ESTIMATING THE EFFECTS OF ELECTRONIC HEALTH RECORDS (EHRS) SOPHISTICATION AND EHRS YEARS OF EXPERIENCE ON HEALTH CARE QUALITY, PATIENT EXPERIENCE, 30-DAY READMISSIONS, AND PROFITABILITY IN U.S ACUTE CARE HOSPITALS

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ABSTRACT

Jason N. Mose: Estimating the Effects of Electronic Health Records (EHRs) Sophistication and EHRs Years of Experience on Health Care Quality, Patient Experience, 30-Day Readmissions, and Profitability in U.S Acute Care Hospitals.
(Under the direction of Shoou-Yih Daniel Lee and Bryan J. Weiner)

The objective of this dissertation was to estimate the effects of EHRs sophistication on health care quality, patient experience, 30-day readmissions, and hospital profitability. EHRs data was sourced from Healthcare Information and Management Systems Society and Meaningful Use program. Healthcare quality, financial and hospital-specific data came from several Centers for Medicare & Medicaid Services files and programs. Demographic data came from the Area Health Resources Files.

The analysis employed ordinary least squares (OLS) with propensity weighting and feasible generalized least squares to investigate the association between EHRs sophistication and healthcare quality, patient experience, and 30-day readmissions. Also, OLS with hospital level fixed effects to evaluate the effects of EHRs sophistication on profitability. Controlling for several factors, a hospital with more sophisticated EHRs was associated with negative performance on clinical process of care and patient outcomes as compared to a hospital with less sophisticated EHRs. The study found a statistically significant association between EHRs enabled patient engagement activities with patient experience, but not between patient engagement, care coordination activities, and 30-day readmission. Nevertheless, there was a positive association between improved patient experience and a reduction in 30-day readmission. Lastly, the study found a statistically significant negative effect on hospital operating margin when moving from a less to a more sophisticated EHRs

system. Also, generally speaking, the longer a hospital remains in any given higher EHRs sophisticated stage, the better a hospital's operating margin. Moreover, the study found EHRs sophistication has a positive effect on profitability through revenue gain and not through a reduction of operating expenses.

Overall, evidence shows there is a substantial operational disruption upon implementing a more sophisticated EHRs. In addition, there is a positive association between EHRs sophistication and clinical process of care and not patient outcomes, between EHRs enabled patient engagement, care coordination activities and 30-day readmission through improved patient experience and not directly, between EHRs sophistication and profitability through operating revenue gain and not through a reduction of operating expenses.

To my wife, Janet, parents, Joash & Priscah Mose, brother Douglas, niece and nephew Kaytrizah and Buchanan, uncle Patrick, aunt Alice and the rest of the family. Thank you for your sacrifices and prayers.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACA	The Patient Protection and Affordable Care Act
AMI	Acute Myocardial Infarction
CDSS	Clinical decision support system
CLABSI	Central Line-Associated Bloodstream Infection
CMS	Centers for Medicare and Medicaid Services
COPD	Chronic Obstructive Pulmonary Disease
CPOE	Computerized provider order entry
DSH	Disproportionate Share Hospital
EHRs	Electronic health records
eMAR	Electronic Medication Administration Record
HAC	Hospital Acquired Conditions Reduction Program
HF	Heart Failure
HHI	Herfindahl-Hirschman Index
HIMSS	Healthcare Information and Management Systems Society
HITECH	Act The Health Information Technology for Economic and Clinical Health
HRRP	Hospital Readmission Reduction Program
MU	Meaningful use
NQS	The National Quality Strategy
PACS	Picture Archiving and Communication System
PN	Pneumonia
SCIP	Surgical Care Improvement Program
VBP	Value-Based Purchasing program
VDT	View, download, or transmit

CHAPTER 1: INTRODUCTION

In 1991, The Health and Medicine Division (HMD) of the National Academy of Medicine (formerly the Institute of Medicine (IOM)) made a case for adopting and implementing sophisticated electronic health records (EHRs) or, as they referred to, the systems "advanced computer-based patient records (CPRs)"[1]. The study and a later revision concluded, "The promise offered by fully computer-based patient records for improving the quality of patient care and advancing medical knowledge is enormous."[1, 2] Other studies, since then, have promoted EHRs as a tool to improve health care quality and operational efficiency, and possible means to transform the healthcare into a learning system [3-5]. A healthcare learning system is one that is "designed to generate and apply the best evidence for the collaborative healthcare choices of each patient and provider; to drive the process of discovery as a natural outgrowth of patient care; and to ensure innovation, quality, safety, and value in health care"[6]. The IOM reports noted that EHRs are critical for reaching the national goals of a safer, less costly and learning system that produces value to stakeholders. The authors noted that comprehensive implementation and effective application of "the full capabilities available in EHRs is an essential prerequisite for the evolution of the learning healthcare system"[7]. Adoption and implementation of EHRs in the United States lagged behind other industries and developed nations, despite years of concerted efforts [8]. That is until two major legislations offered various incentives that spurred a rapid adoption and implementation of EHRs. These actions realigned health care quality aspirations with tangible benefits or penalties if hospitals adopted and implemented EHRs. The first legislation, the Health Information Technology for Economic and Clinical Health (HITECH) Act, part of the stimulus package following the economic recession, offered hospitals and providers financial incentives to adopt, implement and meaningfully use EHRs [9, 10]. The second piece of legislation, The Patient Protection and Affordable Care Act (ACA), aligned care priorities with reimbursement, further boosting the implementation of EHRs[11]. As late as 2008, 9.4% of hospitals had implemented a basic EHR system, by 2015 the number of hospitals with a basic EHR system had risen to 83.8%, a nine-fold increase [12]. A basic EHR system refers to a system with a set of 10 basic EHR functions such as patient demographics, problem lists, medication lists, lab and radiology results management, among others [12, 13].

The substantial investment and aggressive efforts were partly informed by evidence of positive associations between EHRs and outcomes from early adopters such as the Veterans Affairs (VA) Health System, The Intermountain Health Care Corporation, and Kaiser Foundation Hospitals [2]. For example, a study from Kaiser Foundation Hospitals concluded, "Introducing an EHR creates operational efficiencies by offering nontraditional, patient-centered ways of providing care."[14] Subsequent reviews have also found that EHRs are largely associated with positive results on quality, safety and efficiency [15-17]. Intermountain, for example, used sophisticated EHRs to power a robust quality improvement and create management structures that "increased accountability, drove improvement, and produced savings." [18] The VA used their EHRs to re-engineer the preventive, acute and chronic care, resulting in quality improvement and cost savings [19-21]. In general, more sophisticated EHRs have the potential to promote the evidence-based provision of high-quality care through decision support and identifying gaps in care while using data to drive quality improvement and efficiency [23].

The growth in adoption and implementation of EHRs is impressive and commendable; nevertheless, there are calls to fill the gaps in the literature on the effects of EHRs on several outcomes of interest [24]. For example, there are questions on generalizability of previous studies given that a significant portion of previous studies, ranging from 18-25 percent of all published studies, were conducted on early adopters [15-17]. Other gaps were occasioned by researchers not controlling for organizational and market level contextual factors [15]. Also, the widespread of EHRs has created research opportunities that did not exist before. For example, it is now feasible to move from studies with a narrow focus on specific EHR functionalities such as clinical decision support system (CDSS) to studies that look at the full implementation of EHRs and its impact on care quality and patient outcomes [24, 25]. Further, because of the rise in the number of hospitals with EHRs, it is now possible to study the effects of EHRs sophistication on the main outcomes such as profitability, and such results would be generalizable. Sophisticated EHRs are defined as systems with advanced capabilities and functionalities to help create a "smart" and learning health system [3].

This study applies an adapted Healthcare Information and Management Systems Society (HIMSS)'s Electronic Medical Records Adoption Model (EMRAM)$^{SM.}$. The model has been widely used in research studies especially in acute care setting, even though it is validation is considered proprietary. While there are other validated EHRs sophistication tools, they have their own limitations including the granular nature of the components and functionalities that are not readily available in the nationwide surveys. For example, an Information Technology Capacities Assessment Tool developed and validated by Jaana and colleagues includes specific capacities and capabilities that are not available in the data available from hospital surveys such as the annual HIMSS or AHA IT survey.[26] Other tools such as Clinical Information Technology Assessment Tool was developed by Amarasingham et al. but was limited to measuring "a hospital's level of automation based on physician interactions with the information system" only.[27] One thing that all assessment tools and models have in common is the recognition that there is a cumulative progression of EHRs sophistication ranging from basic functionalities such as pharmacy, radiology and laboratory information and management systems to advanced functionalities such as clinical decision support systems.[3, 28-30]

This study categorizes sophistication into five stages ranging from stage 0, which are hospital missing at least one of the laboratory, pharmacy and radiology systems to stage 4, where hospital have implemented sophisticated systems such as CPOE, CDSS, and closed loop electronic administration records, among other applications. The theory is that more sophisticated EHRs will benefit several areas ranging from helping improve healthcare quality to improving efficiency and thereby reducing expenses while boosting revenue. In addition, it is important to offer mid-range evaluations of programs that were implemented following HITECH Act and ACA, programs such as meaningful use. Such as a study as this, might provide policy makers guidance going forward. Thus, this study offers to fill the gaps and adds to our knowledge in three areas: First, it examines the association of EHRs sophistication and health care quality in acute care hospitals in the United States. Second, it determines the association between meaningful use domains and patient outcomes. Finally, it estimates the effect of EHRs sophistication on hospital profitability.

In the first chapter, the study employs two composite measures of quality in both clinical process of care, and patient outcomes to answer three specific question: (1) Do hospitals with more sophisticated EHRs have better performance on clinical processes of care? (2) Do hospitals with more sophisticated EHRs also have better patient outcomes? (3) Do hospitals that have more years of experience with sophisticated EHRs exhibit better performance in the clinical process of care and patient outcomes?

The study adds the following contributions. First, instead of looking at separate applications such CDSS or CPOE, the study focuses on EHRs sophistication which examines the overall effect of an integrated systems working together to improve quality. Second, the study includes two dimensions of quality – clinical process of care and patient outcomes. This is important because of the complexity of providing care in a hospital setting and the interest in understanding the "diffuse effects" of EHRs sophistication. Diffuse effects refer to the impact of a service, structural change or intervention on multiple clinical processes in an institution [25]. This is in contrast to targeted intervention effects, which refer to the impact of an intervention that is closer to the patient and is easy to measure the cause and effect [25]. Third, by including EHR experience (i.e., the number of years in implementing a given level of EHRs), the study examines how the learning of hospitals in the application of EHRs affects the care quality. Fourth, the study controls for internal and external contextual factors that might be related to both EHR implementation and care quality. We also employ propensity score weighting to control for selection of hospital into EHR implementation. These analytical approaches will improve the generalization and validity of the study findings.

In the second chapter examines: 1) whether performance in meaningful use patient engagement and care coordination objectives is associated with improved patient experience; 2) whether performance of meaningful use patient engagement and care coordination objectives is associated with 30-day hospital readmissions; and 3) whether patient experience performance is associated with 30-day hospital readmissions, controlling for MU patient engagement and care coordination.

Examining these relationships is important in the age of concerted efforts to reform the health care system towards a focus on patient and family-centered care and the ultimate goal of improving population health. Also, the study can serve as part of the ongoing interim evaluation of the substantial federal government investment on tools to improve patient engagement, care coordination, and health care outcomes. More importantly, answering these questions is critical because the meaningful use measures were designed to align with the National Quality Strategy top priorities – specifically, engagement of patients and their families as partners in care delivery and effective communication to improve care coordination [31, 32].

Finally, the third chapter is aimed to 1) estimate the effects of EHRs sophistication on hospital profitability, i.e., operating margin; 2) investigate the possible pathway of EHRs sophistication impact on operating margin by estimating the effects of EHRs sophistication on the hospital adjusted operating revenue per inpatient day and estimating the effects of EHRs sophistication on hospital adjusted operating expense per inpatient day; and 3) determine whether hospitals that have more years of experience with sophisticated EHRs also perform better on operating margin, adjusted operating revenue and expenses per inpatient day.

This study, therefore, contributes to the emerging evidence on the effects of EHRs sophistication particularly. For example, the study measures the association between the number of years of EHRs experience at a given stage and patient and financial measures. This approach has the potential of adding value to the analytic process of similar studies in the future. Another contribution is the choice of dependent variables, such as the clinical process of care and patient outcomes, patient experience and hospital readmissions, operating margin, adjusted operating revenue and operating expenses per inpatient day. The choice of such variables enables us to segregate the direct association or effect of EHRs sophistication, which might also be easier to achieve, from the indirect association or effect of EHRs sophistication, which might be harder to achieve. The study utilizes a panel data analysis, on the question of profitability, which has several advantages as compared to a cross section study. These include capturing the dynamics of the healthcare environment, offer more accurate inference and control for unobservable characteristics and behavior and thereby controlling for the impact of omitted variables [33]. The study results will guide hospitals administrators in having realistic expectations on whether implementing sophisticated EHRs will bear positive results on profitability and how long it takes to see those results. Also, this study may add to the evidence to help some hospitals decide whether they should invest in a more sophisticated EHRs system, which is usually a substantial financial investment.

