficient is semi-elasticity, where the dependent variable changes by 100*(coefficient) percent for a one unit increase in the independent variable while all other variable in the model are held constant
Model adjusts for minor teaching hospital status, major teaching hospital status, for profit status, state, nurse to staffed bed ratio, and staffed beds

DISCUSSION

The impact of Meaningful Use attestation on patient safety has been understudied, making it difficult to determine if the specific set of objectives for Meaningful Use Objectives have had a positive impact on outcomes. Our study demonstrates that hospitals attesting to Meaningful Use with their EHR systems improved 2 patient safety outcomes. However, EHR use did not have a significant impact on PSI composite scores in 2013, which is consistent with previous literature (Appari et al., 2014). The evidence suggests that hospitals will not see significant differences in their PSI 90 composite scores with the adoption and use of EHR systems, as they move toward pay-for-performance models that incorporate the PSI 90 in the total performance score (TPS). The hospitals with low TPSs will need to focus on other factors and strategies that may significantly impact the PSI 90 composite score to avoid reductions in reimbursement, such as process improvement and staff training. More research is needed to determine strategies that significantly improve the PSI 90 composite score for providers. Furthermore, policy makers may want to focus on specific patient safety indicators that are highly preventable in payment models to avoid penalizing hospitals through reimbursement, rather than incorporating the PSI 90 composite score.

Our results show that hospitals that had EHR systems attesting to Meaningful Use had significantly decreased risk of perioperative pulmonary embolism or deep vein thrombosis by 89% relative to those hospitals with a partially implemented or no EHR system. Surgery is one of the leading causes of blood clot problems, resulting in conditions such as pulmonary embolism or deep vein thrombosis (Heit, et al., 2002). Venous thromboembolism and pulmonary embolism are often lethal diseases, where 1-week survival rate after a pulmonary embolism is only 71%, and results in sudden death in almost 25% of cases (Heit, et al., 1999). Survivors of both conditions may experience serious and costly long-term complications (Bergqvist, et al., 1997). The appropriate medication can be given before and after major surgeries to greatly reduce the risk and prevent blood clots with low, fixed doses of anticoagulant drugs (Goldhaber, and Bounameaux, 2012). We did not find a significant affect among the fully-implemented EHRs that did not meet Meaningful Use, suggesting the functionalities chosen for Stage 1 had a positive impact of EHR use related to the prevention of perioperative pulmonary embolism or deep vein thrombosis. More research needs to be conducted among the specific functionalities of Stage 1 Meaningful Use that contribute to the increased patient safety related to the prevention of perioperative pulmonary embolism or deep vein thrombosis, which could potentially be related to medication monitoring and decision support.

Previous literature found that the odds of an EHR capable of Stage 1 Meaningful Use (but not attest) had decreased the incidence risk of perioperative pulmonary embolism or deep vein thrombosis by 4% (Incident Rate Ratio=0.96), although not significantly different from their reference group. However, this insignificant finding may have accrued because information regarding the EHR systems were collected from 2007 data, but classified by 2011 Meaningful Use functionalities with patient safety estimates between 2008 to 2010. This kind of gap could misclassify many hospitals that adopted the Stage 1 functionalities for Meaningful Use after 2007, which is likely because of the steep increase in EHR adoption that took place in 2009 and after with the implementation of the Affordable Care Act (DesRoches, et al., 2013). Our study also provides the strength in providing a reference group with limited to no EHR functionality compared with two advanced EHR systems, one being the government standard for EHR use supported by the Meaningful Use program. Not separating the other fully-implemented EHRs out of the reference group may dilute the results, and underestimate the observed impact of EHR use on outcomes. To our knowledge, this comparison has not yet been made in the literature in studying the impact of EHRs.

Furthermore, we found that among both advanced EHR groups (fully-implemented EHRs that did not attest to Meaningful Use and hospitals that attested to Meaningful Use) had a significant positive impact on reducing postoperative physiologic and metabolic derangement rate compared to hospitals that had a partially-implemented or no EHR system including. Meaningful Use had a positive impact on these patient safety indicators, but gains observed among EHRs that did not attest to Meaningful use were greater when comparing to hospitals with partially-implemented or no EHR. EHRs that did not attest to Meaningful Use had significant positive impacts on reducing death rate in low-mortality DRGs and postoperative wound dehiscence rate. Our findings are consistent with previous literature where EHRs saw reductions in postoperative wound dehiscence (Appari, et al., 2014). These results may suggest that hospitals purchasing EHR systems without the Meaningful Use incentives may face more pressure to receive the financial benefits, and may focus their efforts on improving selected outcomes to meet the needs of their practices. The postoperative physiologic and metabolic derangement rate decreased by 242% for those hospitals with a fully-implemented EHR system that did not attest to Meaningful Use compared to hospitals with a partially-implemented or no EHR, and decreased by 199% among hospitals attesting to Meaningful Use respectively. Although not statistically significant for EHRs attesting to Meaningful Use, this same effect between groups was observed among death rate in low-mortality DRGs (291% vs. 93% reductions), and postoperative wound dehiscence (193% vs. 86% reductions). More research is needed to determine the functionalities and drivers behind these gains in patient safety among hospitals not receiving

Meaningful Use incentives. It is possible that these hospitals that do not receive incentives are better leveraging functionalities outside of the Meaningful Use objectives to achieve these heightened gains in patient safety, which may need to be considered in adding to the Meaningful Use objectives.

We did not find significant differences among most individual indicators between EHR groups. When using individual indicators, it is difficult to find significant variation among events that are rare, such as adverse patient safety events. Additionally, some single indicators face criticism for low predictability and reliability to determine hospital's patient safety. For example, we did not find significant differences in respiratory failure between EHR groups. AHRQ and literature reports that this indicator presents issues related to accuracy, reliability of physician diagnosis, and questionable preventability, where diagnosis often overlaps with airway management and most are not preventable cases (Scanlon, et al., 2008; Arozullah, et al., 2001; Lawrence et al., 2006; Utter et al., 2010). It may be likely that this PSI has little to no relation with EHR use, rather more related to the sample. It is reported that there is relatively little surgeons can do to minimize the risk of respiratory failure (Lawrence et al., 2006). Most prominent non-modifiable risks are advanced age, a major operation involving the torso, and substantial neurologic, cardiovascular, or pulmonary comorbidity that might have greatly increased the risk of PRF among our groups with EHRs (Arozullah, et al., 2001; Lawrence et al., 2006; Utter et al., 2010). Furthermore, hospitals with EHRs may have the capacity to take on cases with these complicated risk factors due to their technological capacity. Therein, it is difficult to make inferences on overall patient safety using single indicators where composite scores may be more useful in determining the overall impact on patient safety (AHRQ, 2008).

Given these limitations with using postoperative respiratory failure, previous literature demonstrated a reduction in postoperative respiratory failure rate by 11% (Incident Rate Ratio=0.89) (Appari et al., 2014), which included the use of surgical IT systems and historical composite quality scores as a predictors in their model, which was not available in our datasets. Therein, there is the potential for unobserved effects that were not included into our model due to data availability. Although, every effort was made to include significant factors within our model that was included in our datasets. Future longitudinal studies need to be conducted among a national sample of hospitals to provide an understanding of EHR use on postoperative respiratory failure rate. Moreover, policy makers should take caution when using postoperative respiratory failure rate as a PSI to influence policy decisions, given its concerns to reliability, accuracy, and preventability.

Additionally, it is unclear if rurality impacts patient safety outcomes with the use of EHRs in healthcare delivery, especially given the difficulties rural hospitals have faced to achieve Meaningful Use Stage 2 objectives (Adler-Milstein, et al., 2014). Rural hospitals continually fall behind in HIT adoption in the literature (DesRoches et al., 2013; Tietze MF, Williams J, Galimbertti, 2009; Boon, 2007; Memel et al., 2001; Adler-Milstein et al., 2014). Rural hospitals face unique challenges because they have a smaller population base, serve population with higher uninsurance rate, have more limited supply of health professionals due to difficulties in recruitment and retention, and have financial and human-capital constraints. Furthermore, rural hospitals have reported many challenges, mainly financial, work flow, and staffing challenges in EHR adoption (Gabriel, Jones, Samy, 2015). Therein, rural hospitals may be limited by the ability to afford and receive technical support, train staff, and purchase higher quality EHR systems. As a result, rural hospitals may be limited by the inability to afford and receive technical support, train staff, and purchase higher quality EHR systems that may affect outcomes. Due to the relatively small sample size of rural hospitals, we were unable to achieve model convergence to study the effects of rurality between patient safety and EHR use. Future studies should include larger sample sizes of rural hospitals to study their impact on patient safety outcomes with the use of EHR systems. Hospitals with higher degrees of rurality may implement EHRs to secure resources through Meaningful Use incentives. However, due to unexpected costs and ongoing costs that arise with the implementation and use of EHRs (Miller et al., 2005), hospitals with higher degrees of rurality have limited resources to overcome these challenges, making it more difficult to achieve gains in outcomes when compared to hospitals with partially-implemented or no EHR. Urban hospitals may have better resources and decreased uncertainty to achieve higher gains in patient safety outcomes compared to hospitals with partially-implemented or no EHR. Rural hospitals attesting to Meaningful Use may experience lesser gains in patient safety than their urban counterparts when compared to hospitals with partially-implemented or no EHRs, given the financial and staffing challenges faced by small rural hospitals.