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CHAPTER 2: ESTIMATING THE ASSOCIATION BETWEEN ELECTRONIC HEALTH RECORDS (EHRS) SOPHISTICATION, EHR YEARS OF EXPERIENCE AND HEALTH CARE QUALITY

Introduction

For over two decades, policymakers, researchers, and some providers have advanced Electronic Health Records (EHRs) as a tool to improve health care quality. In 1991, the Health and Medicine Division (then known as the Institute of Medicine) released a report making a case for adoption and implementation of sophisticated EHRs. The report argued that sophisticated EHR systems with applications such as Computerized Provider Order Entry (CPOE) and Clinical Decision Support System (CDSS) have the potential to support evidence-based care and improve patient outcomes [1]. The passage of the HITECH Act in 2009, coupled with advances in hardware and software, accelerated the adoption and implementation of EHRs in acute care settings. The Act provided financial incentives to eligible providers to adopt and implement EHRs [2]. Between May 2011 and September 2016, Centers for Medicare and Medicaid (CMS) paid more than $34.7 billion to over 509,000 health care providers under the Medicare and Medicaid EHR Incentive Programs [3]. By 2015, hospitals with basic EHRs had climbed to 84 percent from 9.4 percent in 2008, a 66.1 percentage point increase [4, 5] [6]. The ultimate goal of EHR investment is to improve health care quality through cutting medical errors, increase provision of evidence-based care, timely feedback to providers with clinical alerts, and access to medical records across care sites to reconcile medications and bridge the gaps in care transition[7-9].

There are hundreds published studies on the effects of EHRs on a long list of clinical conditions, processes, and patient outcomes. By 2015, there were over 30 systematic reviews on health IT interventions and patient safety outcomes[10]. Even so, an identified gap in the literature is the need to look at the full implementation of EHRs and their impact on healthcare quality and patient outcomes[11, 12]. To understand the effects of implementation of health IT, we must also appreciate both internal organizational context and external environmental conditions[13, 14]. These gaps make it harder for leaders of healthcare organizations to determine whether implementation of more sophisticated EHRs should be adopted in their organizations. Other overarching and unresolved issues makes the study of EHRs in general, and effects of sophisticated EHRs particularly, germane in the current environment. First, the Affordable Care Act (ACA) mandated the development of *The National Quality Strategy (NQS),* a product of a "transparent and collaborative process with input from a range of stakeholders" [15]. The latest *NQS* report shows that while quality in the major priority areas such as patient safety, care coordination, and effective prevention and treatment, has improved, wide variation exists across the *NQS* priorities [16]. For example, in 2013, about 60% of the measures of effective treatment and patient safety improved, but fewer than half of the measures of care coordination improved [16]. There is also evidence that each year hundreds of thousands of individuals are harmed or die because of medical errors [17]. This is one of the reasons that the Office of the National Coordinator for Health Information Technology [7] and the Agency for Healthcare Research and Quality [18] have continued to invest in evaluating how best to realize the full potential of EHRs in improving quality. Second, the influence of sophisticated EHRs on health care quality remains uncertain. Some studies have shown a positive correlation between EHRs and clinical outcomes, while others found mixed results[8, 19-23]. Previously, it was argued that hospitals were not incentivized to use sophisticated EHRs to improve quality because implementing EHRs was costly, while payers and patients reaped the benefits more sophisticated EHRs [24]. National programs such as hospital value-based purchasing and the Hospital-Acquired Condition (HAC) Reduction Program have tied high-quality care to reimbursement thereby providing the incentive for hospitals to prioritize healthcare quality. Thus, it is important to re-evaluate the association between EHRs sophistication and healthcare quality.

This study looks at the association between sophisticated EHRs and health care quality in acute care hospitals in the United States. Sophisticated EHRs are systems with advanced capabilities and functionalities to help create a "smart" and learning health system[25]. Examples of such advanced capabilities and functionalities include integrated information exchange, which allows patient health information exchange between hospitals, physicians and nurses, clinical decision support systems that support patient specific information through clinical guidelines, reminder, and alerts, and closed-loop medication administration, which is automation of medication management [25]. This study categorizes sophistication into five stages ranging from stage 0, which are hospital missing at least one of the laboratory, pharmacy and radiology systems to stage 4, where hospital have implemented sophisticated systems such as CPOE, CDSS, and closed loop electronic administration records, among other applications. Also, the study evaluates the association of EHRs years of experience i.e. the number of years a hospital has on a given EHRs sophistication stage, on the dependent variables. The study uses two composite measures to examine three specific questions: (1) On average, does a hospital with more sophisticated EHRs perform better on clinical processes of care? (2) On average, does a hospital with more sophisticated EHRs perform better on patient outcomes? (3) Finally, examine whether more EHRs years of experience is associated with higher performance in the clinical process of care and patient outcomes.

The study makes several new contributions. First, a focus on EHR sophistication moves from understanding the impact of individual EHR applications to examining the effects of multiple applications working together to improve quality. Second, the study includes two dimensions of quality – clinical processes and patient outcomes. This is important because of the complexity of providing care in a hospital setting and the interest in understanding the "diffuse effects" of EHRs sophistication. Diffuse effects refer to the impact of a service, structural change or intervention on multiple clinical processes in an institution [12]. This is in contrast to targeted intervention effects which refer to the impact of an intervention that is closer to the patient and is easy to measure the cause and effect [12]. The two outcome measures the study uses are composite and might capture the improvement of the quality of care. Third, by including EHRs years of experience, the study examines how the learning of hospitals in implementing EHRs affects the improvement in care quality. Fourth, the study controls for internal and external contextual factors that might be related to both sophisticated EHR implementation and healthcare quality. We also employ propensity score weighting to control for selection of hospital into EHR implementation. These analytical approaches will improve the generalization and validity of the study findings.

Conceptual Framework

The pathway between EHRs sophistication and health care quality is a complex web of relationships. The healthcare landscape is going through rapid change and transformation as result of interactions of these relationships, both internal and external. For example, the decision to implement EHRs that are more sophisticated might be because of internal and external considerations. Internally the hospital might see a need to improve healthcare quality, and sophisticated EHRs might look like a tool to help achieve that change. Externally, legislations such as HITECH Act and ACA might prompt a hospital to consider implementing sophisticated EHRs. The study used the *content*, *context, and process of* change paradigm first proposed by Pettigrew in his seminal Imperial Chemical Industries (ICI) study, to untangle the interrelationships[26, 27]. Content refers to the particular areas of transformation under examination, in this case changing technology and health care quality. Context is divided into outer context (the social, economic, political, and competitive environments in which an organization operates) [28, 29] and inner context (the structure, corporate culture, and political context in which the organization must operate to bring change) [27, 28]. The process of change refers to the actions, reactions, and interactions with stakeholders, rather than work processes in general [27, 28]

Hospitals operate in this complex "inner context" and the constantly changing "outer context" to deliver care. The need for more sophisticated EHRs and its hoped contribution to the provision of high-quality healthcare is partly based on the nature of healthcare environment. First, hospitals have to operate in the external context that is governed by rules and regulations set by both the national and state government. Such regulations include the mandate to report some quality measures, use EHRs as is the case under meaningful use among other examples. Also, the external environment also dictates hospital behavior due to pressures such as competition, reimbursement because of insurance or lack of it and geographical location i.e. rural versus urban.

Second, the hospital has also the internal environment to consider the use of sophisticated EHRs. Each day, hospital administrators, who make quality improvement decisions and providers, are faced with the daunting task of navigating through a mosaic of administrative maze ranging from quality improvement issues to high numbers of diagnoses, drugs, and procedures. The flow of the enormous amount of tasks might lead to informational overload, which will likely affect the quality of decision and patient care. Information overload is defined as a condition in which the amount of input to a system exceeds its processing capacity[30, 31]. Decision makers, in this case, hospital administrators and providers, "have fairly limited cognitive processing capacity" [32, 33]. For example, the International Disease Classification (ICD-10) includes 14,199 different diagnoses, and there are more than 6,000 drugs, more than 4,000 medical and surgical procedures to choose from [34, 35]. Besides this complexity, every patient encounter introduces its idiosyncrasies and complexity. Furthermore, there are complex regulatory and reimbursement requirements. All these combined could produce informational overload among health care providers and administrators potentially leading to errors, delay in decision making or poor decisions [36]. Health care providers, like any other busy human being, have a limitation on how much information they can observe and retain. A more sophisticated EHR system with capabilities such as clinical decision support, embedded with evidence-based guidelines, can mitigate the overload and cut the potential for errors. The systems can offer reminders, suggestions, and alerts that will enable the provision of high-quality care. Also, these sophisticated EHR systems potentially can be enablers of provider-to-provider communication, facilitate clear and concise orders including prescription orders, all which in turn are likely to improve care processes, cut errors, and improve patient outcomes [37].

Similar to other changes, implementation of sophisticated EHRs requires many adjustments in hospital human resources (such as recruitment and training of staff), workflow, patient-provider relationship, and occupational roles among other changes[38, 39]. The adjustments take time. We posit, therefore, that as hospitals have more experience with an EHR system, they are more likely to have positive effects on clinical care processes and patient outcomes. In sum, we propose the following hypotheses:

(a) On average, a hospital with more sophisticated EHRs would exhibit higher performance in the clinical process of care than hospitals with less sophisticated EHRs, all else being equal.

(b) On average, a hospital with more sophisticated EHRs would exhibit better patient outcomes than a hospital with less sophisticated EHRs, all else being equal.

(c) On average, greater experience, i.e., more years, in higher EHRs sophistication stages (stage 3 and 4) is associated with greater performance on clinical process of care and patient outcomes composite measures.

Methods

Data Sources

The data for this study come from several sources. EHR data come from Healthcare Information and Management Systems Society (HIMSS) through The Dorenfest Institute for Health Information hospital survey database for the calendar year 2012. The Dorenfest Institute provides historical data, reports, white papers and other tools regarding adoption, implementation and the use of informational technology in hospitals and integrated healthcare delivery networks [40]. The study also utilizes several data file from the Centers for Medicare and Medicaid Services (CMS). These include: Hospital Value-Based Purchasing (VBP) program for fiscal year (FY) 2015 [41], for healthcare quality data; Final Rule files(FY 2015) [42, 43] for hospital-level data, Provider of Service file (2015) for service mix data, Structural Measures file (2015) for registry information, and Cost Reports (2012) for financial information. The market data comes from the Health Resources and Services Administration's Area Health Resource File, 2014-2015 edition.

Sample

The study analysis sample is limited to hospitals participating in the VBP program. Of 4,974 community hospitals in the U.S [44] in 2015, 3,089 (62%) hospitals participated in CMS' VBP program [41]. The VBP data, though, vary in availability from measure to measure. For example, 2,964 hospitals are reporting results in clinical process measures and 2,757 in outcome measures and data is available for 3,089 hospitals in total performance measure.

Study design

The study employed a cross-sectional analysis design covering 2012 EHR sophistication measures and 2015 calendar year health care quality measures. The control variable cover 2012 and 2014-2015. The unit of analysis was a US acute care hospital

Measures

Dependent Variables: The study uses the clinical process of care score and outcome domain score as dependent variables. The clinical process of care domain score is a composite of 12 hospital performance across the following conditions: Acute Myocardial Infarction (AMI), Heart Failure (HF), Pneumonia (PN) and Surgical Care Improvement Program (SCIP) [41]. These items measure how closely a hospital adheres to the best clinical practice guidelines. The outcome domain score contains measures on AMI, HF, and PN 30 day mortality, in addition to AHRQ's Patient Safety Indicators (PSI) #90 composite measure of patient safety and central line-associated bloodstream infection (CLABSI) [41, 45]. This outcome composite measure is supposed to provide critical information on the how well the hospital performs on patient outcomes and patient safety.

There are three reasons for choosing these two measures. First, it is likely that EHRs sophistication directly affects the clinical process of care measures while indirectly affecting patient outcome measures. It is imperative, therefore, to investigate the association of the EHRs sophistication and the clinical process of care and patient outcomes measures separately. Second, CMS measures rank high based on nine key metrics on measure assessment which include: transparent methodology, evidence-based, risk adjustment, data quality, most current data, data consistency, measure alignment and hospital review [46]. This is especially important in the age of "a multitude of uncoordinated, inconsistent, and often duplicative measurement and reporting initiatives" [47, 48]. Lastly, these measures are of interest to two key stakeholders; policy makers and providers. The federal government has indicated its interest in expanding the incentive programs to include reimbursing a higher proportion of care under value-based payments systems [49]. These changes will affect providers in how they deliver care, how they are reimbursed and how they implement and use EHRs to facilitate care delivery.

Independent variables: EHR sophistication is an ordinal variable that ranges from stage 0 to stage 4; it reflects the incremental sophistication of EHRs based on automation of clinical processes using an adaptation of HIMSS EMR Adoption Model[50, 51]. The study defines a hospital's EHR as Stage 0 if it is missing one or more of laboratory, radiology, pharmacy; Stage 1 if it has implemented laboratory, radiology, pharmacy and clinical data repository; Stage 2 if it has implemented nursing documentation and electronic medication administration record (eMAR) in addition to attaining Stage 1. A hospital is considered to be in Stage 3 if it implemented CDSS and CPOE and its eMAR included closed loop medication administration, in addition to having attained Stage 2. Lastly, we define a hospital to be in Stage 4 if it has attained Stage 3 and also implemented physician documentation and electronic transactions to share data while the picture archiving and communication system (PACS) are integrated. The second independent variable is the years in EHR stage to account for the possible learning curve and disruption following implementation of EHRs systems. The years range from 1 to 8 years for EHRs stages 0 to 2 and 1 to 4 in stages 3 and 4.

Control variables: The choice of the control variables is largely based on the theory of the effect of contextual factors. In the past, experts have urged researchers to include contextual factors for two major reasons[13, 14, 52]. One, for generalizability purposes. This is important especially for providers who have to assess whether EHRs described will have a similar effect on their unique setting. Second, the organizational characteristics and the environment can have an effect on both the successful implementation of EHRs and the clinical process of care and patient outcomes. For example, it is possible to implement the same EHRs functionality in different settings and yet achieve different results[53, 54]. Experts also acknowledge that rich contextual data are difficult to collect and particularly absent in state or national-level data sets such as ones used in this study [11]. For example, variables that measure teamwork, leadership, and management tools are hard to find.

Nevertheless, the study controls for several organizational and environmental characteristics associated with both EHR adoption and hospital health care quality. Such variables include teaching status, safetynet indicator, system status indicator, Saidin Index and structural measures (for example, whether or not a hospital participates in a Cardiac Surgery Registry). This study defines teaching status as either a major teaching hospital, teaching hospital or non-teaching hospital based on indirect medical education (IME) payment adjustment factor. The IME payments are extra payments that PPS hospitals with approved residency program receive for Medicare discharges to reflect the higher patient care costs of teaching hospitals relative to nonteaching hospitals [55]. The adjustment factor is based on a hospital's ratio of residents to beds. A major teaching hospital is defined as the top 25 percent hospitals of the adjustment factor. The teaching hospital comprises the remaining 75 percent of hospitals receiving the adjustment and non-teaching are those with zero adjustment factor, i.e. they do not have a CMS recognized residency program. Safety net hospitals are identified using CMS' Disproportionate Share Hospital (DSH) patient percent, which is determined from cost report data and Social Security Administration data. DSH Patient Percent is derived as (Medicare SSI Days / Total Medicare Days) + (Medicaid, Non-Medicare Days / Total Patient Days) [56]. The safety net hospital is defined as top 25 percent of the DSH patient percent hospitals. DSH percentage is widely accepted as a proxy for hospitals that care for a large proportion of poor patients and frequently used by health services and policy researchers.

Structural measures such as the presence of a nursing care registry and stroke care registry reflect the environment in which hospital delivers care. These measures can also "provide a real-world view of clinical practice, patient outcomes, safety, and clinical, comparative, and cost-effectiveness" [57]. Also, these variables can serve as surrogate indicators of patient safety culture and leadership decisions to invest in tools that will enable continuous quality improvement. Another measure that reflects the leadership element and financial stability is the change of ownership. It is theoretically possible that a hospital will be acquired if it is attractive to a buyer financially or it brings an increase in patient referrals. It is also plausible that a hospital is likely to change hands if it is facing a threat of closure or facing an internal and external pressure. The study employs two variable to control for the shocks that will be expected when a hospital changes ownership, the number of times a hospital has changed ownership and whether or not the hospital changed ownership in the last twelve years.

The study also controls for the use of rare high technology by including Saidin Index, which also can reflect the complexity of the internal environment, to isolate the effects of EHR sophistication. Saidin Index is a weighted sum of the number of technologies and services available in a hospital. The weights are the percentage of hospitals in the country that do not possess the technology or service [58, 59]. Therefore, a rare high technology service will be weighted higher than a common technology. The weights are computed as follows: Weights: $a_k = 1\text{-}(\frac{1}{N})\sum_{i=1}^{N} \tau_{i,}k$ where N is the number of hospitals in the United States, $\tau_{i,}$ take the value of 1 if the hospital i has technology k. Then the weight is used to compute the index. $\text{Saidin Index} = \sum_{k=1}^{k}(a_k\,,\tau_{i,}k)$. Saidin Index is included for two reasons. First, it controls for quality effects, negative or positive, that may be attributed to the presence of high technology. Second, it controls for the possible patient self-selection. It is possible that patients will pass a hospital with few high technology services that is closer to their location, opting for a distant hospital with a reputation of comprehensive rare high technology services. The study also controls for financial strength by including operating margin. In addition, to operating margin, the study controls for wage index, a measure that reflects the cost of labor in the hospital market relative to the national average.

The study also controls for CMS case mix index, a measure of resources required reflecting the complexity or severity of the patients the hospital often treats. Other internal variables include hospital ownership, system status, hospital size, magnet status, trauma level designation and adjusted occupancy rate. The idea is that hospital ownership incentivizes administrators differently. For example, for-profit hospitals will be under pressure to meet Wall Street expectation such that they might invest in systems that will improve quality and hence increase revenue. At the same time, the same hospital might cut back on necessary care to save costs. Hospital size and system status are intended to control for economies of scale, availability of expertise both on EHRs and clinical practice areas, which can potentially affect both the likelihood of implementing sophisticated EHRs and at the same time affect the quality of care. Also, hospital magnet status and trauma level designation can be signals of the structural factors that can potentially affect patient self-selection to the facility and indicates resource availability to implement EHRs. Moreover, magnet status and trauma level require particular expertise and requirement of resources as a condition to maintain the designation. Adjusted occupancy rate is based on what is called reservation quality which is an adjustment to account for the probability that a patient will be turned away from the hospital when it is full [60]. This is based on a long acknowledged feature of acute care hospital sector and its unique attribute of demand uncertainty[60-64]. The idea is that occupancy rate needs to account for a safety margin to allow for community protection in case of an emergency. In other words, a higher occupancy rate can signal quality issues, especially in an emergency. The reservation quality is defined as $\beta = \frac{(B\text{-}\mu)}{\sqrt{\mu}}$. Where *B* is the number of staffed hospital beds in active use and μ is the average daily census. The β is the number of standard deviations above the mean census represented by the number of beds. Adjusted occupancy rate, therefore, is defined as $AOR = \frac{1}{1+\beta/\sqrt{\mu}}$ [60, 61]. Market control variables include demographic and market hospital concentration. The demographic variables will include population density, unemployment rate, the uninsured rate for 64 and below year old individuals, location (rural versus urban) and geographic region. These variables are included due to their potential effect on the local patient population and the hospital's resources. For example, a high unemployment and uninsured rate can signal a hospital that might be seeing sicker patients who do not have usual access to care. At the same time, these two factors will impact the hospital bottom line which in turn will affect resources allocation including implementing and maintaining sophisticated EHRs. The study uses Herfindahl-Hirschman Index (HHI) to control for hospital concentration and competition, which can affect health care quality. The index is computed as follows:

$HHI = \sum_{i=1}^{N} \left[\frac{\text{Patient days}_i}{\sum \text{Patient days}_i}\right]^2$. Lastly, the study controls for whether a hospital is in a state that expanded Medicaid under the ACA. This may signal to statewide policy choices that potentially have an effect on the healthcare environment under which a hospital operates.

Empirical Specification

The analysis will employ the following empirical model for both clinical process of care and patient outcome models:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6 + \beta_7 x_7 + u$$

Equation 2.1

Where y is the dependent variable: clinical process of care score or outcome domain score.

x_1 Will be a vector of organizational level control variables such as region, bed size, adjusted occupancy rate, hospital ownership (Private for profit, public, not-for-profit). Other hospital level control variables were teaching status, safety net, whether urban or rural, system status and whether a sole community hospital. In addition, x_2 was a vector of market control variables which will include: unemployment rate, HHI and whether a hospital is in a Medicaid expansion state. Other characteristics will include geographic region and percent 18-64 year old individuals without health insurance. x_3 was a vector of patient mix variable such as case mix index. Meanwhile, x_4 measures the EHRs sophistication level. x_5 was how many years since the hospital attained that sophistication level which intended to capture the effect of EHR experience. x_6 was a vector of structural factors such as presence of nursing care registry, stroke care registry and general surgery registry. x_7 was the EHRs year dummies which enters the models as factor indicators. u is the statistical noise.

Note the models were built starting with the basic model, i.e., sophistication stages regressed against the dependent variables. Then sequentially adding control variables such as years in each stage, then internal control variable and finally external control variables. Every model was tested for evidence of heteroscedasticity using Breusch-Pagan and Cook-Weisberg test for heteroscedasticity, test for higher ordered terms using Ramsey regression specification error test (RESET) and for multicollinearity using variance inflation factors (VIF). When heteroscedasticity was detected, feasible generalized least squares (FGLS) was used instead of ordinary least squares (OLS). FGLS is appropriate in this case for several reasons. First, tests indicated the existence of heteroscedasticity in some models, and therefore, OLS was not appropriate. Possibly, heteroscedasticity was present because several variables are aggregated across the entire hospital, and some essentially measure experience, i.e. those with years of experience treating conditions tracked are more likely to perform better. Other variables are also likely to be a function of the hospital size [65, 66]. Secondly, we do not know the structure of heteroscedasticity. In FGLS models, the study followed steps as suggested by Wooldridge [65].

There is also a concern that the level of EHR sophistication could vary across hospital types, regions, hospital sizes among other factors. From previous studies, it has been reported that hospital size, location, ownership, and teaching status were more likely to influence adoption of EHR [67]. In addition to controlling for these factors, the study employed propensity weighting to control for the probability of having more sophisticated EHRs. The study used Generalized Ordered Logistic model to estimate the likelihood of hospitals falling in one of the five levels of EHR sophistication. The predicted probabilities are then used as an inverse probability weight in the regression.

The unconstrained generalized ordered logit model takes the following form:

$$P(Y_i > j) = g(X_i\beta_j) = \frac{\exp(\alpha_j + X_i\beta_j)}{1 + \{\exp(\alpha_j + X_i\beta_j)\}} \quad j = 1,2, \ldots . M\text{-}1$$

Equation 2.2

where M is the number of categories of the ordinal dependent variable. The variables used in this model included teaching status, hospital size, magnet designation indicator, case mix index, wage index, adjusted occupancy rate, Medicare Advantage penetration rate, unemployment rate, population density, the uninsured rate (<65 years old), Medicaid expansion indicator, change of ownership, urban location indicator, region and trauma level indicators.

Generalized ordered logistic regression is appropriate and advantageous in this case given its strengths over the traditional ordered logistic regression, which often fails its proportional odds or the parallel regression assumption. Some of these strengths include the model's ability to estimate models that are less restrictive than ordered logistic regression and researchers have found, can estimate models (i.e. partial proportional odds) that are more parsimonious than non-ordinal alternatives, such as mixed logistic regression[68].

Results

Summary Statistics

EHRs sophistication stage 4 accounted for 439 hospitals, or 8.88 % of our sample (see Table 2.1 summary statistics). 1,195 hospitals (24.18%) had attained stage 3, 1988 (40.23%) stage 2, 839 (16.98%) stage 1 and 481 (9.73 %) were in stage 0. In the 2015 calendar year, the average clinical process of care score was 55.41, with 2808 hospitals participating in the clinical process of care domain. The average score under patient outcome domain was 45.04 points with 2685 hospitals participating in this domain.

EHRs sophistication and clinical process of care performance

The study tested the hypothesis that hospitals with more sophisticated EHRs would exhibit higher performance in the clinical process of care than hospitals with less sophisticated EHRs, by running several regressions, as presented in Table 2.2. The EHRs sophistication alone was not associated with a statistically significant change in the clinical process of care score (Basic model in Table 2.2). Model 2 shows that EHRs sophistication (Stage 2 and 3) is associated with a negative performance on clinical process of care. When EHRs years of experience, internal and external factors are controlled for, (Models 3 and 4), a hospital with more sophisticated EHRs such as Stages 3 and 4 is associated with negative performance on clinical process of care as compared to a hospital with less sophisticated EHRs, i.e., Stage 0. For example, in model 4, a hospital in stage 3 is associated with 11.92 ($p<0.01$) percentage point less in the expected clinical process of care score, as compared to a hospital in Stage 0, holding EHRs years of experience, internal and external context constant. Similarly, a hospital with EHRs sophistication Stage 4 is associated with a 14.44($p<0.01$) percentage point less in expected clinical process of care score as compared to a hospital in Stage 0. Overall, it appears that EHRs sophistication alone is not associated with an increase in performance on clinical process of care as hypothesized. Instead, when others factors are controlled for, a hospital with more sophisticated EHRs experiences a drastic drop in clinical process of care score. This suggests of a significant disruption of the care delivery when a hospital adopts and implements a higher sophisticated EHRs.

<u>EHRs sophistication years of experience and clinical process of care performance</u>

The study also hypothesized that greater experience, i.e., more years; in higher EHRs sophistication stages (stage 3 and 4) would be associated with greater performance on clinical process of care. It appears the more years a hospital spends on higher EHRs sophistication stages, the better it performs on clinical process of care score. For example, model 4 shows that by the end of the first year, a hospital at Stage 3 is associated with 4.65($p<0.01$) percentage point more in the expected clinical process of care score as compared to a hospital in other stages. The performance advance for the same hospital is expected to increase to 10.03 ($p<0.01$) percentage point by the end of the fifth year, holding other factors constant. Similarly, by the second year, a hospital in EHRs stage 4 is associated with a 10.19 ($p<0.01$) percentage increase in expected clinical process of care score as compared to a hospital in other stages. However, this increase does not seem to persist through the third and fourth year at this Stage.