Limitations

First, due to the cross-sectional nature to our study, we were not able to establish a causal relationship between EHR use and patient safety. Longitudinal studies are needed to show the long-term impacts these systems have on patient safety outcomes over time. Second, more studies need to be conducted with larger samples in the references group. Our study included 32 hospitals in the reference group, with hospitals containing partially-implemented and no EHR systems. National studies are needed to produce larger sample sizes, where these may be classified into two separate groups on varied EHR functionalities. Furthermore, the sample size was also relatively small in the

EHR group with fully-implemented EHRs that did not attest to Meaningful Use (n=30). We were also not able to study the impact of rurality on patient safety, because of the small sample size we were not able to achieve model convergence. More studies need to be conducted to determine the impact of rurality on outcomes with the use of EHR systems among a nationally representative sample.

Our sample included significant differences between states and EHR use, where 72.3% of our sample was from the states of Florida and New York. Furthermore, we performed a sensitivity analysis to determine the impact of state as a cluster effect in our GLM model (Appendix B). We found consistency within our effects, but the sensitivity analysis did show some differences in our significant findings, suggesting the effect of state may need to be further explored for future studies. Among EHRs that did not attest to Meaningful Use, we still found significant improvements in death rate in low mortality DRGs, postoperative physiologic and metabolic derangement rate, and postoperative would dehiscence rate when treating state as a cluster effect. Furthermore, between the two models we found the same significant improvements in postoperative physiologic and metabolic derangement rate for EHRs that attested to Meaningful Use compared to partially-implemented or no EHR. However, the significant outcome in perioperative pulmonary embolism or deep vein thrombosis rate for EHRs that attested to Meaningful Use was no longer a significant finding when treating state as a cluster effect, where we observed an increase in the standard error. Although, we did find a significant improvement (157% decrease) in postoperative wound dehiscence rate for EHRs that attested to Meaningful Use compared to partially-implemented to or EHR. In our study, we adjusted for state in our regression analysis, and our post-estimation link test showed that the model used in this study was a good predictor of patient safety (p=0.793). By including state as a cluster effect in the model also showed that our model was a good predictor of patient safety (p=0.603). Although, using state as a cluster effect in the GLM model may not be the most efficient model to account for this effect. Studies with larger samples within states should be conducted to be able to more accurately capture the fixed effect at the state-level in studying patient safety and EHR use.

Furthermore, we did not study the impact of specific EHR functionalities, but rather a set of functionalities chosen for Stage 1 Meaningful Use in 2013. The results show that Stage 1 Meaningful Use did have a positive impact on 2 patient safety indicators. Although based on the results of this study, policymakers may need to revisit the current Meaningful Use objectives and standards in order for hospitals to have a larger impact on patient safety with the use of their EHRs. Standards of Meaningful Use may need to be more stringent or functionalities may need to be expanded in order to have a significant impact on patient safety. However, to direct future development and implementation of the Meaningful Use objectives, studies need to be conducted to show the relationship between specific EHR functionalities within Meaningful Use objectives that are associated with positive outcomes. Although, this study demonstrates the impact of the government benchmark for EHR use has had on achieving in patient safety in 2013. Lastly, there is the potential for unobserved effects due to limited data availability for confounders correlated with the explanatory variable that were not included into our model, including leadership positions in safety/quality, having a surgical IT system, and historical composite scores of quality (Appari et al., 2014). Additionally, future studies should include hospital's financial condition as it may have an impact on technology adoption and patient safety outcomes. Although, it is likely that postoperative respiratory failure has low reliability and preventability. The strength of our study is that we were able to classify hospital that actually attested to Meaningful Use, which to our knowledge is the first study to do so in studying patient safety.

CONCLUSION

Our study demonstrates that hospitals attesting to Meaningful Use with their EHR systems improved 2 patient safety outcomes. More research needs to be conducted to determine which functionality or set of functionalities that contribute to these increases in patient safety to direct future Meaningful Use incentives, as hospitals with fully-functional EHRs that did not attest to Meaningful Use had greater effects on patient safety among some indicators. However, EHR use did not have a significant impact on PSI composite scores in 2013, suggesting that hospitals will not see significant differences in their PSI 90 composite scores with the adoption and use of EHR systems as they move toward pay-for-performance models that incorporate the PSI 90 in the total performance score (TPS). Policy makers may want to focus on specific patient safety indicators that are highly preventable when incorporating patient safety into payment models to avoid penalizing hospitals through reimbursement, rather than incorporating the PSI 90 composite score. Longitudinal studies are needed to show the long term impacts these systems have on patient safety outcomes.

CHAPTER 3: The Impact of Electronic Health Records and Meaningful Use on Inpatient Quality

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ABSTRACT

Background: The HITECH Act's goal was not solely for providers to make "meaningful use" of EHRs, but also achieve significant improvements in care processes and outcomes. However, it is unclear if the investments into EHRs have improved the quality of inpatient care given the current state of the literature.

Objective: The objective of this study is to determine the impact of EHRs use and Meaningful Use on inpatient quality.

Methods: Inpatient hospitalization information and discharge data were obtained from Healthcare Cost and Utilization Project (HCUP) 2013 State Inpatient Databases (SID) from Florida, Nebraska, New York, and Washington. Additionally, we used 2013 American Hospital Association (AHA) annual survey data and CMS Meaningful Use attestation records to gather hospital characteristics, Meaningful Use attestation, and information regarding their EHR systems. Our final sample included 349 hospitals from Florida, Nebraska, New York, and Washington that provided information about their EHR systems. We used the Agency for Healthcare Research and Quality (AHRQ) IQI software version 5.0 and SAS version 9.4 statistical software to determine the hospital-level risk-adjusted standardized rates for IQI indicators and composite scores.

First, we produced data summary statistics and performed a bivariate analysis to examine the difference in outcome variables and explanatory variables by EHR use. Then, we performed multivariate regression analysis for IQI composite scores to

examine the impact of EHR use. Generalized linear model (GLM) method was used with log link function and gamma family distribution to determine the effect between EHR use on patient inpatient quality. In the final model, we adjusted for minor teaching hospital status, major teaching hospital status, for profit status, state, nurse-to-staffed bed ratio, staffed beds squared, facility payer mix squared, and Herfindahl-Hirschman index (HHI).

Results: The majority of the hospitals included in the sample attested to Meaningful Use Stage 1 with the use of their EHR systems (82.2%), followed by having partially-implemented or no EHR system (9.2%) and having a fully-implemented EHR system that does not attest to Meaningful Use (8.6%). The majority of hospitals had 100-299 beds (38.7%), were non-profit hospitals (91.4%), were non-teaching hospitals (57.0%), located in a metropolitan area (74.8%), from New York (37.3%), had an average Medicare and Medicaid payers per total admissions payer mix ratio of 0.68, had an average HHI of 0.35, and had an average nurse-to-bed ratio of 1.73.

There were significant differences in the mean IQI 90 composite scores ($p=0.001$) and IQI 91 composite scores ($p<0.001$) between EHR groups. Hospitals with fully-implemented EHRs (mean=0.90) that did not attest to Meaningful Use and hospitals with partially-implemented or no EHR (mean=0.89) had the highest mean composite scores for IQI 90 as compared to hospitals with EHRs that attested to Meaningful Use (mean=0.79), indicating lower quality than EHRs that attested to Meaningful Use. Hospitals with fully-implemented EHRs (mean=0.88) that did not attest to Meaningful Use and hospitals with partially-implemented or no EHR (mean=0.89) had the highest mean composite scores for IQI 91 as compared to hospitals with EHRs that attested to Meaningful Use (mean=0.73), indicating lower quality than EHRs that attested to Meaningful Use.

After adjusting for confounding factors, there were no significant differences in IQI 90 or 91 composite scores between fully-implemented EHRs that did not attest to Meaningful Use compared to their counterparts that had partially-implemented or no EHRs. There were significant differences in IQI 90 and IQI 91 composite scores between EHRs that attested to Meaningful Use compared to partially-implemented or no EHRs, with a 8% decrease composites for mortality for selected procedures and 18% decrease in composites for mortality for selected conditions compared to hospitals with partially-implemented or no EHR.

Conclusion: Meaningful Use attestation may be an important driver related to inpatient quality. In this study, we found that hospitals that have EHRs attesting to Meaningful Use have significantly better inpatient quality for IQI 90 and 91 composite scores compared to hospitals with a partially-implemented or no EHR. We did not observe significant differences in IQI composite scores for hospitals that had EHRs that did not attest to Meaningful Use with their EHR systems compared to hospitals with partially-implemented or no EHR. Policymakers should focus on setting priorities in order to improve population health by studying the impact of Meaningful Use on quality of care with composite measures. More research is needed to determine the Meaningful Use objectives that are associated with higher inpatient quality.

INTRODUCTION

The use of Health Information Technologies (HITs), such as Electronic Health Records (EHRs), will be critical in transforming the United States healthcare system (Chaudhry, et al, 2006; Jones, et al, 2014). The adoption and use of EHRs has been accelerated by the implementation of the Meaningful Use incentive program supported through The Health Information Technology for Economic and Clinical Health Act (HITECH) Act. Through the Meaningful Use program, many healthcare providers and organizations have been eligible to receive financial incentives for demonstrating “meaningful use” with their EHR systems by meeting a set of objectives and criteria specified by Medicare and Medicaid Services (CMS) (Blumenthal and Tavenner, 2010). Although, the HITECH Act authorized the incentive payments through CMS, its goal is not solely for providers to make “meaningful use” of EHRs, but also achieve significant improvements in care processes and outcomes (Blumenthal and Tavenner, 2010). Studying the ability of providers to improve outcomes through attesting to Meaningful Use is a timely topic for researchers, policy makers, healthcare providers, payers, and consumers.

The volume of inpatient care has increased over the past decade, and it is projected to increase by approximately 19 percent between the years 2013 to 2025 (Dall et al, 2013). It will be important for the healthcare system to improve the quality of inpatient care to avoid any negative impacts of population health. However, it is unclear if the investments into EHRs have improved the quality of inpatient care. About half of the research studies in the literature has demonstrated mixed and neural impacts of EHR use on quality outcomes (Jones et al, 2011; Cochran, et al, 2011; Lapane, et al., 2011; Wiljer et al, 2010; Cook, et al, 2011; Furukawa et al., 2010; Jones et al, 2011a; Lakshminarayan et al, 2012; Austrian, et al, 2011; Milani, et al, 2011; Schenarts, et al, 2012; Connelly, et al, 2012; Dowding, et al., 2012; Mazars, et al., 2012). Furthermore, no studies have used Meaningful Use attestation records to determine the impact of EHR that attest to Meaningful Use on quality outcomes (Jones, et al, 2014). The majority of studies only focus on specific Meaningful Use functionalities and their ability to achieve positive outcomes among single quality indicators (Jones et al, 2014; Quinn et al, 2011; Lavinge, et al, 2011; Neafsey et al, 2011; O'Connor, et al., 2011; Holt, et al, 2010; Williams, et al, 2010; Holbrook, et al., 2011; Virga, et al, 2012; Tang et al, 2012; Gustafson, et al, 2012; Wagner, et al, 2012; Tenforde, et al, 2012; Shelley et al, 2011), where it is difficult to determine the overall impact on quality of care from single indicators (AHRQ, 2008). For example, one study found mixed results when studying the impact of computerized provider order entry, and found a 2.1% reduction in mortality among heart attack and heart failure patients (Jones et al, 2011). The results of these studies are also largely mixed (Jones et al, 2014). Given the currently state of the literature, it is difficult to make general inferences about whether or not the Meaningful Use program has produced a positive impact on the overall quality of care. More research is needed to determine if providers attesting to Meaningful Use are improving the overall quality of care.

Inpatient Quality Indicators (IQIs) and composite scores developed by the Agency for Healthcare Research and Quality (AHRQ) have been extensively tested, and used to study the variation in quality across a variety of payer settings (e.g., Medicaid, Medicare, and commercial), patient cohorts, and facilities (Haytham et al, 2011; AHRQ 2008). However, to our knowledge IQIs have not yet been used to study the impact of hospitals attesting to Meaningful Use on quality of care. IQI composite scores are useful to monitor performance regarding inpatient quality, as it is difficult to determine overall differences in quality based on specific indicators (AHRQ, 2008). Currently, there are two composite scores developed by AHRQ that describe inpatient quality including (1) IQI 90 based on mortality for selected procedures and (2) IQI 91 based on mortality for selected conditions. Furthermore, IQI 91 (mortality for selected conditions) is also endorsed by the National Quality Forum (NQF) (AHRQ, 2011; NQF, 2009). These IQI composite scores were created with aims to monitor performance regarding inpatient quality and represent the quality of care “inside hospitals and include measures of utilization of procedures for which there are questions of overuse, underuse, or misuse” (AHRQ, 2007). Furthermore, IQI composite scores pose a wide variety of benefits including: (1) identifying the drivers in quality, (2) detecting differences in quality, and (3) prioritizing actions for quality improvement (AHRQ, 2008).

AHRQ IQI composite scores can provide useful information for consumers to select hospitals, for providers to identify the drivers of quality, for purchasers to select hospitals to improve health outcomes, and for policymakers to set policy priorities (AHRQ, 2008). To our knowledge no studies have determined the impact of Meaningful Use attestation on overall inpatient quality. Studying IQI composite scores will allow us to detect the impact of EHR use on the overall inpatient quality of care. The objective of this study is to determine the impact of EHRs use and Meaningful Use on inpatient quality of care.

THEORETICAL FRAMEWORK

In this study we adapted technology, organizational, and environment (TOE) innovation adoption framework developed by Tornatzky and Fleischer (1990) to describe the impact of EHR use on inpatient quality of care. TOE framework incorporates three contexts that impact the adoption of technological innovations, including: (1) environmental context, (2) organizational context, and (3) technology context. Environmental context is defined by the organization’s environment to conduct business, which includes its industry, competitors, and governmental factors (Tornatzky and Fleischer 1990). The organizational context provides information about the size and scope of organization, managerial structures, and other characteristics of the organization. Technological context takes into account both the internal and external technologies relevant to the organization. This framework has been highly utilized and supported by results of previous research to explain technology adoption across organizations (Brancheau and Wetherbe, 1990; Baker, 2012; Fichman, 1992; Bretschneider, 1990; Cooper and Zmud, 1990). TOE framework provides elements that are important in studying outcomes of technology use, and can be modified to support important factors when studying the impact of EHRs on care outcomes. From this framework, we have incorporated factors that may impact inpatient quality of care to study the impact of EHRs.

The external environment of organizations will have a significant impact on quality of care and technology adoption. Hospitals that face higher degrees of rurality may implement EHRs to secure resources through Meaningful Use incentives. However, due to unexpected costs and ongoing costs that arise from the implementation and use of EHRs (Miller et al., 2005), hospitals with higher degrees of rurality have limited resources to overcome these challenges, making it more difficult to achieve gains in outcomes compared to their better resourced urban counterparts. Furthermore, market competition was included in this framework because of its potential impact on inpatient quality (Propper et al, 2004; Mutter et al, 2008). Past studies have demonstrated that market competition has a significant impact on a number of quality measures, although the indicators may have a positive, negative, or neutral (Mutter et al, 2008). Future research is needed to determine the directional impact of market competition on quality of care.

Furthermore, the literature demonstrates that organizational characteristics have a significant impact on healthcare outcomes (Armstrong et al., 2009; Donabedian, 2003; Lehrman et al., 2010). Important organizational characteristics that may impact on quality and safety outcomes include for-profit status, teaching hospital status, and academic hospital status (Appari et al., 2014). Additionally, studies have shown that organizational support of nurses may affect patient outcomes (Aiken et al., 2002; Rivard et al., 2010). The nurse-to-bed ratio has been used in previous studies to adjust for the effect of nurse support within the organization (Appari et al., 2014). Furthermore, engagement in safety/quality metrics that is linked to compensation may have an impact on patient safety and quality of care at the facility-level (Appari, et al., 2014). Hospital size using number of hospital beds may be a potential confounding factor that impacts the quality of care (Jha, and Epstein, 2010). One view is that larger hospitals may have more resource, technologies, and be involved in teaching activities to produce higher quality of care compared to their smaller counterparts with less resources (Shotel, and LoGerfo et al, 1981). Conversely, other studies have found that medium size hospitals have greater quality compared to large hospitals, where there large size may limit their quality improvement implementation efforts (El-Jardali et al, 2008). Patient characteristics are important to determine the risk adjustment for quality related indicators at the facility-level (Coffey et al, 2013). Previous literature has included facility payer mix to study the impact of advanced information technology use on quality of care (Bourgeois, and Yaylacicegi, 2012). Facility payer mix is associated with organizational resources and may impact the provision of quality (Grabowski, 2001; Bourgeois, and Yaylacicegi, 2012).

HITs were envisioned to improve patient safety and quality. Furthermore, there are several important factors that impact the use of HITs, including interoperability, functionality, and usability of systems. It is widely cited that interoperability and information sharing will play a large role in improving the healthcare system and health outcomes (Cutler et al., 2006; Kvedar et al., 2014; Tan, 1999), but has been a challenge to achieve an efficient system design in the healthcare sector. One of the long term goals of the Meaningful Use program is to achieve information sharing and interoperability in order to improve quality of care and process outcomes. EHRs may vary by functionalities and usability. In this study, we aim to determine the impact of EHRs on patient safety by focusing on a set of functionalities in receiving Meaningful Use incentives, which represents the government standard for EHR adoption and use. It is unclear if the specific set of objectives chosen for the Meaningful Use program have had a positive impact on outcomes.

In addition, users with different backgrounds and needs interact with HITs in different ways. Implementing HITs with high usability are necessary to reduce waste and direct development through focusing on measuring the technology's ability to meet the intended purpose. HIT usability evaluation has been overlooked widely during technology development, which has negatively impacted the system's efficiency, effectiveness, and satisfaction (Minshall, 2013; Yen & Bakken, 2012), and needs to be controlled for when studying HIT adoption and utilization. However, the Office of the National Coordinator for Health Information Technology (ONC-HIT) created a Certified Health IT Product List (CHPL). The purpose of certifying of EHRs was to implement systems with higher functionality, interoperability, and usability. In order to receive EHR incentives in 2016, providers and hospitals must use a CMS certified EHR by an ONC Authorized Certification Body (ONC-ACB). Study the impact of the national certification of EHRs will help better predict the impact on the system design thresholds set by the ONC. Therein, ONC certified EHR systems may have higher levels of functionality, interoperability, and usability, impacting the ability of the hospital to achieve intended outcomes. Studying the EHR certification into the future will provide an opportunity to study the standards set by the ONC. Future studies should incorporate these factors into their theoretical framework, as they impact outcomes of technology use.