The results suggest that for a hospital in Stages 1, the number of years on the stage does not seem to improve performance, while a hospital in Stage 2 overcomes the disruption and the possible learning curve by the sixth year. It also appears that even though there is significance disruption when a hospital implements EHRs Stages 3 and 4, on average a hospital overcomes the disruptions fairly quickly. Overall, the results indicate that the total number of years of EHRs experience does not have an influence on the process of care score, while EHRs years of experience on a higher EHRs Stage seems to be associated with improved performance on clinical process of care.

<u>EHRs sophistication and patient outcomes performance</u>

When it came to patient outcomes, the study hypothesized that a hospital with more sophisticated EHRs would exhibit better patient outcomes than a hospital with less sophisticated EHRs, all else being equal. The results, presented in Table 2.3, indicate that EHRs sophistication alone, as shown in Model 1, is associated with negative performance on patient outcomes score. The negative performance persists across models, except for EHRs stage 4. For example, controlling for EHRs years of experience, internal and external factors, a hospital in Stage 3 is associated with 10.91 ($p<0.01$) percentage point less in patient outcome score as compared to a hospital in Stage 0. Similarly, a hospital in stage 2 is associated with a 10.07 ($p<0.01$) percentage point less in expected patient outcomes score as compared to a hospital in Stage 0, all else being equal. There is no significant statistical difference in patient outcomes scores between a hospital in Stage 4 as compared to a hospital in Stage 0.

<u>EHRs sophistication years of experience and patient outcomes performance</u>

Lastly, the study hypothesized that the greater experience, i.e., more years, in higher EHRs sophistication stages (Stage 3 and 4) would be associated with more significant performance improvements on the patient outcomes composite measure. Overall, the total years of EHRs experience and the number of years on any given EHRs sophistication stages does not seem to have an influence on patient outcomes. The only exception appears to be for a hospital in EHRs sophistication Stage 3 and 1. For example, in model 4, by the end of the fourth year, a hospital in Stage 3 is associated with 3.46($p<0.1$) percentage points more in expected patient outcomes score as compared to a hospital in other stages, others factors remaining constant. This increases to 3.99 (0.1) percentage point by the end of the fifth year. By the end of the year, a hospital in Stage 1 is associated with 4.41(0.05) percentage points more in expected patient outcomes than a hospital in other stages.

Internal and external factors association with performance on process of care and patient outcomes

While the focus of this study was in the estimation of EHRs sophistication and EHRs experience, there are some additional results worth noting. For example, presence of infection surveillance systems, the number of times a hospital has changed ownership, the teaching status, hospital size, case mix index, hospital ownership, and hospital trauma level designation, among others factors were all associated significantly with hospital process of care performance. While the direction of the association for most was expected, some were surprising, while others in others the magnitude was bigger than anticipated. For example, the results indicate that a hospital changing ownership one additional time is associated with a 1.46 ($p<0.01$) percentage point increase in expected clinical process of care score (Table 2.2 Model 4). In addition, a major teaching hospital was associated with 7.91 ($p<0.05$) percentage points decrease in clinical process of care score, while a teaching hospital was associated with a 2.81($p<0.05$) percentage point decrease. Similarly, several factors were found to be substantially associated with patient outcomes score. These include hospital size, hospital ownership, and the presence of stroke care registry, wage index, county unemployment rate and whether a hospital is a rural hospital. The results from controlling for these factors suggest that it takes more to see improvement on process care and patient outcomes measures.

Discussion

Following a spike in adoption and implementation of sophisticated EHRs, there is interest in examining the association on these systems to the clinical process of care and patient outcomes. Also, in systematic reviewers called for additional research in this area to fill identified gaps including controlling for some contextual factors. This study focused on evaluating the effect of EHRs sophistication on clinical process of care, patient outcomes and whether EHRs years of experience at a higher sophistication stage improved performance in these two areas.

EHRs sophistication, EHRs years of experience and clinical process of care performance

The study did not find evidence to support the hypothesis that on average, a hospital with more sophisticated EHRs would exhibit higher performance in the clinical process of care than hospitals with less sophisticated EHRs, all else being equal. Across models, a hospital with higher sophistication was associated with a decrease in performance as compared to a hospital in the lowest EHRs sophistication stage. However, we found strong evidence to support the hypothesis that a hospital with that greater experience, i.e., more years in higher EHRs sophistication stages (stage 3 and 4) would be associated with greater performance on clinical process of care. The takeaway message from these results is that it appears EHRs sophistication indeed is associated with improved performance on clinical process of care only after overcoming the disruption effect upon implementation of more sophisticated EHRs. This is in line with a previous study that found performance gains over time on process adherence as a result of higher levels of EHRs adoption [23]. The study found improvement in process adherence in 2010/2011 period as more than the 2008/2009 period indicating time-related effects on higher levels of EHRs adoption[23]. There is also an expectation and evidence that there will be temporary workflow disruptions when a hospital moves to a more sophisticated EHRs[69, 70]. For hospital administrators, this means thoroughly preparing for such expected disruptions and possibly testing contingency plans not only for expected disruptions but also for the unexpected ones. This is more so given a report from the Department of Health and Human Services Inspector General that found 59% of hospitals in 2015 experienced an EHRs outage and a quarter of the hospitals reported that care was delayed as a result [71].

EHRs sophistication, EHRs years of experience and patient outcomes performance

The study also sought to examine whether a hospital with more sophisticated EHRs would exhibit better patient outcomes than a hospital with less sophisticated EHRs. The study did not find evidence to support this hypothesis. Instead, across the four models, from the basic model to the full model, EHRs sophistication was associated with a decrease in expected performance on patient outcomes. There is a possibility that the decreases in expected patient outcomes are due to workflow disruptions and providers learning curve. However, evidence indicates also shows that more EHRs years of experience did not mitigate the poor performance. This is opposite of a previous study that found no evidence of adverse patient outcomes following EHRs conversion, and another that reported a few months-long workflow disruptions[70, 72]. There are possible explanations for these results. First, it is possible that hospital with sophisticated EHRs is better at documenting and reporting adverse events, while also they correctly attribute and report patients' outcomes. For example, researchers have noted that PSI-90, which is a measure included in the outcome composite score is flawed[73, 74]. They indicate that a hospital might be penalized unfairly due to a high postoperative venous thromboembolism (VTE) event rate due to increased vigilance in detection and not due to poor quality of care[73, 74]. It is plausible, therefore, that sophisticated EHRs are associated with negative patient outcome performance due to the flaws in the underlying outcomes measures in what is referred to as surveillance bias[73].

It is also likely that patient outcomes such as 30-day mortality are complex and hard to affect and as a result, require more resource allocation over time and a transformation of how each hospital delivers care. There are hundreds of processes that map to each patient outcome, therefore, for more sophisticated EHRs to affect each patient outcome, such as mortality or patient safety measures, requires a convergence of hundreds or even thousands of individual processes [11, 12]. This is a painstaking order that might indeed require first improving clinical processes before affecting patient outcomes. For perspective, Donchin and colleagues reported that in intensive care unit clinical process per patient averaged 178 per day [75]. This fact is tangentially supported by the results that show several other internal and external factors are associated with patient outcomes.

For hospital administrations, this has several implications. First, it is important to prepare for possible disruptions; this includes for both workflow and unplanned disruptions such as EHRs outages. Mitigation plans might include unintended consequences such as "increased medical errors, negative emotions, changes in the power structure, and overdependence on technology" [76]. Second, it appears that for sophisticated EHRs to be of benefit to effect improved outcomes, hospitals must also look at other factors that are associated with patient outcomes. This is important especially in the age of value-based purchasing and accountable care organizations. Therefore, sophisticated EHRs can be a tool to transform care, but it might not be a solution to every ill in care delivery.

For policy makers, this might mean to re-review the measures that are used to penalize and reward hospitals including under meaningful use and value-based purchasing programs. This also adds to the evidence that some hospitals such as large hospitals that serve sicker patients are likely to perform poorly in the outcome measures[66]. It is, therefore, important to consider measures used that do not adequately adjust for the kind of patient served.

Limitations

The major limitation of this study stems from the lack of data on factors that might also influence the quality of care, such as sophistication EHRs specific training, a hospital's quality improvement culture, and the overall organization culture of change [14] in addition to unobservable patient social-economic factors. Although propensity weighting might have mitigated some of these unobservable factors, it is possible that it does not entirely account for all patient level and hospital factors. Second, we used patient clinical outcomes to evaluate health care quality; however, patient outcomes are likely to be affected by other factors other than quality care, such as social-economic factors[77]. This is referred to as low signal to noise ratio, which leads to a high risk of false negative results[77, 78]. Furthermore, even though this study's outcome measure is a composite measure and possibly a good barometer of diffuse effects of sophisticated EHRs, it is still possible that the observed negative effects are as a result of the unobserved mediating factors. Lastly, it is important to acknowledge that sophistication categorization also may be flawed. The adapted categorization was originally built largely through an expert panel consensus opinion. It is possible; some functionalities belong in a different stage than currently categorized.

Conclusion

This study set out to examine one overarching area; whether sophisticated EHRs contribute to improved healthcare quality. To answer the study question the study looked at whether a hospital with more sophisticated EHRs performs better on clinical processes of care and patient outcomes. In addition, the study sought to examine if there is an association between the EHRs years of experience and the clinical process of care and patient outcomes. The evidence indicates that both in clinical process of care and patient outcomes, more sophisticated EHRs is associated with a decrease in performance, possibly due to workflow and learning curve disruptions. The study also found evidence that the longer experience a hospital has on a higher sophisticated EHRs stage; the better it performed on clinical process of care score. However, the results did not support the same hypothesis for patient outcomes. The results have several implications for hospital administrators, policy makers, and researchers. This includes thoroughly preparing for the expected care delivery disruption and testing contingency plans for the unexpected disruptions such as EHR outages. There is a need to re-evaluating measures that are used to reward and penalize providers including under meaningful use and value-based purchasing. Lastly, for researchers, it is important to control for EHRs years of experience when evaluating EHRs sophistication and its association to healthcare quality. There are also areas that the study did not look at due to the lack of relevant data. For example, it is important to review the implementation process of the effects on the EHRs sophistication of health care quality. Also, other factors such as culture, leadership involvement, and general internal hospital-specific characteristics might shed more light on how EHRs sophistication might influence the provision of high-quality health services.

Chapter 2 Tables

Table 2.1: Summary statistics					
Outcome measures	Obs	Mean	Std dev	Min	Max
Normalized process of care domain score	2808	55.41	20.06	0	100
Normalized outcome domain score	2685	45.04	18.47	0	100
Analytic measures	**Obs**	**Percent**			
EHRs sophistication stage 0	481	9.73			
EHRs sophistication stage 1	839	16.98			
EHRs sophistication stage 2	1,988	40.23			
EHRs sophistication stage 3	1,195	24.18			
EHRs sophistication stage 4	439	8.88			
Categorical control variables					
EHRs Applications (if installed and live)	**Obs**	**Percent**			
Electronic Medication Administration Record (eMAR)	3,858	78			
Clinical Decision Support Systems (CDSS)	4,429	89.62			
Computerized Physician Order Entry (CPOE)	3,212	65			
Infection Surveillance Systems	1,671	34			
Outcomes & Quality Management Systems	3,587	73			
Teaching status					
Major teaching hospital	258	8.2			
Teaching hospital	765	24.32			
Non-teaching hospital	2,121	67.48			
Hospital size	**Obs**	**Percent**			
Small hospitals (1-99 beds)	1,076	34.21			
Medium Hospitals (100-399 beds)	1,696	53.93			
Large hospitals (400 + beds)	372	11.83			
System status	**Obs**	**Percent**			
Yes	2,362	74.7			
No	798	25.25			
Magnet status	**Obs**	**Percent**			
Yes	465	9.41			
No	4,477	90.59			
Ownership	**Obs**	**Percent**			
Public	1,077	22.2			
Private, For-profit	948	19.54			
Private, Not-for-profit	2,826	58.26			
Changed ownership between 2007-2016 years	**Obs**	**Percent**			
Yes	324	6.56			

No	4,555	93.44			
Location	**Obs**	**Percent**			
Urban	2,337	73.93			
Rural	824	26.07			
Structural factors	**Obs**	**Percent**			
Nursing care registry	**1,636**	**33.1**			
Stroke care registry	1,678	33.95			
General surgery registry	712	14.41			
Trauma level designation	**Obs**	**Percent**			
Trauma level 1	303	6.13			
Trauma level 2	360	7.28			
Trauma level 3	459	9.29			
Geographic region	**Obs**	**Percent**			
Northeast	496	15.78			
South	1,337	42.53			
Midwest	717	22.81			
West	594	18.89			
Continuous control variables	**Observations**	**Mean**	**Std dev**	**Min**	**Max**
Years in EHRs stage 1	4942	1.36	2.00	0	8
Years in EHRs stage 2	4942	2.06	2.18	0	8
Years in EHRs stage 3	4942	2.43	2.31	0	4
Years in EHRs stage 4	4942	0.55	1.03	0	4
Number of times hospital has changed ownership	4942	0.91	1.37	0	10
Saidin Index	3161	13.34	7.16	0	34.23
HHI	4678	0.58	0.36	0	1
Adjusted Occupancy Rate	3137	0.50	0.19	0	0.99
CMS Case Mix Index	3424	1.52	0.36	0.65	3.98
Operating Margin	4631	0.02	0.16	-1.9	1.42
Unemployment rate	3160	6.38	1.85	0	23.6
Under 65 years old uninsured rate	3161	16.89	5.6	0	38.2