In our framework, we apply the RDT to hypothesize the effect of Meaningful Use attestation on the impact of EHR use on inpatient quality outcomes. The Resource Dependence Theory (RDT) central proposition is that organizations will alter their behaviors to manage their resource dependencies in order to achieve greater autonomy and reduce uncertainty in the flow of vital resources from the environment (Pfeffer and Salancik, 1978; Pfeffer and Salancik, 2003). Constructs of the RDT are uncertainty, munificence, and interdependence. Uncertainty refers “to the degree to which future states of the world cannot be anticipated and accurately predicted” (Pfeffer and Salancik, 1978). Munificence refers to the abundance of critical resources in the environment to support the organizations survival. Interdependence refers to organizations reliance on one another for the acquisition of resources.

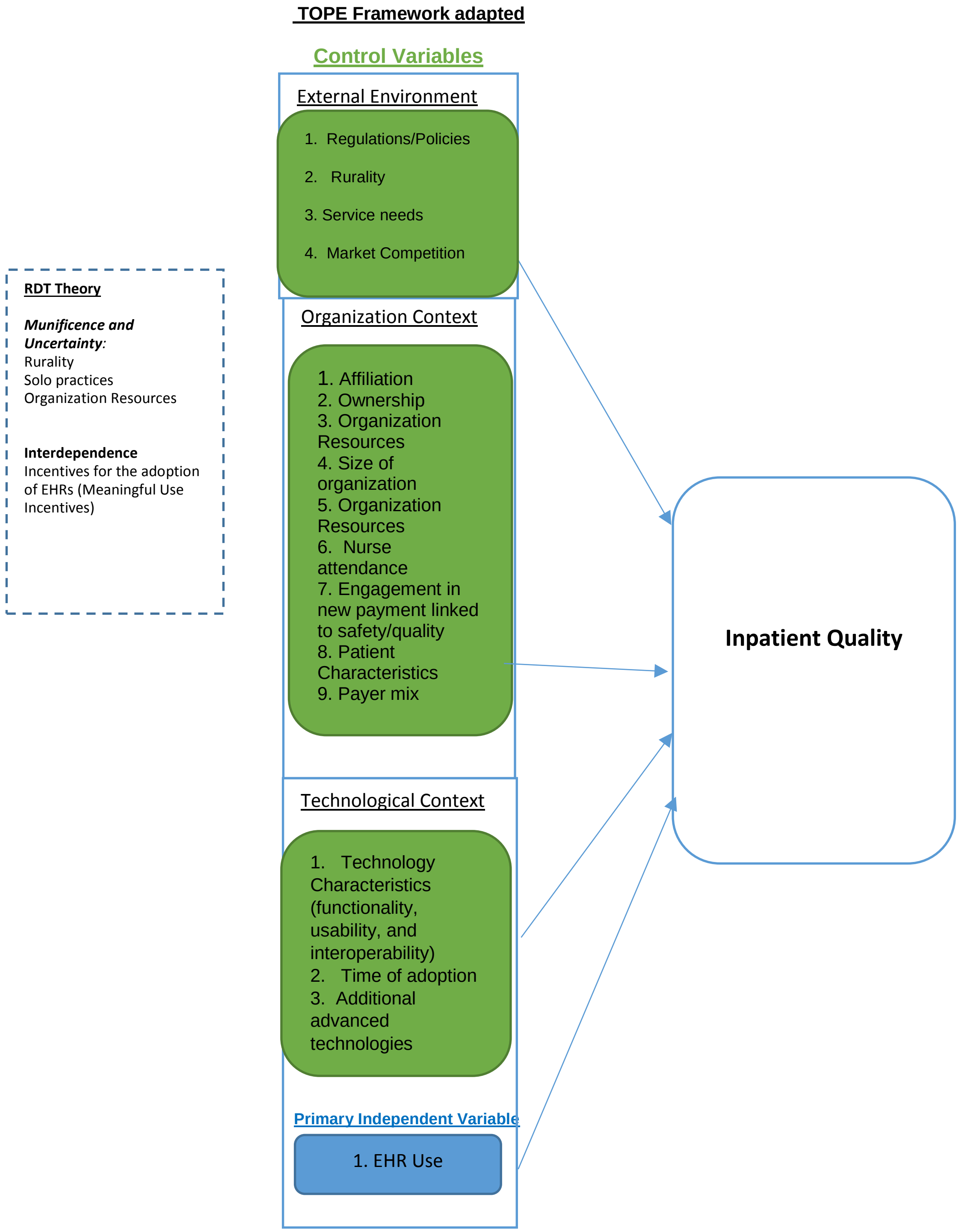
According to the RDT, hospitals may be adopting and implementing EHRs to attest to Meaningful Use in order to secure resources “to achieve greater autonomy and reduce uncertainty in the flow of vital resources from the environment.” Securing these resources may be the driving force in adopting Meaningful Use capable EHR systems, while improve the resources in order to adopt and implement more comprehensive EHR systems. Meaningful Use objectives allow facilities to capture and share better data, which should result in improvements in quality, safety, efficiency, and reduce health disparities. In essence, the ability to adopt necessary functionalities and securing resources to properly implement and use their EHR systems may allow these hospitals to achieve higher quality of care and better outcomes. In contrast, those hospitals that have fully-implemented EHR systems that are not receiving incentives through the Meaningful Use program may face greater financial pressure when unexpected costs arise in implementing and adopting EHRs, that may decrease their ability to improve quality outcomes.

H1.Hospitals that attest to Meaningful Use and receive incentives for their EHR systems will have a positive impact on inpatient quality outcomes compared to their counterparts with partially-implemented or no EHR system.

H2. However, hospitals that have fully-implemented EHR systems that do not receive Meaningful Use incentives will have a less positive impact on inpatient quality outcomes than hospitals that attest to Meaningful Use when compared to their counterparts with partially-implemented or no EHR system.

The newly developed framework views technology's impact on inpatient quality from an institutional and resource dependence perspective, and focuses on describing the characteristics of hospitals that influence the impact of EHR technologies on inpatient quality outcomes. The constructs of the newly develop framework includes: (1) external environment, (2) organizational context, and (3) technological context (Figure 7).

Figure 7. A framework for HIT impact on inpatient quality: Information Technology-Technology, Organizational, Provider, and Environmental (IT-TOPE)



METHODS

Data and Study Sample

We used three data sources in this study to determine the impact of EHRs on patient safety outcomes. Inpatient hospitalization information and discharge data was obtained from Healthcare Cost and Utilization Project (HCUP) 2013 State Inpatient Databases (SID) from Florida, Nebraska, New York, and Washington. One state was chosen from each of the census regions to help us generalize the study sample to a geographically representative national sample. Additionally, we used 2013 American Hospital Association (AHA) annual survey data and CMS Meaningful Use attestation records to gather hospital characteristics and information regarding their EHR systems. Our final sample included 349 hospitals from Florida, Nebraska, New York, and Washington that provided information about their EHR systems.

Data Elements

Outcomes Variables

We used the Agency for Healthcare Research and Quality (AHRQ) IQI software version 5.0 and SAS version 9.4 statistical software to determine the hospital-level risk-adjusted standardized rates for IQIs and composite scores. IQI composite scores were developed by AHRQ, and are comprised of a set of indicators providing information on mortality for certain conditions or procedures (Table 10). Composite scores for mortality for selected procedures (IQI 90) and mortality for selected conditions (IQI 91) were created with aims to monitor performance regarding inpatient quality, as it is difficult to determine overall differences in quality based on specific indicators (AHRQ, 2008). The AHRQ IQIs represent the quality of care “inside hospitals and include measures of utilization of procedures for which there are questions of overuse, underuse, or misuse" (AHRQ, 2007).

Risk adjustments for IQIs were made for age, gender, age-gender interaction, and 3M™. The 3M™ All Patient Refined Diagnosis Related Groups (APR-DRG) System with severity score and risk of mortality were used for risk adjustment of the utilization indicators and the in-hospital mortality indicators through regression-based prior to loading the data (Coffey et al, 2013). First, the risk adjusted rate (RR) is computed through a simple logistic regression model to determine the predicted value (PV). The predicted value for all the cases in each facility are summed to determine the expected rate (ER). The risk-adjusted rate is determined by indirect standardization of the observed rate (OR) divided by the expected rate (ER) and multiplied by the reference population rate (PR) (AHRQ 2008). The 2013 population file was used in the software to produce risk-adjusted rates based on the population at risk during the year 2013.

$$(RR) = (OR/ER \times PR)$$

Second, the risk-adjusted rate is scaled by the reference population. Each IQI indicator risk-adjusted rate is divided by the reference population rate to determine the ratio to the reference population rate for each indicator. The indicators that are part of the composite score are scaled by the reference population rate to reflect the degree of deviation from the overall average performance. Third, the reliability-adjustment ratio (RAR) is computed using the weighted average of the risk adjusted ratio and the reference population ratio. The reliability weights are assigned by the software ranging from 0 to 1, and determined through empirical analysis based on provider size and the indicator (AHRQ 2008).

$$RAR = [\text{risk-adjusted ratio} \times \text{weight}] + [\text{reference population ratio} \times (1 - \text{weight})]$$

Last, the software takes the weighted average of the scaled and reliability-adjusted ratios for the component indicators to determine the composite scores. The composite scores are constructed by summing the weighted average of each of the component indicators using the selected weights and the scaled and reliability-adjusted indicators for each facility (AHRQ 2008):

IQI Composite Score = [indicator1 RAR × weight1] + [indicator2 RAR × weight2] + . . . + [indicatorN RAR × weightN]

The component measures are expressed as a ratio to the reference population rate, where a provider will have a composite rate of 1 if the risk adjusted ratio component score is the same as the reference population. Composite scores that include 1 represent the same quality as the national average.

Table 10. AHRQ IQI Composite Measure Components and Weights

IQI #90: Mortality for Selected Procedures	**IQI #91: Mortality for Selected Conditions**
IQI #08 Esophageal Resection Mortality Rate	IQI #15 Acute Myocardial Infarction (AMI) Mortality Rate
IQI #09 Pancreatic Resection Mortality Rate	IQI #16 Congestive Heart Failure (CHF) Mortality Rate
IQI #11 Abdominal Aortic Aneurism (AAA) Repair Mortality Rate	IQI #17 Acute Stroke Mortality Rate
IQI #12 Coronary Artery Bypass Graft (CABG) Mortality Rate	IQI #18 Gastrointestinal Hemorrhage Mortality Rate
IQI #13 Craniotomy Mortality Rate	IQI #19 Hip Fracture Mortality Rate
IQI #14 Hip Replacement Mortality Rate	IQI #20 Pneumonia Mortality Rate
IQI #30 Percutaneous Transluminal Coronary Angioplasty (PTCA) Mortality Rate	
IQI #31 Carotid Endarterectomy Mortality Rate	

*Endorsed by NQF

Primary Independent Variable

The primary independent variable was determined by combining the Meaningful Use attestation records and the AHA annual survey question about EHR use. Meaningful Use attestation was determined from the CMS attestation records which identifies the stage of Meaningful Use attested to by the hospital, the incentives they received, and the years they attested. The CMS attestation records provided information on the providers who received incentives and attested to Meaningful Use in 2013. The 2013 American Hospital Association (AHA) annual survey data was used to identify information regarding the use of an EHR system. The AHA survey asks “Does your hospital have an electronic health record?” with where providers can report either using no EHR, a partially-implemented EHR, or fully-implemented EHR. Hospitals were categorized into three group: (1) meeting Meaningful Use with the use of their EHRs, (2) having a fully-implemented EHR but have not attested to Meaningful Use, and (3) having partially-implemented EHR or no EHR system from the AHA survey. This categorization has never been compared in the literature, but provides the opportunity to study outcomes among hospitals that attest to Meaningful Use with the use of their EHRs (the government standard for EHR functionality) and those that have fully-implemented EHR systems that do not attest to Meaningful Use compared to those hospitals with limited EHR use. Our sample included in the study had 90.8% of hospitals had an EHR system, either that attested to Meaningful Use or fully implemented. This is fairly consistent with the national sample where about 94% of hospitals reported having a certified EHR in 2013 (Henry, et al., 2016).

Other Independent Variables

The 2013 American Hospital Association (AHA) annual survey data was used to identify hospital characteristics, such as number of staffed beds, ownership, teaching hospital status, rurality, facility payer mix, nurse-to-staffed bed ratio, and Herfindahl-Hirschman index (HHI). Total facility staffed beds were reported as set up and staffed at the end of reporting period in the AHA annual survey. Teaching hospital status was coded as a categorical variable including major teaching hospital, minor teaching hospital, and non-teaching hospital. Hospitals that reported having Council of Teaching Hospitals designation of the Association of American Medical Colleges were categorized as major teaching hospital. Hospitals were categorized as minor teaching hospitals if they reported any one or more of the following: (1) approval to participate in residency and/or internship training by the Accreditation Council for Graduate Medical Education (ACGME), (2) medical school affiliation reported to the American Medical Association (AMA), (3) Internship approved by American Osteopathic Association, and/or (4) residency approved by American Osteopathic Association. Ownership status was categorized by for-profit and non-profit/government. Nurse to bed ratio was determined by number of full time equivalent (FTE) registered nurses (RN) and licensed practical nurses (LPN) to the number of staffed beds. Facility payer mix was included because it is associated with organizational resources and can impact the provision of quality (Grabowski, 2001; Bourgeois, and Yaylacicegi, 2012), which has also been used in previous literature to study the impact of advanced information technology use on quality of care (Bourgeois, and Yaylacicegi, 2012). Facility payer mix ratio was determined by adding the total number of Medicare and Medicaid admissions divided by the total admissions for each facility. We constructed a Herfindahl-Hirschman Index (HHI) on bed shares at the county-level to represent the market competition. We calculate the county-level bed share by dividing the total facility beds in the facility by the sum of the total facility beds in the county. Herfindahl-Hirschman Index was constructed by summing the squares of the county-level bed shares.

Statistical Analysis

First, we produced data summary statistics and performed a bivariate analysis to examine the differences between outcome variables and explanatory variables by EHR use. Analysis of variance (ANOVA) and chi squared tests were used during our bivariate analysis, among continuous and categorical variables respectively. Then, we performed multivariate estimation to examine the impact of EHR use on IQI composite scores. Generalized linear model (GLM) method was used with log link function and gamma family distribution to determine the effect between EHR use on inpatient quality. This is consistent with the previous literature where adverse events, if measured using with a Poisson parameter (ex. mean rate for patients) across each facility, should be considered gamma distributed (Appari et al., 2014; Singer et al., 2009; Gardner, Mulvey, and Shaw, 1995). The model coefficient represents the semi-elasticity, where the dependent variable changes by 100*(coefficient) percent for a one unit increase in the independent variable while all other variable in the model are held constant. In the final model, we adjusted for minor teaching hospital status, major teaching hospital status, for profit status, state, nurse-to-staffed bed ratio, staffed beds, facility payer mix squared, and HHI. Due to model convergence, we used staffed beds as a continuous variable in the final model. Rurality was excluded from the model because of its strong correlation with teaching hospital status, where teaching hospitals are primarily located in metropolitan areas compared to rural areas. Post-estimation link test was performed, and determined final model as a well-fit model. All analysis conducted using Stata/IC v.14.1.

RESULTS

The majority of the hospitals included in the sample attested to Stage 1 Meaningful Use with the use of their EHR systems (82.2%), followed by having partially-implemented or no EHR system (9.2%) and having a fully-implemented EHR system that does not attest to Meaningful Use (8.6%). The majority of hospitals had 100-299 beds (38.7%), were non-profit hospitals (91.4%), were non-teaching hospitals (57.0%), located in a metropolitan area (74.8%), from New York (37.3%), had an average Medicare and Medicaid payers per total admissions payer mix ratio of 0.68, had an average HHI of 0.35, and had an average nurse to bed ratio of 1.73.

Table 11 shows there were not many significant differences across EHR groups. There were significant differences in number of staffed hospital beds ($p=0.002$) and the state where hospitals were located ($p<0.001$) between EHR groups (Table 11). The majority of hospitals with partially-implemented or no EHR (46.9%) and with fully-implemented EHRs not attesting to Meaningful Use (56.7%) had less than 100 staffed beds in their facilities, compared to the majority of hospitals that attested to Meaningful Use with their EHRs (40.8%) had 100-299 staffed beds in their facilities. The majority of hospitals with partially-implemented or no EHR were from Nebraska (31.3%) and New York (34.4%), compared to fully-implemented EHRs that did not attest to Meaningful Use were from Florida (30%) and Washington (33.3%). The majority of hospitals attesting to Meaningful Use were located in Florida (37.3%) and New York (39.7%).

Table 11. Description of EHR use and Hospital Characteristics

	Total sample n(%) **(N=349)**	**Partially-implemented or No EHR** n(%) **(n=32)**	**Full-EHR without MU** n(%) **(n=30)**	**EHR that attests to MU** n(%) **(n=287)**	**P-value**
Organization Characteristics					
Number of staffed beds *Mean (SD)*	292.2 (17.2)	237.8 (73.5)	217.8 (79.2)	306.1 (17.4)	0.218
<100	97 (27.8)	15 (46.9)	17 (56.7)	65 (22.7)	
100-299	135 (38.7)	11 (34.4)	7 (23.3)	117 (40.8)	0.002
300-399	36 (10.3)	2 (6.25)	3 (10.0)	31 (10.8)	
400-499	20 (5.7)	0	1 (3.3)	19 (6.6)	
500 & greater	60 (17.5)	4 (12.5)	2 (6.7)	55 (19.2)	
N (%) for profit	30 (8.60)	4 (12.50)	2 (6.67)	24 (6.36)	0.676
Teaching status					
Non-teaching	199 (57.0)	21 (65.6)	19 (63.3)	159 (55.4)	
Minor teaching	110 (31.5)	8 (25.0)	7 (23.3)	95 (33.1)	0.687
Major teaching	40 (11.5)	3 (9.4)	4 (13.3)	33 (11.5)	
Payer mix ratio *Mean (SD)*	0.68 (0.01)	0.68 (0.03)	0.67 (0.04)	0.69 (0.01)	0.832
Nurse Attendance					
Nurse to bed ratio *Mean (SD)*	1.73 (0.03)	2.02 (0.38)	1.84 (0.22)	1.81 (0.05)	0.577
Location					
State					
Florida	122 (35.0)	6 (18.8)	9 (30.0)	107 (37.3)	
Nebraska	38 (10.9)	10 (31.3)	6 (20.0)	22 (7.7)	<0.001
New York	130 (37.3)	11 (34.4)	5 (16.7)	114 (39.7)	
Washington	59 (16.9)	5 (15.6)	10 (33.3)	44 (15.3)	
Rurality					
Rural	88 (25.2)	12 (37.5)	9 (30.0)	67 (23.3)	
Metropolitan	261 (74.8)	20 (62.5)	21 (70.0)	220 (76.7)	0.177
HHI *Mean (SD)*	0.35 (0.02)	0.33 (0.05)	0.36 (0.06)	0.35 (0.02)	0.957