Table 2-1 Summary statistics

Table 2.2: Association between EHRs Sophistication and Performance on Clinical Process of Care

	(1)FGLS Basic Model	(2)FGLS + Years of EHRs experience	(3)FGLS + Applications & internal context factors	(4)FGLS + External context factors
EHR Stage 1	-5.19	-4.00	-6.69*	-7.34*
	(3.61)	(3.78)	(3.60)	(3.87)
EHR Stage 2	-2.63	-8.19**	-3.64	-4.08
	(3.60)	(3.86)	(4.30)	(4.31)
EHR Stage 3	-2.19	-10.19**	-10.88**	-11.92***
	(3.49)	(3.97)	(4.65)	(4.60)
EHR Stage 4	-0.46	-8.61	-14.22**	-14.44***
	(3.59)	(6.19)	(5.85)	(5.50)
EHR Stage 1 Year 1		2.78**	3.14***	2.51**
		(1.31)	(1.21)	(1.09)
EHR Stage 1 Year 2		1.88	1.82	1.69
		(1.48)	(1.35)	(1.21)
EHR Stage 1 Year 3		2.41	1.69	1.80
		(1.57)	(1.53)	(1.49)
EHR Stage 1 Year 4		0.71	1.25	1.00
		(1.96)	(1.81)	(1.69)
EHR Stage 1 Year 5		2.53	1.43	1.05
		(2.17)	(2.03)	(1.96)
EHR Stage 1 Year 6		2.80	3.56	2.64
		(2.41)	(2.28)	(2.23)
EHR Stage 1 Year 7		0.47	2.67	2.09
		(3.07)	(2.83)	(2.70)
EHR Stage 1 Year 8		-2.60	-1.06	-1.29
		(3.44)	(3.25)	(2.93)
EHR Stage 2 Year 1		-0.79	-1.63	-1.27
		(1.22)	(1.15)	(1.08)
EHR Stage 2 Year 2		-0.71	-1.14	-0.38
		(1.40)	(1.32)	(1.20)
EHR Stage 2 Year 3		2.24	0.83	0.84
		(1.48)	(1.44)	(1.39)
EHR Stage 2 Year 4		4.00**	3.13*	2.92
		(1.92)	(1.89)	(1.79)
EHR Stage 2 Year 5		2.99	0.04	-1.27
		(2.25)	(2.27)	(2.12)
EHR Stage 2 Year 6		9.39***	6.89**	6.02**
		(3.03)	(2.71)	(2.64)
EHR Stage 2 Year 7		11.83***	8.09**	6.83**
		(3.26)	(3.23)	(3.17)
EHR Stage 2 Year 8		12.23***	8.31**	6.27
		(4.18)	(4.05)	(4.35)
EHR Stage 3 Year 1		3.94**	4.62***	4.65***
		(1.68)	(1.63)	(1.57)
EHR Stage 3 Year 2		5.05***	4.22**	4.63***

		(1.77)	(1.67)	(1.73)
EHR Stage 3 Year 3		8.66***	9.64***	9.33***
		(2.19)	(2.05)	(1.99)
EHR Stage 3 Year 4		8.96***	6.74***	7.72***
		(2.22)	(2.18)	(2.10)
EHR Stage 3 Year 5		11.72***	10.73***	10.03***
		(2.41)	(2.36)	(2.27)
EHR Stage 4 Year 1		1.06	4.11	3.49
		(4.56)	(3.63)	(3.20)
EHR Stage 4 Year 2		9.07	10.81***	10.19***
		(5.67)	(4.00)	(3.47)
EHR Stage 4 Year 3		3.17	5.98	4.02
		(5.26)	(4.08)	(3.61)
EHR Stage 4 Year 4		1.28	5.27	2.95
		(5.95)	(4.62)	(4.91)
Total EHRs Years		-0.22	-0.08	-0.49
		(0.41)	(0.41)	(0.43)
eMAR			-5.85**	-4.84*
			(2.89)	(2.55)
CDSS			4.57*	4.94*
			(2.39)	(2.78)
CPOE			6.16***	5.64**
			(2.35)	(2.20)
Infection Surveillance Systems			1.53*	1.82**
			(0.83)	(0.75)
Outcomes & Quality Management Systems			1.06	0.87
			(1.15)	(1.10)
Change of ownership (2007-15)			-3.42**	-3.77***
			(1.45)	(1.26)
Change of ownership count			0.61**	0.42*
			(0.27)	(0.24)
Saidin Index			-0.18***	-0.14**
			(0.06)	(0.06)
Major teaching			-2.45	-3.72**
			(1.80)	(1.62)
Teaching			-1.22	-1.65*
			(0.94)	(0.87)
Safety net			-2.09**	-0.70
			(1.00)	(0.96)
Medium Hospital (100-399 beds)			-0.71	-2.10*
			(1.14)	(1.13)
Large hospital (400+ beds)			-1.43	-3.46**
			(1.75)	(1.69)
Standalone hospital			-1.00	-0.77
			(0.84)	(0.79)
Adjusted occupancy rate			-0.03	-0.04
			(0.03)	(0.03)
Case Mix Index			2.91*	4.09**
			(1.69)	(1.70)

For-profit hospital			6.04***	5.36***
			(1.13)	(1.11)
Government hospital			-2.82**	-3.19***
			(1.13)	(1.10)
Operating margin			0.21***	0.19***
			(0.03)	(0.03)
Magnet Designated Hospital			0.08	-0.01
			(1.04)	(0.94)
Trauma Level 1 hospital			0.23	-0.26
			(1.53)	(1.40)
Trauma Level 2 hospital			-2.24**	-2.14**
			(1.11)	(0.99)
Trauma Level 3 hospital			-0.06	0.37
			(1.16)	(1.17)
Nursing care registry			2.40***	2.03**
			(0.91)	(0.87)
Stroke care registry			4.17***	4.00***
			(0.92)	(0.85)
General Surgery Registry			-1.27	-0.61
			(0.92)	(0.84)
Medicaid Expansion State				-1.58*
				(0.91)
Herfindahl-Hirschman Index				-1.45
				(1.40)
Wage Index for FY				1.18
				(2.97)
Unemployment Rate, (16 yrs +)				-0.13
				(0.24)
% < 65 without Health Insurance				-0.01
				(0.10)
Rural hospital				-2.72**
				(1.15)
South				0.17
				(1.46)
Midwest				0.10
				(1.11)
West				-4.33***
				(1.40)
Constant	57.80***	59.53***	49.49***	51.32***
	(3.45)	(4.22)	(5.20)	(6.91)
Observations	2767	2767	2767	2767
R^2	0.0045	0.0346	0.1202	0.1271
AIC	24384.11	24273.65	23862.35	23771.01

Table 2-2: Association between EHRs Sophistication and Clinical Process of Care

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 2.3: Association between EHRs Sophistication and Performance on Patient Outcomes

	(1)	(2)	(3)	(4)
	Basic Model	+ Years of EHRs experience added	+ Applications & internal context factors	+ External context factors
EHR Stage 1	-10.12***	-12.95***	-9.42***	-10.42***
	(3.80)	(4.44)	(3.39)	(2.93)
EHR Stage 2	-9.61**	-10.60**	-10.78***	-10.07***
	(3.85)	(4.67)	(4.06)	(3.67)
EHR Stage 3	-9.72***	-12.90***	-9.09**	-10.91***
	(3.68)	(4.59)	(4.56)	(4.14)
EHR Stage 4	-8.39**	-13.64	-9.16	-8.81
	(3.86)	(8.98)	(9.82)	(10.25)
EHR Stage 1 Year 1		-1.86	-0.83	-1.81
		(1.91)	(1.19)	(1.15)
EHR Stage 1 Year 2		1.34	-0.41	0.35
		(3.41)	(1.29)	(1.35)
EHR Stage 1 Year 3		1.27	1.23	1.37
		(2.51)	(1.46)	(1.44)
EHR Stage 1 Year 4		1.03	-0.83	-0.05
		(3.01)	(1.68)	(1.64)
EHR Stage 1 Year 5		3.72	1.29	1.85
		(3.65)	(2.02)	(1.98)
EHR Stage 1 Year 6		7.67**	3.83*	4.41**
		(3.80)	(2.20)	(2.14)
EHR Stage 1 Year 7		-2.53	-1.87	-2.53
		(3.99)	(2.92)	(2.48)
EHR Stage 1 Year 8		5.90	2.77	3.70
		(4.26)	(3.01)	(2.91)
EHR Stage 2 Year 1		-0.72	-1.05	-0.92
		(2.04)	(1.17)	(1.16)
EHR Stage 2 Year 2		1.47	2.33*	1.38
		(1.99)	(1.21)	(1.20)
EHR Stage 2 Year 3		-1.43	0.43	0.45
		(2.40)	(1.46)	(1.42)
EHR Stage 2 Year 4		2.40	2.04	2.36
		(2.80)	(1.74)	(1.66)
EHR Stage 2 Year 5		-1.27	-1.13	-1.27
		(3.17)	(1.90)	(1.88)
EHR Stage 2 Year 6		3.34	1.43	2.33
		(4.33)	(3.26)	(3.29)
EHR Stage 2 Year 7		3.20	1.90	1.87
		(4.18)	(3.09)	(3.02)
EHR Stage 2 Year 8		0.68	-0.17	0.63
		(5.18)	(3.78)	(3.58)
EHR Stage 3 Year 1		1.87	0.79	1.67
		(2.35)	(1.72)	(1.64)

EHR Stage 3 Year 2		1.84	0.51	1.83
		(2.10)	(1.79)	(1.73)
EHR Stage 3 Year 3		1.74	-1.05	0.30
		(2.30)	(1.94)	(1.87)
EHR Stage 3 Year 4		5.57*	2.26	3.46*
		(2.99)	(2.17)	(2.08)
EHR Stage 3 Year 5		5.63*	1.61	3.99*
		(3.04)	(2.42)	(2.35)
EHR Stage 4 Year 1		1.62	0.98	-0.92
		(7.71)	(8.76)	(9.43)
EHR Stage 4 Year 2		5.70	4.80	2.46
		(7.97)	(8.87)	(9.59)
EHR Stage 4 Year 3		6.64	5.40	3.82
		(8.24)	(9.18)	(9.83)
EHR Stage 4 Year 4		8.02	6.18	2.73
		(9.11)	(9.82)	(10.17)
Total EHRs Years		-1.08	-0.73*	-0.53
		(0.79)	(0.41)	(0.44)
eMAR			3.45	2.53
			(2.81)	(2.63)
CDSS			1.43	2.06
			(2.64)	(2.74)
CPOE			-2.34	-0.89
			(2.48)	(2.33)
Infection Surveillance Systems			0.33	0.05
			(0.78)	(0.77)
Outcomes & Quality Management Systems			-0.50	-0.01
			(1.00)	(1.01)
Change of ownership (<9 years)			-2.53**	-2.25*
			(1.18)	(1.29)
Change of ownership count			0.13	0.08
			(0.24)	(0.24)
Saidin Index			-0.22***	-0.22***
			(0.06)	(0.06)
Major teaching			4.09**	3.36**
			(1.63)	(1.70)
Teaching			0.03	-0.73
			(0.94)	(0.93)
Safety net			0.51	-0.14
			(0.92)	(0.96)
Medium Hospital (100-399 beds)			2.56**	1.92*
			(1.07)	(1.12)
Large hospital (400+ beds)			4.05**	3.73**
			(1.66)	(1.74)
Standalone hospital			-0.70	-0.78
			(0.81)	(0.80)
Adjusted occupancy rate			0.01	-0.00
			(0.03)	(0.03)
Case Mix Index			-2.03	-2.70

			(1.87)	(1.99)
For-profit hospital			0.65	0.51
			(1.07)	(1.09)
Government hospital			-2.26**	-2.33**
			(1.01)	(1.00)
Operating margin			-0.08***	-0.06***
			(0.02)	(0.02)
Magnet Designated Hospital			2.41**	2.36**
			(1.05)	(1.05)
Trauma Level 1 hospital			-6.68***	-6.08***
			(1.55)	(1.54)
Trauma Level 2 hospital			-1.34	-1.23
			(1.09)	(1.04)
Trauma Level 3 hospital			0.60	0.09
			(1.12)	(1.15)
Nursing care registry			0.52	-0.04
			(0.89)	(0.89)
Stroke care registry			-1.47*	-2.13**
			(0.88)	(0.87)
General Surgery Registry			1.00	0.25
			(0.93)	(0.90)
Medicaid Expansion State				1.82*
				(1.00)
Herfindahl-Hirschman Index				-0.05
				(1.37)
Wage Index				8.29***
				(3.04)
Unemployment Rate, (16 yrs +)				-0.65***
				(0.19)
% < 65 without Health Insurance				0.17*
				(0.09)
Rural hospital				-1.54
				(1.09)
South				0.59
				(1.47)
Midwest				1.48
				(1.26)
West				-2.19
				(1.47)
Constant	54.45***	61.48***	60.29***	53.80***
	(3.65)	(6.16)	(5.01)	(6.52)
Observations	2645	2645	2645	2645
R^2	0.0301	0.0543	0.0448	0.0612
AIC	22843.58	22828.59	22770.27	22695.53

Table 2-3: Association between EHRs Sophistication and Patient Outcomes

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

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CHAPTER 3: THE ASSOCIATION BETWEEN MEANINGFUL USE PERFORMANCE AND PATIENT EXPERIENCE, HOSPITAL 30-DAY READMISSIONS

Introduction

In 2009, Congress enacted The Health Information Technology for Economic and Clinical Health (HITECH) Act, as part of the American Recovery and Reinvestment Act of 2009, following the 2008 economic recession [1]. In 2011, based on provisions of the Act, the Centers for Medicare and Medicaid Services developed Electronic Health Records (EHR) Incentive Programs "to encourage eligible professionals and eligible hospitals to adopt, implement, upgrade (AIU), and demonstrate meaningful use of certified EHR technology"[2]. The Programs, also referred to as meaningful use (MU), were divided into three stages. Stage 1 required providers to capture clinical data and provide patients and their families' with electronic access to their health records. Stage 2 expanded the requirements to use EHRs for continuous quality improvement at the point of care and the exchange of information among providers [3]. Finally modified stage 2 (for the program year 2015-2017) and stage 3 "will focus on the advanced use of certified EHR technology to support health information exchange and interoperability, advanced quality measurement, and maximizing clinical effectiveness and efficiencies." [2]

The MU programs are considered cornerstones in reaching national and CMS strategic goals outlined in the 2016 strategy update [4]. Among these targets is to strengthen patient engagement in their care and promote effective communication and coordination of care [4]. Meaningful use of EHR functionalities to improve patient engagement can enhance health care quality[5, 6]. For example, patient portals may foster consumer empowerment and self-management of their care [7]. In summary, EHRs have the potential to empower patients, foster patient engagement, and enhance self-care and preventive behaviors. MU also has the potential to improve care coordination by marshaling personnel and other resources needed to facilitate the exchange of information among care providers [8].