Notes: P-values were derived with ANOVA and Chi-squared tests; MU=Meaningful Use

Impact of EHR Use on Inpatient Quality

Table 12 shows the mean IQI 90 composite score for mortality for selected procedures was 0.81, and 0.76 for IQI 91 for mortality for selected conditions (Table 12), indicating inpatient quality better than the national average. The component measures are expressed as a ratio to the reference population rate, where a provider will have a composite rate of 1 if the risk adjusted ratio component score was the same as the reference population. Composite scores that include 1 represent the same quality as the national average. There were significant differences in the mean IQI 90 composite scores ($p=0.001$) and IQI 91 composite scores ($p<0.001$) between EHR groups. Fully-implemented EHRs (mean=0.90) that did not attest to Meaningful Use and partially-implemented or no EHR (mean=0.89) that did not attest to Meaningful Use had the highest mean composite scores for IQI 90 as compared to EHRs that attested to Meaningful Use (mean=0.79), indicating lower quality than EHRs that attested to Meaningful Use. Furthermore, similar effects were observed for IQI 91 composite scores. Fully-implemented EHRs (mean=0.88) that did not attest to Meaningful Use and partially-implemented or no EHR (mean=0.89) had the highest mean composite scores for IQI 91 as compared to EHRs that attested to Meaningful Use (mean=0.73), indicating lower quality than EHRs that attested to Meaningful Use.

Table 12. Summary Statistics of Inpatient Quality among EHR use

IQI Composite Scores	**Total** *Mean (SD)*	**Partially-Implemented or No EHR** *Mean (SD)*	**Full-EHR not receiving MU** *Mean (SD)*	**EHR that attests to MU** *Mean (SD)*	**P-value**
IQI #90: Mortality for Selected Procedures	0.81 (0.01)	0.89 (0.03)	0.90 (0.03)	0.79 (0.01)	0.001
IQI #91: Mortality for Selected Conditions	0.76 (0.01)	0.89 (.003)	0.88 (0.03)	0.73 (.01)	<0.001

Notes: MU=Meaningful Use; SD=Standard Deviation

Unadjusted estimates indicated there were no significant differences in IQI 90 composite scores fully-implemented EHRs that did not attest to Meaningful Use and partially-implemented or no EHRs (p=0.846). Similarly, unadjusted estimates indicated there were no significant differences in IQI 91 composite scores between fully-implemented EHRs that did not attest to Meaningful Use and partially-implemented or no EHRs (p=0.805). There were significant differences in IQI 90 and IQI 91 composite scores between EHRs that attested to Meaningful Use and partially-implemented or no EHRs (p=0.012; p<0.001, respectively). IQI 90 composite scores for mortality for selected procedures decreased by 12% for hospitals that had EHRs that attested to Meaningful Use compared to their counterparts partially-implemented or no EHR. IQI 91 composite scores for mortality for selected conditions decreased by 20% for hospitals that had EHRs that attested to Meaningful Use compared to their counterparts partially-implemented or no EHR.

We performed forward model selection, where model 1 adjusts for basic organization characteristics, such as minor teaching hospital status, major teaching hospital status, for profit status, state, nurse to staffed bed ratio, and staffed beds. In model 1, there were no significant differences in IQI 90 composite scores between fully-implemented EHRS that did not attest to Meaningful Use (p=0.836) compared to their counterparts that had partially-implemented or no EHRs. In model 1, there were significant differences in IQI 90 composite scores between EHRs that attested to Meaningful Use (p=0.009) compared to their counterparts that had partially-implemented or no EHRs. IQI 90 composite scores for mortality for selected procedures decreased by 11% for hospitals that had EHRs that attested to Meaningful Use compared to their counterparts partially-implemented or no EHR. Similarly, there were no significant differences in IQI 91 composite scores between fully-implemented EHRS that did not attest to Meaningful Use compared to partially-implemented or no EHRs (p=0.431). There were significant differences in IQI 91 composite scores between EHRs that attested to Meaningful Use and partially-implemented or no EHRs (p<0.001). IQI 91 composite scores for mortality for selected conditions decreased by 21% for hospitals that had EHRs that attested to Meaningful Use compared to their counterparts partially-implemented or no EHR.

In model 2, we adjust for all significant factors that may impact quality of care and the use of EHR systems, including minor teaching hospital status, major teaching hospital status, for profit status, state, nurse-to-staffed bed ratio, staffed beds, facility payer mix squared, and HHI. In model 2, there were no significant differences in IQI 90 composite scores between fully-implemented EHRs that did not attest to Meaningful Use (p=0.723) compared to their counterparts that had partially-implemented or no EHRs. However, there were significant differences in IQI 90 composite scores between EHRs that attested to Meaningful Use (p=0.033) compared to their counterparts that had partially-implemented or no EHRs. For example, IQI 90 composite scores for mortality for selected procedures decreased by 8% for hospitals that had EHRs that attested to Meaningful Use compared to their counterparts partially-implemented or no EHR.

Similarly, there were no significant differences in IQI 91 composite scores between fully-implemented EHRS that did not attest to Meaningful Use and those that had partially-implemented or no EHRs (p=0.971). There were significant differences in IQI 91 composite scores between EHRs that attested to Meaningful Use and partially-implemented or no EHRs (p<0.001). IQI 91 composite scores for mortality for selected conditions decreased by 18% for hospitals that had EHRs that attested to Meaningful Use compared to their counterparts partially-implemented or no EHR.

Table 13. The impact of EHR use on IQI Outcomes

IQI Composite Scores	**Unadjusted (CI)**	**P-value**	**Model 1 Coefficient (CI)**	**P-value**	**Model 2 Coefficient (CI)**	**P-value**
Mortality for Selected Procedures (IQI #90)						
Full-EHR not receiving MU	0.01 (-0.11, 0.14)	0.846	0.01 (-0.11, 0.10)	0.836	0.02 (-0.09, 0.12)	0.723
EHR that attests to MU	-0.12 (-0.21, -0.03)	0.012	-0.11 (-0.19, -0.03)	0.009	-0.08 (-0.16, -0.01)	0.033
Mortality for Selected Conditions (IQI #91)						
Full-EHR not receiving MU	-0.01 (-0.13, 0.10)	0.805	-0.04 (-0.16, 0.07)	0.431	0.003 (-0.10, 0.10)	0.971
EHR that attests to MU	-0.20 (-0.29, -0.12)	<0.001	-0.21 (-0.29, -0.13)	<0.001	-0.18 (-0.26, -0.11)	<0.001

Notes: Reference= No EHR or Partially-implemented EHR; MU=Meaningful Use
Coefficient is semi-elasticity, where the dependent variable changes by 100*(coefficient) percent for a one unit increase in the independent variable while all other variable in the model are held constant
Model 1 adjusts for minor teaching hospital status, major teaching hospital status, for profit status, state, nurse to staffed bed ratio, and staffed beds
Model 2 adjusts for minor teaching hospital status, major teaching hospital status, for profit status, state, nurse to staffed bed ratio, staffed beds, facility payer mix squared, and HHI
Post-estimation link test determined final model as a significant predictor of inpatient quality

In the final model, major teaching status (coef -0.17; p=0.001), minor teaching status (coef -0.06; p=0.038), staffed beds (coef -0.06; p=0.038), and payer mix squared (coef 0.27; p<0.001) were other significant predictors of inpatient quality for selected procedures (IQI 90). Additionally, the state was also a significant predictor where Florida (coef -0.11; p<0.001) and Washington (coef -0.08; p=0.017) had significantly better inpatient quality for IQI 90 composite scores compared to New York. In the final model, major teaching status (coef 0.12; p=0.009), staffed beds (coef -0.0002; p<0.001), and HHI (coef 0.12; p=0.004) were other significant predictors of inpatient quality for selected conditions (IQI 91). Additionally, the state was also a significant predictor where Florida (coef -0.23; p<0.001) and Washington (coef -0.09; p=0.008) had significantly better inpatient quality for IQI 91 composite scores compared to New York.

DISCUSSION

Section 1886 of the Social Security Act states, “The Secretary shall seek to improve the use of electronic health records and health care quality over time by requiring more stringent measures of meaningful use.” However, it is unclear if inpatient quality of care has been positively impacted by the use of EHRs and the Meaningful Use program given the current state of the literature (Jones, et al, 2014). Both IQI composite scores 90 and 91 are used for quality reporting measures under Centers for Medicare and Medicaid Services (CMS) program to achieve aims described in the Section 1886 of the Social Security Act. The composite scores were used under the Reporting Hospital Quality Data for Acute Payment Update (RHQDAPU) program by CMS, currently known as Hospital Inpatient Quality Reporting (IQR) Program (AHRQ, February 2010). The RHQDAPU was adopted with aims to move toward implementing value-based purchasing to incorporate quality into payment. Under the program, hospitals receive financial incentive to report the quality of care metrics, and provides CMS with data to help consumers make more informed decisions about their health care.

In this study, we found that hospitals that have EHRs that attest to Meaningful Use have significantly better inpatient quality for IQI 90 (mortality for selected procedures) and 91 (mortality for selected conditions) composite, with a 8% decrease in IQI 90 composite scores and 18% decrease in IQI 91 in composite scores compared to hospitals with partially-implemented or no EHR. Based on constructs of the RDT, the Meaningful Use incentives may be providing the additional financial support needed to overcome challenges related to EHR use and adoption in order to see improvements in quality, including technical support, staff training, workflow disruption, and purchase more advanced functionalities. This evidence suggests that in 2013 the Meaningful Use objectives set by the CMS in the government incentive program has improved inpatient quality related to mortality and procedures for selected conditions. This is consistent with other research, where one study found a significant association between EHR use and inpatient quality for conditions (IQI 91) among large hospitals, but not for mortality for selected procedures (IQI 90) (Michell and Yaylacicegi, 2012). However, this study was a single state study with relative small sample size conducted only among Texas acute care hospitals. Furthermore, they did not classify EHR status by the ability of the system to attest to Meaningful Use. From our results, hospitals that do not attest to Meaningful Use may not observe the same significant gains in inpatient quality. Furthermore, there we Meaningful use had smaller effect among mortality for selected procedures (IQI 90) composite scores compared to inpatient quality for conditions (IQI 91) composite scores. Our study helps provide insight of the impact of hospitals attesting to Meaningful Use with their EHRs. Future studies should determine which Meaningful Use objectives are associated with higher quality of care to help tailor and prioritize Meaningful Use objectives for providers, as it has been a challenge for hospitals to achieve Stage 2 Meaningful Use.

Studying IQI composite scores has strengthened our study in several ways. First, by combining multiple indicators allows researchers to detect the impact of EHRs on the overall inpatient quality of care, and determine the differences between the inpatient quality of care between hospitals with varied EHR use. Using individual indicators may not be able to provide enough discrimination in performance of hospitals as compared to combining the indicators in the composite scores (AHRQ 2008). In our preliminary analysis, we were not able to detect any variation among individual indicators, because mortality outcomes are rare. In order to detect differences in individual indicators, national samples are needed to increase the sample size. Second, the composite scores are comprised of weighed indicators based on the probability for each condition, and offers greater reliability by providing information to maximize the outcomes for the population (AHRQ 2008; NQF, 2009).

Among our study sample, the mean IQI 91 score for mortality for selected conditions was 0.73 for hospitals that attest to Meaningful Use compared to a mean of 0.89 for hospitals with partially-implemented or no EHR, indicating better inpatient quality than the national average. The composite scores are a weighted average of the component measures expressed as a ratio to the reference population rate. For an example, a providers with a composite score of 1 will have risk adjusted component scores that are the same as the reference population, indicating that the provider's inpatient quality is not different from the national average. However, if a provider has a composite score below 1, then provider is doing better than the national average for inpatient quality. Our estimates may provide as a reference for providers regarding IQI composite measures, where hospitals that attested to Meaningful Use with their EHRs had an average IQI 91 score of 0.73 and IQI 90 of 0.79 in our sample. Policymakers might need to set policy priorities in order to improve population health through research studying the impact of Meaningful Use on quality of care with composite measures. For example, national studies are needed to determine the benchmarks for the IQI composite measures with the use of EHRs, which may be linked to reimbursement. This study validates that Meaningful Use of EHRs may be an important driver related to quality of inpatient care, where the study suggests the national investments in the technology have had system-level improvements on inpatient quality. Although, healthcare stakeholders may need to prioritize their actions for quality improvement in order to leverage their EHRs to better improve IQI 90 composite score for mortality for selected procedures, as we saw a lesser impact on IQI 90 compared to IQI 91.

Last, it should be warranted that hospitals that attest to Meaningful Use may have become interdependent on the Meaningful Use incentives in order to secure resources in supporting their EHR implementation and use efforts. This study has demonstrated improvements in inpatient quality among hospitals that receive Meaningful Use incentives. As the Meaningful Use program is eventually phased out, healthcare stakeholders may experience unintended consequences that may negatively impact the ability of hospitals to achieve improvements in outcomes with the use of their EHR systems, especially as ongoing software updates, technical support infrastructure, and staff training will still be needed. Future research should examine factors that require ongoing support in order to fully utilize EHRs among hospitals that attest to Meaningful Use in order to avoid negative unintended consequences in achieving gains in outcomes after the term of the program, such as inpatient quality.

Limitations

Due to data availability, we have a relatively small sample size in the reference group that included 32 hospitals. Furthermore, the sample size was also relatively small in the EHR group with fully-implemented EHRs that did not attest to Meaningful Use (n=30). We were unable to detect variance between specific indicators that contribute to the significant differences in IQI composite scores, as mortality related events are rare as compared to adverse events. However, it is difficult to determine differences in quality of care by using single indicators (AHRQ, 2008). This study does provide insight of the impact of Meaningful Use on overall inpatient quality. Future studies need to include national samples of providers to determine the impact of EHR use on specific quality indicators, where we found significant differences in IQI composite scores between hospitals with varied EHR use. Second, we were not able to establish causality due to the cross-sectional study design. Longitudinal studies are needed to determine the impact of EHRs on quality of care regarding the change in regulations of the Meaningful Use objectives and stages.

Our sample included significant differences between states and EHR use, where 72.3% of our sample was from the states of Florida and New York. Furthermore, there may be a cluster effect at the state-level that was not accounted for in our study. After a sensitivity analysis treating state as a cluster effect, there were no significant differences observed in the IQI 91 scores (coef -0.21; p=0.093) for EHRs that attested to Meaningful Use compared to partially-implemented or no EHR. Similarly, there were no significant differences observed in the IQI 90 scores (coef -0.10; p=0.061) for EHRs that attested to Meaningful Use compared to partially-implemented or no EHR. Using cluster effect for the state in our GLM model may not be the most efficient way to account for this effect resulting in an increased standard error. However, the state was accounted for in our regression analysis and post-estimation link test determined our model to be a good predictor of inpatient quality (p=0.520). Post-estimation link test also showed that treating the state as a cluster effect in our GLM model was a significant predictor of inpatient quality (p=0.385). Future studies should include larger samples at the state-level to more accurately account for this fixed effect in studying the impact of inpatient quality and EHR use.

CONCLUSION

To our knowledge, this is the first study to determine the impact of Meaningful Use attestation on overall inpatient quality of care among hospitals in the United States. Meaningful Use attestation may be an important driver related to inpatient quality. In this study, we found that hospitals that have EHRs attesting to Meaningful Use have significantly better inpatient quality for IQI 90 and IQI 91 composite scores, with a 8% decrease composites for mortality for selected procedures and 18% decrease in composites for mortality for selected conditions compared to hospitals with partially-implemented or no EHR. Although, we did not observe significant differences in IQI composite scores among hospitals with EHRs that did not attest to Meaningful Use with their EHR systems. Policymakers should focus on setting priorities in order to improve population health by studying the impact of Meaningful Use on quality of care with composite measures, especially related to the IQI 91 composite score. More research is needed to determine the Meaningful Use objectives that are associated with higher inpatient quality.

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APPENDIX A. Primary, Surgical, Medical Specialties

AMA SPECIALTIES REGROUPED INTO PRIMARY CARE, SURGICAL, AND MEDICAL SPECIALTIES

Below is a list of the AMA physician specialties comprising the NAMCS sample strata, regrouped into primary care, surgical, and medical specialties for analytic purposes (see SPECCAT variable on file layout).