MU, therefore, is intended to enable providers to share information and bridge the gaps that have existed in the delivery system. In addition, it is also possible that empowered patients who have information on how to care for themselves are also less likely to be readmitted within 30 days after discharge.

Both patient engagement and care coordination have long been identified as strategies to improve care and reduce overutilization of high-cost health care services, especially for chronically ill individuals[5, 9-11]. In this study, we focus on patient experience and 30-day hospital readmissions, which are outcomes that are part of CMS' Hospital Value-Based Purchasing program (VBP) and Hospital Readmission Reduction Program (HRRP)[12-14]. Patient experience, defined as "the sum of all interactions, shaped by an organization's culture, that influence patient perceptions, across the continuum of care"[15], is critical to patient-centered care. Readmissions within 30 days may signal quality problems in the discharging hospital. Although patient experience and readmissions are important measures independently, researchers have also concluded that there is also a connection between patient experience and readmissions[14, 16-19].

The purpose of the study, therefore, is to determine whether:

a) performance in meaningful use patient engagement and care coordination objectives are associated with improved patient experience,

b) performance on meaningful use patient engagement and care coordination objectives are associated with 30-day hospital readmissions, and

c) patient experience performance is associated with 30-day hospital readmissions, controlling for MU patient engagement and care coordination.

Examining these relationships is important in the age of concerted efforts to reform the health care system towards a focus on patient and family-centered care and the ultimate goal of improving population health. In addition, the study can serve as part of the ongoing interim evaluation of the heavy federal government investment on tools to improve patient engagement, care coordination, and health care outcomes. More importantly, answering these questions is critical because the meaningful use measures were designed to align with the National Quality Strategy key priorities – specifically, engagement of patients and their families as partners in care delivery and effective communication to improve care coordination [20, 21].

Conceptual framework

There are two theorized pathways from meaningful use to hospital readmissions. First, patient engagement through EHRs utilization under MU – e.g., patient portals – improves patients' understanding of their conditions, empowers patients, and enhances disease self-management [10], which contributes to reducing hospital readmissions. For example, using EHRs nurses can communicate relevant information to patients and their families on a range of care issues such as patient medication, medication side effects, the kind of treatment they received and what to do when they get home. All these activities are likely to improve patient experience and in the end, enable patients and their families to cut unnecessary trips to the emergency room or an admission.

The second pathway is more direct. MU performance might affect readmissions directly through care coordination activities. This is based on the idea that MU activities such as preparing patients for the transition by using EHRs to reconcile their medication, allowing access to patient health information and exchanging such information with providers would influence readmissions. The general intent of these care coordination strategies is to ease "delivery of the right health care services in the right order, at the right time, and in the right setting"[8]. This point is borne by previous studies that show that patient-related information can facilitate to effective coordination and medical decision-making[22-29]. In addition, the choice of the dependent variables is premised on the theory and past research that patient engagement and care coordination will be associated with better care experiences, and better health outcomes through improved condition self-management skills, preventative health behavior and improved patient-providers and provider-provider communication [6, 30-32].

Nevertheless, there is no published evidence, to the best of my knowledge, to suggest one way or the other if there is an association between MU performance on patient care coordination and 30-day readmissions. The meaningful use is premised on the believe that EHRs will facilitate delivery of patient-centered, high-quality care. The theory is that as more patients have access to their records, receive customized education resources, and be informed and empowered to take charge of their health, more of those patients will have better care experience and be likely to follow post-discharge care directions. For example, patients who view, download and transmit their health records are more likely to be more interactive with their provider because of their positive care experience. This, in turn, may reduce readmission to an acute care hospital. Also, electronically sending health records to a referral provider or from a referral will close the information gap between transitions thereby improving the care the patient receives, avoid unnecessary tests and exams and ultimately reduce readmissions. Thus, I hypothesize:

a. On average, an increase in a hospital's performance on MU patient engagement and care coordination measures will be associated with an increase in performance on patient experience, everything else being equal.
b. On average, an increase in a hospital's performance on MU patient engagement and care coordination will be associated with lower 30-day readmission rates, holding everything constant.
c. On average, an increase in hospital's performance on patient experience measures, controlling for MU patient engagement and care coordination, will be associated with a decrease in 30-day readmission rates.

<u>Methods:</u>

<u>Data Sources and sample</u>

The data for this study comes from several sources, including the CMS, most of them from the CMS. The MU data comes from the 2015 Medicare EHR Incentive Program Eligible Hospitals Public Use File (PUF) [33]. A total of 3,563 eligible hospitals attested to meeting the modified stage 2 criteria, which encourages providers to use EHR for continuous quality improvement at the point of care and the exchange of information in the most structured format possible [2]. The 30-day readmission data were from the HRRP via Hospital Compare database [34]. The HRRP, which was established under section 3025 of ACA, requires CMS to reduce payments to Inpatient Prospective Payment Systems (IPPS) hospitals with excess readmissions [13]. The data used here comprise the following conditions: pneumonia (PN), heart failure (HF), chronic obstructive pulmonary disease (COPD), hip and knee, stroke and hospital-wide readmission rates. The numbers of eligible hospitals reporting their performance vary across the conditions; from 2611 hospital reporting stroke readmission rates to 4402 hospital reporting hospital-wide readmission rates. The collection of the data across the measures started on July 1, 2012, and ended June 30, 2015, except for the collection of hospital-wide readmission rates that began on July 1, 2014, and ended on June 30, 2015. Data on patient experience was also sourced from the Hospital Value-Based Purchasing program (VBP) via Hospital Compare Database. VBP was created under Affordable Care Act as an incentive program to link payments to the value of care patients get[12]. The study used data from 3,544 hospitals that reported patient experience measures that were collected during the 2015 fiscal year (October 1, 2014, to September 30, 2015).

EHRs data for 4,942 hospitals came from HIMSS through The Dorenfest Institute for Health Information hospital survey database for the calendar year 2012. The Dorenfest Institute provides free historical data, for eligible institutions, researchers and students, and other tools for adoption, implementation and the use of IT in hospitals and integrated healthcare delivery networks [35]. Hospital-level data, such as hospital ownership, size, location, occupancy rate and other hospital characteristics are sourced from several CMS file including Final Rule files(FY 2015) [36, 37], Provider of Service file (2015), Structural Measures file (2015), and Cost Reports (2012), all publicly available data. Data on the local hospital market such as unemployment rate, the rate of the uninsured came from HRSA's Area Health Resource File, 2014-2015 edition and CMS' Cost Reports (2012).

Study design

This study employed a cross section analysis design in evaluating the association between meaningful use patient engagement and care coordination core objectives performance and patient experience and 30-day hospital readmissions. The study acute care hospitals participating in the meaningful use, VBP and HRRP programs. These programs exempt psychiatric, rehabilitation, long-term care, children's, cancer, and critical access hospitals, and in the case of HRRP, all hospitals in Maryland [12, 13, 38, 39].

Measures

Dependent Variables: The study included two dependent variables. First, patient experience of care comes from The Consumer Assessment of Healthcare Providers and Systems (CAHPS) survey under VBP. Patient experiences include eight measures; however, we selected six that are closely related to EHRs: nurse communication, pain management, medicine communication, discharge information, overall rating, and recommend the hospital. We include these variables as indicators of patient experience that are likely to be affected by the meaningful use EHR functions. For example, we theorize that based on the use of electronic medication administration record (eMAR), computerized provider order entry (CPOE), clinical decision support systems (CDSS) among other EHRs functionalities, providers will be equipped and able to provide patient specific clear and understandable information on their medications, manage their pain and offer useful patient discharge information. We left out two patient experience domain variables, cleanliness and quietness of the hospital environment and responsiveness of hospital staff that we believed might not be associated with EHRs use.

The second dependent variables are 30-day hospital readmissions on heart failure (HF), stroke, hip and knee, chronic obstructive pulmonary disease (COPD), and pneumonia (PN), respectively. The conditions were included based on the recommendation that they were the most common readmission conditions[13, 40]. Also included is the hospital-wide readmission rate. These are hospital specific 30-day risk-standardized readmission rates (RSRR) and are computed in several steps based on this formula: RSRR = (Predicted 30-day readmission/Expected readmission) * U.S. national readmission rate [41]. First, the predicted 30-day readmission for a particular hospital is computed using a hierarchical regression model; then this is divided by the expected readmission for that hospital, which is similarly obtained from the regression model [41]. This ratio is then multiplied by the national unadjusted readmission rate for the condition for all hospitals to get hospital-specific RSRR. Predicted readmission "is the number of readmissions (following discharge for assessed conditions) that would be anticipated in the particular hospital during the study period, given the patient case mix and the hospital's unique quality of care effect on readmission."[41] Expected readmission "is the number of readmissions (following inpatient or ED discharge) that would be expected if the same patients with the same characteristics had instead been treated at an "average" hospital, given the "average" hospital's quality of care effect on readmission for patients with that condition."[41]

Independent variables: To answer the first two study questions; a) Whether performance in meaningful use patient engagement and care coordination core objective is associated with improved patient experience and b). Whether performance on meaningful use patient engagement and care coordination core objective is associated with reduced 30-day hospital readmissions, the study will employ patient electronic access, patient-specific education resources, medication reconciliation and health information exchange variables. Patient electronic access variable is divided into two: a. The percentage of patients (or patient-authorized representative) who view, download, or transmit to a third party their health information (henceforth labeled as Patient eAccess: Patient who VDT) and b. The percentage of patients who have access to view, download, and transmit their health information within 36 hours after the information is available to the eligible hospital or CAH (henceforth labeled as Patient eAccess: Patient with the ability to VDT). Second, patient-specific education resource variable that measures the percentage of patients who were provided patient-specific education resources identified by Certified EHR Technology (CEHRT). There are two variables under the MU care coordination domain; medication reconciliation and health information exchange (HIE). The medication reconciliation variable measures the percentage of patients, those who are received by the hospital from another setting of care or provider of care and medication reconciliation is performed. Last, HIE measures the MU aim that the eligible hospital "who transitions their patient to another setting of care or provider of care or refers their patient to another provider of care provides a summary care record for each transition of care or referral" [33].

To answer the third question of the study: Whether patient experience performance is associated with reduced 30-day hospital readmission rate, the study will use VBP variables comprising: performance score on patient experience on nurse communication, pain management, medication communication, discharge information, and average patient experience composite variable.

Control variables: We selected control variables based on the theory that they will tend to confound the outcome measures. Also, experts have recommended the controlling of contextual variables that have been found to affect outcome variables such as readmissions and the analytic variables such as EHRs use [42-44]. This study controlled for several hospital level organization and market characteristics such as teaching status, safety net indicator, Saidin Index, structural measure (presence of a nursing care registry), Herfindahl-Hirschman Index(HHI), wage index among other factors. The study defines teaching status as either a major teaching hospital, teaching hospital or non-teaching hospital based on indirect medical education (IME) payment adjustment factor. IME payments are extra payments hospitals with approved residency program receive for Medicare discharges, based on the hospital's ratio of residents to beds, to reflect the higher patient care costs of teaching hospitals relative to nonteaching hospitals [45]. A major teaching hospital is defined as the top 25 percent hospitals of the adjustment factor. The teaching hospital comprises the remaining 75 percent of hospitals receiving the adjustment and non-teaching are those a CMS approved residency program. Safety net hospitals are identified using CMS' DSH patient percent, which is determined from cost report data and Social Security Administration data. In this study, a safety net hospital is defined as a hospital belonging to the top 25 percent of the DSH patient percent hospitals. DSH percentage is widely accepted as a proxy for hospitals that care for a large proportion of poor patients and frequently used by health services and policy researchers.

The study also controls for nursing care registry structural measures which reflect the environment in which hospital delivers care and is likely to affect patient experience measures and readmission rates. This measure can also "provide a real-world view of clinical practice, patient outcomes, safety, and clinical, comparative, and cost-effectiveness, and can serve a number of evidence development and decision-making purposes" [46]. Nursing care registry and change of ownership variable can reflect the hospital culture and leadership focus on patient-centered care and financial stability. For example, change of ownership usually reflects turmoil and often a scarcity of resources. Therefore, a hospital that has recently been acquired might take the time to stabilize and thus focus resources on primary assets such as plant and not on patient experience or EHRs. The study uses two variable to control for the shocks that will be expected when a hospital changes ownership, the number of times a hospital has changed ownership and whether the hospital changed ownership in the last nine years. The other variables that this controls for that can affect stability and allocation of hospital's often-limited resources are the operating margin and wage index. The operating margin might reflect the flexibility of a hospital in using the EHRs and other resources to boost patient experience and implementation of interventions that will reduce readmission rates. In the same way, a hospital with a high wage index might be financially squeezed by high labor cost, which will affect the occupational mix that will have a direct effect on patient experience and readmissions.

The study further uses several measures to control for the severity of illness, the complexity of hospital services and the local markets. This is based on the reasoning that if a particular hospital such as a major teaching hospital, seems to attract sicker patients than usual, and then it is likely that these patients might perceive health care quality differently as opposed to healthier patients. Also, patients from a hospital within a county with high unemployment rate, uninsured rate or from a rural area their experience and therefore, the likelihood of readmission might be different from patients in a county with the low unemployment rate, low uninsured rate, and a metro area. Thus, this study controls for CMS case mix index, Saidin Index, unemployment rate, the rate of the uninsured and whether a hospital is based in a rural area and whether a hospital is in a state that expanded Medicaid as of 2012. Saidin Index, a weighted sum of the number of technologies and services available in a hospital, is designed to control for rare high technology. The weights are the percentage of hospitals in the country that do not possess the technology or service [47, 48]. Therefore, a rare high technology service will be weighted higher than a common technology. The weights are computed as follows: Weights: $a_k = 1\text{-}(\frac{1}{N}) \sum_{i=1}^{N} \tau_{i,} k$ where N is the number of hospitals in the United States, $\tau_{i,}$ take the value of 1 if the hospital i has technology k. Then the weight is used to compute the index. $\text{Saidin Index} = \sum_{k=1}^{k} (a_k \, , \tau_{i,} k)$. Saidin Index in this case serves two purposes: First, it controls for quality effects, negative or positive, that might be attributed to the presence of high technology, which might also be attributed to EHRs use. Second, it controls for the possible patient self-selection. It is possible that patients will pass a hospital with few high technology services that is closer to their location, choosing a distant hospital with a reputation of comprehensive rare high technology services. CMS case mix index is a measure of resources required reflecting the complexity or severity of the patients the hospital often treats.

Other internal variables include hospital ownership, system status, hospital size, magnet status, trauma level designation and adjusted occupancy rate. The reasoning here is that hospital ownership incentivizes administrators and other stakeholders such as the board of directors or shareholders differently. For example, for-profit hospitals might be under pressure from shareholders to improve and distribute dividends to the detriment of the long-term investments or non-short-term-revenue boosting investments. It is also possible that for-profit hospitals will scale back on staff who manages patient experience to save costs, which will have an effect on the patient experience. Hospital size and system status are intended to control for economies of scale, which can affect resources, both human and financial availability. Alternatively, large hospitals might not offer personalized care that small hospitals might. The study also controls for Magnet status designation and trauma level 1 status. Magnet status designation emphasizes the role of nurses in care delivery and usually has stringent criteria, which might confound both EHRs use under MU and outcomes such as readmissions[49].

The study further controls for adjusted occupancy rate, which is based on what is called reservation quality which is an adjustment to account for the probability that a patient will be turned away from the hospital when it is full [50]. This is because of the unique attribute of acute care hospital of demand uncertainty[50-54], which can have an effect patient experience and patient discharge decision, which might determine a patient's readmission. A higher adjusted occupancy rate can signal quality issues especially in the case of an emergency. For example, a patient with an emergency might not access appropriate service in a hospital in a timely manner if occupancy rate is at 100%. The reservation quality is defined as $\beta = \frac{(B\text{-}\mu)}{\sqrt{\mu}}$. Where *B* is the number of staffed hospital beds in active use and μ is the average daily census. The β is the number of standard deviations above the mean census represented by the number of beds. Adjusted occupancy rate, therefore, is defined as $\text{AOR} = \frac{1}{1+\beta/\sqrt{\mu}}$ [50, 51].

Market control variable comprises demographic and hospital market variables. The demographic variables will include population density, unemployment rate, the uninsured rate for 18-64 year individuals, location (rural versus urban) and geographic region. These variables are included because of their potential effect on the local patient population and the hospital's resources. For example, a high unemployment and uninsured rate can signal a hospital that might be seeing sicker patients who don't have usual access to care. At the same time, these two factors will impact the hospital bottom line which in turn will affect resources allocation including implementing and maintaining sophisticated EHRs. To control for hospital concentration, which can affect health care quality due to competition, the likelihood of having more sophisticated EHRs and patient selection to a particular hospital, the study uses Herfindahl-Hirschman Index (HHI). The index is computed as follows:

$$HHI = \sum_{i=1}^{N} \left[\frac{\text{Patient days}_i}{\sum \text{Patient days}_i}\right]^2.$$

<u>Empirical Specification</u>

The analysis employed three different sets of models to answer the study questions. To determine whether performance in meaningful use patient engagement and care coordination core objectives are associated with improved patient experience the study employed the following ordinary least squares model.

$$y = \delta_0 + \delta_1 X_1 + \delta_2 X_2 + \delta_3 X_3 + \delta_4 X_4 + \delta_5 X_5 + \delta_6 X_6 + u$$

<u>Equation 2.1</u>

Where y is patient the experience dependent variables including a patient rating of their experience with medicine communication, discharge information, pain management, nurse communication, overall hospital rating and patient experience composite measure. X_1 is a vector of analytic variables which include Patient eAccess: Patients who VDT, Patient eAccess: Patients with ability to VDT, patient-specific education resources identified by CERT, medication reconciliation and health information exchange (HIE). X_2 is a vector of EHRs stage control variables, these are stages 1 to stage 4, with stage 0 as the referent category. X_3 are EHRs stage years for each stage. In addition, X_4 is a vector of individual EHRs applications including eMAR, CDSS, infection surveillance systems, outcomes quality management systems and MU utilization attestation on CPOE for laboratory orders, CPOE for radiology orders and CPOE for medication orders. The vector X_5 contains hospital characteristics including operating margin, wage index, CMS case mix index, Saidin Index, Herfindahl-Hirschman Index (HHI), adjusted occupancy rate, magnet status designation, trauma level 1, nursing care registry, teaching status, safety net, hospital size, system status, ownership, ownership change in the last nine years and ownership change count. The vector X_6 contains the market or environment factors such as whether the hospital is in a Medicaid expansion state, the county level unemployment rate, the rate of the uninsured for those 64 years old and below, rural setting and regional setting. The models were tested for omission of higher orders of explanatory variables using regression specification-error test (RESET) and for multicollinearity using variance inflation factors (VIF). In addition, every model was tested for evidence of heteroscedasticity using Breusch-Pagan and Cook-Weisberg test for heteroscedasticity, in all the models, under this study question heteroscedasticity was detected and feasible generalized least squares was used over ordinary least squares.

To determine whether performance on meaningful use patient engagement and care coordination core objectives were associated with reduced 30-day hospital readmissions, the study used the following specification:

$$y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + u$$

Equation 2.2

Where y 30-day readmission is rate variable for heart failure, stroke, hip and knee, COPD, pneumonia and hospital wide readmission rate. The analytic and control variables are the same as in equation 1.1 above.

Lastly, to determine whether patient experience performance is associated with a reduction in 30-day hospital readmission rate.

$$y = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 + \alpha_4 X_4 + \alpha_5 X_5 + \alpha_6 X_6 + \alpha_7 X_7 + u$$

Equation 2.3

Where y 30-day readmission rate variable for heart failure, stroke, hip and knee, COPD, pneumonia and hospital wide readmission rate. The vector X_1 contains the patient experience analytic variables including nurse communication, doctor communication, pain management, medicine communication, discharge information, in lieu of overall hospital rating the study uses whether a patient can recommend the hospital measure and finally patient experience of care transition. X_2 is a vector of MU patient engagement and care coordination domain utilization rates which include Patient eAccess: Patients who VDT, Patient eAccess: Patients with ability to VDT, patient-specific education resources identified by CERT, medication reconciliation and health information exchange (HIE). The vectors X_3 to X_7 contains the same control variable as in equation 1.1(vectors X_2 to X_6)

Results

Summary statistics

3544 hospitals reported patient experience performance scores; patient experience rating on medicine communication, discharge information, pain management, nurse communication, overall hospital rating and recommend hospital (see Table 3.1). The average score for each of these areas ranged from 78.68(SD =4.27) for medicine communication to 91.22(SD=2.55) for nurse communication. There was a wide variation in the number of hospitals reporting their readmission rates across conditions. For example, 2611 hospital reported their stroke readmission rates, 4096 hospitals reported their 30-day pneumonia readmission rate, while 4402 hospitals reported their hospital-wide readmission rates. Similarly, there was a variation in the reported average readmission rates across conditions ranging from 4.61% readmission rate for hip and knee to 21.96% readmission rate for heart failure. When it comes to performance on meaningful use patient engagement and care coordination core objectives, hospitals performance varied across measures. The average performance ranged from the low of 14.34 percent (SD 13.78) patient VDT their health records to the high of 90.71 percent (SD 11.16) on medication reconciliation (See Table .1)

Performance on meaningful use patient engagement and care coordination objectives and patient experience

They study hypothesized that on average, an increase in a hospital's performance on MU patient engagement and care coordination measures will be associated with an increase in performance on patient experience, everything else being equal. The results, presented in Table 3.2, show that across several MU patient engagement and care coordination measures; generally, there is evidence to support the hypothesis. For example, a one percentage point increase in the number of patients who electronically viewed, downloaded and transmitted their records was associated with a 0.02 (P <0.01) percentage point increase in expected performance on patient experience on medicine communication, discharge information, and a patient who would recommend the hospital to family and friends. This means that if all patients were able to view, download and transmit their health records electronically, there would be a 2-percentage point increase in performance on patient experience with medication communication, discharge information and recommend the hospital. There was also a statistically significant association between performance on a patient who electronically viewed, downloaded and transmitted their health records and performance on patient experience on pain management, nurse communication, and overall hospital rating. Health information exchange, part of the MU care coordination domain, did not seem to have any significance effect across all patient experience measures

It is also worth noting, several control variables were notable for their statistically significant association with patient experience. Wage index, case mix index, Magnet designation, presence of nursing care registry, teaching hospitals, hospital size among several others were statistically significant. For example, a one-point increase in wage index was associated with a 1.63 ($p<0.01$) percentage point decrease in expected performance on recommending the hospital to friends and family measure, holding everything else equal. Similarly, a one point increase in the case-mix index was associated with a 4.44 ($p<0.01$) percentage point increase in expected performance on the number of patients who would recommend the hospital to family and friends. This shows that an increase in the number of patients who require fewer resources are associated with positive hospital experience as compared to a patient who needs more intensive resources.

<u>Association between meaningful use patient engagement and care coordination performance and 30-day readmissions</u>

Table 3.3 presents results from analysis to test the hypothesis that an increase in a hospital's performance on MU patient engagement and care coordination will be associated with lower 30-day readmission rates, holding everything constant. In general, the study did not find evidence to support the hypothesis. Across conditions, there was no statistically significant association between MU patient engagement and care coordination measures and with 30-day readmissions. In the few cases, there was a statistically significant association, such as between health information exchange and COPD readmission or patient-specific education resources and heart failure readmission, the results suggest the association was practically insignificant, 0.00 percentage points. However, some control measures that were not the focus of the study were found to be associated

with readmissions. For example, case mix index was negatively associated with readmission rates across all conditions included in the evaluation. The results suggest that the less clinically complex and fewer resources intense patients were associated with low readmission rates across heart failure, stroke, hip and knee, COPD, pneumonia and across the entire hospital. Other factors such as adjusted occupancy rate, major teaching hospitals, large hospitals (400 + beds), for-profit hospitals and unemployment rate on average were consistently associated with higher readmission rates.

Association between patient experience performance and 30-day hospital readmissions, controlling for MU patient engagement and care coordination

Lastly, the study also tested the hypothesis that on average, an increase in hospital's performance on patient experience measures, controlling for MU patient engagement and care coordination, will be associated with a decrease in 30-day readmission rates. The results of this analysis are presented in Table 3.4. An increase in performance on the discharge information patient experience measure, which measures whether a patient given information about what to do during their recovery at home, was associated with a statistically significant lower readmission on heart failure, stroke, pneumonia and hospital wide. For example, a one percentage point increase in performance on discharge information experience was associated with 0.04($p<0.01$) percentage point decrease in expected heart failure readmission rate, holding other factors constant. That means that if a hospital increased its performance on discharge information experience to 100%, it would expect a four-percentage-point decrease in expected heart failure readmission rate. That is a substantial reduction for a hospital with an average readmission rate of 21.96. Holding other factors constant, care transitions, which is a measure of whether patients understood their care on discharge, was also associated with lower readmission rates and this was statistically significant across all conditions evaluated, ranging from 0.03($p<0.05$) percentage point decrease in hip and knee readmission to a 0.07 ($p<0.05$) percentage points in heart failure readmissions. Like the previous analysis, other factors such as hospital size, teaching status, profit status, and unemployment rate were found to be statistical significantly associated with 30-day readmission rates. Overall, the results suggest that MU patient engagement and care coordination influences readmission through patient experience.