PRIMARY CARE SPECIALTIES
ADL - Adolescent Medicine (Pediatrics)
AMF - Adolescent Medicine (Family Practice)
AMI - Adolescent Medicine (Internal Medicine)
EFM - Emergency Medicine/Family Medicine
FP - Family Practice
FPG - Geriatric medicine (Family Practice)
GP - General Practice
GYN - Gynecology
HPF - Hospice & Palliative Medicine (Family Medicine)
IFP - Internal Medicine/Family Practice
IM - Internal Medicine
IMG - Geriatric Medicine (Internal Medicine)
IPM - Internal Medicine/Preventive Medicine
MPD - Internal Medicine/Pediatrics
OBG - Obstetrics & Gynecology
OBS - Obstetrics
PD - Pediatrics
PSM - Pediatric Sports Medicine

SURGICAL SPECIALTIES
AS - Abdominal Surgery
CCS - Surgical Critical Care (Surgery)
CFS - Craniofacial Surgery
CHS - Congenital Cardiac Surgery (Thoracic Surgery)
CRS - Colon & Rectal Surgery
CS - Cosmetic Surgery
DS - Dermatologic Surgery
FPS - Facial Plastic Surgery
GO - Gynecological Oncology
GS - General Surgery
HO - Hematology/Oncology
HNS - Head & Neck Surgery
HS - Hand Surgery
HSO - Hand Surgery (Orthopedics)
HSP - Hand Surgery (Plastic Surgery)
HSS - Hand Ssurgery (Surgery)
MFM - Maternal & Fetal Medicine
NO - Neurotology (Otolaryngology)
NS - Neurological Surgery
NSP - Pediatric Surgery (Neurology)
OAR - Adult Reconstructive Orthopedics
OCC - Critical Care Medicine (Obstetrics & Gynecology)
OFA – Foot And Ankle, Orthopedics
OMF - Oral and Maxillofacial Surgery
OMO- Musculoskeletal Oncology
ON - Medical Oncology
OP - Pediatric Orthopedics
OPH - Ophthalmology
ORS - Orthopedic Surgery
OSM - Sports Medicine (Orthopedic Surgery)
OSS - Orthopedic Surgery Of The Spine
OTO - Otolaryngology
OTR - Orthopedic Trauma
PCS - Pediatric Cardiothoracic Surgery
PDO - Pediatric Otolaryngology
PDS - Pediatric Surgery (Surgery)
PO - Pediatric Ophthalmology
PRD - Procedural Dermatology
PS - Plastic Surgery
PSH - Plastic Surgery Within the Head & Neck
SO - Surgical Oncology
TRS - Trauma Surgery
TS - Thoracic Surgery
TTS - Transplant Surgery
U - Urology
UP - Pediatric Urology
VS - Vascular Surgery

MEDICAL SPECIALTIES
A - Allergy
ADM - Addiction Medicine
ADP - Addiction Psychiatry
AI - Allergy & Immunology
ALI - Clinical Laboratory Immunology (Allergy & Immunology)
AM - Aerospace Medicine
MEDICAL SPECIALTIES (cont.)
CAP - Child Abuse Pediatrics
CBG - Clinical Biochemical Genetics
CCG - Clinical Cytogenetics
CCM -Critical Care Medicine (Internal Medicine)
CCP - Pediatric Critical Care Medicine
CD - Cardiovascular Disease
CG - Clinical Genetics

MEDICAL SPECIALTIES (continued)

CHN - Child Neurology
CHP - Child and Adolescent Psychiatry
CMG -Clinical Molecular Genetics
CN - Clinical Neurophysiology
CPP - Pediatrics/Psychiatry/Child & Adolescent Psychiatry
D - Dermatology
DBP - Developmental-Behavioral Pediatrics
DDL – Clinical And Lab Derm Immunology
DIA - Diabetes
EM - Emergency Medicine
EMP - Pediatrics/Emergency Medicine
END - Endocrinology, Diabetes and Metabolism
EP - Epidemiology
ESM - Sports Medicine (Emergency Medicine)
ETX - Medical Toxicology (Emergency Medicine)
FPP – Psychiatry/Family Practice
FSM – Family Practice/Sports Medicine
GE - Gastroenterology
GPM -General Preventive Medicine
HEM - Hematology (Internal Medicine)
HEP - Hepatology
HO - Hematology/Oncology
HPE - Hospice & Palliative Medicine (Emergency Medicine)
HPI - Hospice & Palliative Medicine (Internal Medicine)
HPM - Hospice & Palliative Medicine
HPR - Hospice & Palliative Medicine (Physical Medicine)
IC - Interventional Cardiology
ICE - Clinical Cardiac Electrophysiology
ID - Infectious Disease
IEC - Internal Medicine/Emergency Medicine/ Critical Care Medicine
IG - Immunology
ILI - Clinical and Laboratory Immunology (Internal Medicine)
IMD - Internal Medicine/Dermatology
ISM – Internal Medicine – Sports Medicine
LM - Legal Medicine
MDM -Medical Management
MEM- Internal Medicine/Emergency Medicine
MG - Medical Genetics
MN - Internal Medicine/Neurology
MP - Internal Medicine/Psychiatry
MPM - Internal Medicine/Physical Medicine And Rehabilitation
N - Neurology
NC - Nuclear Cardiology
NDN - Neurodevelopmental Disabilities (Psychiatry & Neurology)
NDP - Neurodevelopmental Disabilities (Pediatrics)
NEP - Nephrology
NMN – Neuromuscular Medicine
NMP – Neuromuscular Medicine (Physician Medicine and Rehabilitation)
NPM - Neonatal-Perinatal Medicine
NRN - Neurology/Diagnostic Radiology/Neuroradiology
NTR - Nutrition
NUP - Neuropsychiatry
OM - Occupational Medicine
OMM - Osteopathic Manipulative Medicine
ON - Medical Oncology
P - Psychiatry
PA - Clinical Pharmacology
PCC - Pulmonary Critical Care Medicine
PDA - Pediatric Allergy
PDC - Pediatric Cardiology
PDD - Pediatric Ddermatology
PDE - Pediatric Endocrinology
PDI - Pediatric Infectious Diseases
PDM - Pediatrics/Dermatology
PDP - Pediatric Pulmonology
PDT - Medical Toxicology (Pediatrics)
PE - Pediatric Emergency Medicine (Emergency Medicine)
PEM - Pediatric Emergency Medicine (Pediatrics)
PFP - Forensic Psychiatry
PG - Pediatric Gastroenterology
PHL - Phlebology
PHM - Pharmaceutical Medicine
PHO - Pediatric Hematology/Oncology
PHP - Public Health and General Preventive Medicine
PLI - Clinical and Laboratory Immunology (Pediatrics)
PLM - Palliative Medicine
PM - Physical Medicine & Rehabilitation
PMM - Pain Medicine
PMN - Pain Medicine (Neurology)
PMP - Pain Management (Physical Medicine & Rehabilitation)
PN - Pediatric Nephrology
PPM - Pediatrics/Physical Medicine & Rehabilitation
PPN - Pain Medicine (Psychiatry)

MEDICAL SPECIALTIES (continued)

PPR - Pediatric Rheumatology
PRO - Proctology
PRS - Sports Medicine (Physical Medicine & Rehabilitation)
PTX - Medical Toxicology (Preventive Medicine)
PUD - Pulmonary Disease
PYA - Psychoanalysis
PYG - Geriatric Psychiatry
PYM - Psychosomatic Medicine
PYN - Psychiatry/Neurology
REN - Reproductive Endocrinology
RHU - Rheumatology
RPM - Pediatric Rehabilitation Medicine
SCI - Spinal Cord Injury Medicine
SME - Sleep Medicine
SMI - Sleep Medicine (Internal Medicine)
SMN - Sleep Medicine (Psychiatry & Neurology)
THP – Transplant Hepatology (Internal Medicine)
UCM -Urgent Care Medicine
UCM -Urgent Care Medicine
UM - Underseas Medicine (Preventive Medicine)
UME - Underseas Medicine (Emergency Medicine)
VM - Vascular Medicine
VN - Vascular Neurology
OS - Other Specialty
US - Unspecified Specialty

APPENDIX B. The impact of EHR use on Patient Safety Outcomes treating state as a cluster effect

	Coefficient	Confidence Interval	P-value
Death Related PSI			
Death Rate in Low-Mortality DRGs			
Full-EHR not receiving MU	-2.75	-5.29 to -0.21	0.034
EHR that attests to MU	-1.24	-3.18 to 0.70	0.211
Death Rate among Surgical Inpatients with Serious Treatable Complications			
Full-EHR not receiving MU	0.23	-0.29 to 0.76	0.381
EHR that attests to MU	0.29	-0.15 to 0.73	0.202
Non-Death Related PSI			
Iatrogenic Pneumothorax Rate (collapsed lung due to medical treatment)			
Full-EHR not receiving MU	-0.27	-4.06 to 3.52	0.890
EHR that attests to MU	0.46	-0.88 to 1.81	0.497
Postoperative Physiologic and Metabolic Derangement Rate			
Full-EHR not receiving MU	-3.92	-5.78 to -2.05	<0.001
EHR that attests to MU	-2.16	-2.95 to -1.37	<0.001
Postoperative Respiratory Failure Rate (breathing failure after surgery)			
Full-EHR not receiving MU	0.81	-0.23 to 1.85	0.126
EHR that attests to MU	0.66	-0.15 to 1.47	0.112
Perioperative Pulmonary Embolism or Deep Vein Thrombosis Rate (serious blood clots after surgery)			
Full-EHR not receiving MU	-0.44	-1.31 to 0.43	0.324
EHR that attests to MU	-1.00	-2.06 to 0.07	0.067
Postoperative Sepsis Rate			
Full-EHR not receiving MU	0.79	-0.60 to 2.18	0.264
EHR that attests to MU	-0.04	-0.43 to 0.35	0.838
Postoperative Wound Dehiscence Rate (wounds split open after surgery)			
Full-EHR not receiving MU	-2.68	-4.26 to -1.10	0.001
EHR that attests to MU	-1.57	-2.77 to -0.37	0.010
PSI 90 Composite Score			
Full-EHR not receiving MU	-0.02	-0.09 to 0.06	0.659
EHR that attests to MU	-0.06	-0.17 to 0.04	0.266

Notes: Reference= No EHR or Partially-implemented EHR
Coefficient is semi-elasticity, where the dependent variable changes by 100*(coefficient) percent for a one unit increase in the independent variable while all other variable in the model are held constant
Model adjusts for minor teaching hospital status, major teaching hospital status, for profit status, cluster(state), nurse to staffed bed ratio, and staffed beds