Discussion

Meaningful use patient engagement and care coordination measures are part of the national movement towards patient-centered care that is believed to serve the patient better, has the potential of improving outcomes and eventually reduce overall healthcare cost. This study was designed to evaluate the association of these measures and their pathway to patient outcomes.

Performance on meaningful use patient engagement and care coordination objectives and patient experience

The question whether an increase in a hospital's performance on MU patient engagement and care coordination measures are associated with an increase in performance on patient experience is essential as it goes to the core of meaningful use. Overall, there is evidence that patient engagement and care coordination measures are associated with an increase in some aspects of patient experience. It appears that patients who viewed, downloaded and transmitted their health records reported to have a better experience and were likely to recommend the hospital to their family and friends. This is good news for hospitals that are currently being faced with value-based care program that require them to improve their patient experience or face a penalty. While the average performance on these measures is low, such VDT, it is a promising sign. For hospitals, the positive results indicate an opportunity area where they can encourage more patient to access their health records if the portals are already functional. This might prove a low hanging fruit given the potential effect on the patient experience. In addition, previous research has suggested that patient portals particularly, can optimize patient value and increase patient engagement[55]. Another study reviewed the effects of patient portals and found that, among others, they were associated with increased patient satisfaction and customer retention[56].

Association between meaningful use patient engagement and care coordination performance and 30-day readmissions

We did not find enough evidence to support the hypothesis that an increase in a hospital's performance on MU patient engagement and care coordination will be associated with lower 30-day readmission rates. The results are in line with previous systematic review results that found a weak link between patient access to their health records and medical outcomes[56]. This is largely in line with previous studies that suggest that hospital readmissions are associated with factors such as social-economic factors other than hospital quality[57-61]. Therefore, hospitals there are incentives to seek ways to improve on these factors. It is also important for policymakers to look at these other factors before they penalize hospitals under the MU and VBP programs. This is even critical for hospitals that serve the low-income or vulnerable population, such as safety net and academic hospitals that have been found to be more likely to face penalties[57, 62].

<u>Association between patient experience performance and 30-day hospital readmissions, controlling for MU patient engagement and care coordination</u>

The study found some evidence to support the hypothesis that an increase in hospital's performance on patient experience measures, controlling for MU patient engagement and care coordination, will be associated with a decrease in 30-day readmission rates. The results suggested that patient engagement and care coordination aspects of meaningful use influenced hospital readmissions through patient experience. The results support previous research findings that improved patient experience led to a reduction in unplanned hospital readmissions. For example, several studies have found a positive correlation between patient experience and patient outcomes in general and hospital readmission specifically[16-19]. In addition, other studies have shown an association between patient experience and patient adherence to medical recommendations[63, 64]. Furthermore, a review of published evidence on effective interventions to reduce avoidable readmissions by Boutwell A. and colleagues found that successful interventions fell into four broad categories including enhanced care and support during transitions and improved patient education and self-management support [14]. These categories are likely to be affected by higher performance MU patient engagement and care coordination. This implies that for hospitals policymakers, the way to reduce unplanned readmissions may come down to among others, improving patient engagement and care coordination. But also making sure hospitals are not penalized for measures that are out of their control.

<u>Limitations</u>

The association of these factors with the patient experience and hospital readmissions also point to one of the weaknesses of this study. While the primary outcome measures are risk-adjusted, and care was taken to control for both hospital and community level factors such as case mix index, Saidin Index, adjusted occupancy rates, hospital size, teaching status, unemployment, location among others, there is a possibility that patient experience and readmissions are still influenced by unobservable social economic and generally patient characteristics factors. Also, policy interventions such as MU and utilization of EHRs achieve what is referred to as diffuse effects. Diffuse effects refer to the impact of a service, structural change or intervention on several clinical processes within an institution [65]. In other words, it is harder to link these interventions directly to specific outcomes. Another limitation of the study is due to the categorization of the major teaching hospitals and safety net hospitals. While we believe, the classification in this paper is appropriate others might prefer a different method. Lastly, this study was limited to hospitals that participated in CMS' IPPS, as such might not be generalizable to exempted hospitals, such as children and cancer hospitals.

Conclusion

This study's primary objectives were to determine a) Whether performance in meaningful use patient engagement and care coordination core objectives is associated with improved patient experience, b). Whether performance on meaningful use patient engagement, care coordination core objective is associated with reduced 30-day hospital readmissions, and finally c.) Whether patient experience performance is associated with reduced 30-day hospital readmission rate, controlling for MU patient engagement and care coordination. The results indicate that, in general, performance in MU patient engagement and care coordination was associated with improved patient experience such as medicine communication, discharge information, pain management, nurse communication, and overall patient experience. However, there was not enough evidence support the idea that performance in patient engagement and care coordination were associated with reduced readmission. Instead, evidence from our analysis indicated that patient engagement and care coordination domains are associated with reduced readmissions through improved patient experience. This study also confirmed previous studies, especially on readmissions, that demographic, hospital level and general social-economic factors are critical in predicting the risk of readmissions [58, 59, 61, 66-68]. In addition, the study revealed new information on the possible effects of adjusted occupancy rate on patient experience and readmission. Overall, the results of this study suggest that improving patient engagement and care coordination, while it will not benefit every patient experience and readmission, have the potential to transform care delivery toward a direction of patient-centered care.

The study added our understanding to what is possible under meaningful use patient engagement and care coordination. However, it also revealed persistent argument against measures such as readmissions. Going forward, it is important to review measures that might unfairly penalize hospitals for issues out of their control. However, for hospitals, there is a glimmer of hope that is using successful implementing and meaningfully using EHRs to help engage patients and coordinate care, may result in improvement on patient experience and readmission. Moreover, this improvement will move the hospital in the direction of providing patient-centered care and avoiding penalties under programs such as VBP and HRRP.

Chapter 3 Tables

Table 3.1: Summary statistics					
Dependent variables	Obs	Mean	Std dev	Min	Max
Medicine communication	3544	78.68	4.27	61	98
Discharge information	3544	86.64	3.65	62	99
Pain management	3544	87.52	2.56	64	100
Nurse communication	3544	91.22	2.55	66	100
Overall hospital rating	3544	88.59	3.25	69	98
Recommend hospital	3329	87.75	4.25	62	100
30-day heart failure readmission rate	3660	21.96	1.50	16.30	31.30
30-day stroke readmission rate	2611	12.57	1.07	9.10	17.70
30-day hip & knee readmission rate	2736	4.61	0.55	2.40	7.80
30-day COPD readmission rate	3657	20.00	1.27	15.90	26.10
30-day pneumonia readmission rate	4096	17.11	1.44	12.90	24.70
30-day hospital wide readmission rate	4402	15.58	0.83	10.80	19.90
Independent variables	**Obs**	**Mean**	**Std dev**	**Min**	**Max**
Patient eAccess: Patients who VDT	3517	14.34	13.78	0.01	100
Patient-specific education resources	3555	80.09	23.67	10.11	100
Medication reconciliation	3555	90.71	11.16	50.19	100
Health information exchange	3555	52.60	32.39	10.04	100
Continues control variables	**Obs**	**Mean**	**Std dev**	**Min**	**Max**
EHRs stage 0 years if still on stage 0	481	5.24	2.06	1	8
EHRs stage 1 years if still on stage 1	839	4.49	2.24	1	8
EHRs stage 2 years if still on stage 2	1988	3.88	2.16	1	8
EHRs stage 3 years if still on stage 3	1195	2.04	1.02	1	4
EHRs stage 4 years if still on stage 4	439	1.94	1.09	1	4
CPOE for laboratory orders	3555	77.92	16.66	30.83	100
CPOE for radiology orders	3555	80.01	16.89	30.11	100

CPOE for medication orders	3555	84.61	11.27	60.01	100
Saidin Index	3161	13.34	7.16	0	34.23
HHI	4678	0.58	0.36	0	1
Adjusted Occupancy Rate	3137	49.74	19	0	99
CMS Case Mix Index	3424	1.52	0.36	0.65	3.98
Operating Margin	4631	2.61	0.16	-238.36	72.13
Unemployment rate	3160	6.38	1.85	0	23.6
Under 65 years old uninsured rate	3161	16.89	5.6	0	38.2
Categorical control variables					
EHRs sophistication stage	**Obs**	**Percent**			
EHRs sophistication stage 0	481	9.73			
EHRs sophistication stage 1	839	16.98			
EHRs sophistication stage 2	1,988	40.23			
EHRs sophistication stage 3	1,195	24.18			
EHRs sophistication stage 4	439	8.88			
Teaching status	**Obs**	**Percent**			
Major teaching hospital	258	8.2			
Teaching hospital	765	24.32			
Non-teaching hospital	2,121	67.48			
Hospital size	**Obs**	**Percent**			
Small hospitals (1-99 beds)	1,076	34.21			
Medium Hospitals (100-399 beds)	1,696	53.93			
Large hospitals (400 + beds)	372	11.83			
System status	**Obs**	**Percent**			
Yes	2,362	74.7			
No	798	25.25			
Magnet status	**Obs**	**Percent**			
Yes	465	9.41			
No	4,477	90.59			

Ownership	**Obs**	**Percent**			
Public	1,077	22.2			
Private, For-profit	948	19.54			
Private, Not-for-profit	2,826	58.26			
Changed ownership between 2007-2015	Obs	Percent			
Yes	324	6.56			
No	4,555	93.44			
Location	**Obs**	**Percent**			
Urban	2,337	73.93			
Rural	824	26.07			
Structural factor	**Obs**	**Percent**			
Nursing care registry	1,636	33.1			
Trauma level designation	**Obs**	**Percent**			
Trauma level 1	303	6.13			
Geographic region	Obs	Percent			
Northeast	496	15.78			
South	1,337	42.53			
Midwest	717	22.81			
West	594	18.89			

Table 3-1 Summary statistics

Table 3.2: The association between meaningful use patient engagement and care coordination domains functions and patient experience of care

	(1)	(2)	(3)	(4)	(5)	(6)
	Meds Communication	Discharge Information	Pain Management	Nurse Communication	Overall Hospital Rating	Recommend Hospital
Patient eAccess: Patients who VDT	0.02***	0.02***	0.01**	0.01**	0.01**	0.02***
	(0.01)	(0.01)	(0.00)	(0.00)	(0.01)	(0.01)
Patient-specific education resources	0.01*	0.00	-0.00	0.00	0.01**	0.01**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Medication Reconciliation	0.01	0.00	0.01***	0.01**	0.01	0.01*
	(0.01)	(0.01)	(0.00)	(0.00)	(0.01)	(0.01)
Health Information Exchange	-0.00	0.00	-0.00	-0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
EHRs stage 1	-0.15	-0.93*	-0.37	-0.36	-0.82*	-1.62***
	(0.60)	(0.52)	(0.37)	(0.35)	(0.44)	(0.59)
EHRs stage 2	-0.74	-0.72	-0.68	-0.81**	-0.92*	-1.71***
	(0.63)	(0.57)	(0.44)	(0.38)	(0.51)	(0.64)
EHRs stage 3	-0.92	-1.13*	-0.61	-0.84**	-1.12**	-1.75***
	(0.66)	(0.59)	(0.45)	(0.39)	(0.52)	(0.67)
EHRs stage 4	-0.49	-0.81	-0.54	-0.45	-0.90	-1.78**
	(0.70)	(0.62)	(0.48)	(0.42)	(0.57)	(0.73)
EHRs stage 1 years	-0.17***	0.01	-0.06**	-0.06**	-0.15***	-0.17***
	(0.05)	(0.04)	(0.03)	(0.03)	(0.04)	(0.05)
EHRs stage 2 years	-0.09*	0.05	-0.03	-0.04	-0.08**	-0.08
	(0.05)	(0.04)	(0.03)	(0.03)	(0.03)	(0.05)
EHRs stage 3 years	-0.02	0.15*	0.02	0.01	0.03	0.05
	(0.09)	(0.09)	(0.05)	(0.05)	(0.07)	(0.10)
EHRs stage 4 years	-0.03	0.15	-0.07	-0.11	-0.03	0.04
	(0.16)	(0.13)	(0.09)	(0.08)	(0.13)	(0.16)
eMAR	0.43	-0.01	0.26	0.56*	0.12	0.43
	(0.44)	(0.38)	(0.29)	(0.29)	(0.37)	(0.49)
CDSS	0.95**	0.46	0.36	0.48*	0.59*	0.84*
	(0.44)	(0.33)	(0.33)	(0.25)	(0.34)	(0.45)
Infection surveillance system	0.36***	0.19	0.20***	0.13*	0.13	0.16
	(0.13)	(0.13)	(0.07)	(0.07)	(0.10)	(0.13)

Outcome quality management system	-0.02	0.18	-0.12	-0.20*	-0.06	0.11
	(0.19)	(0.17)	(0.11)	(0.11)	(0.15)	(0.21)
CPOE for laboratory orders	-0.01*	-0.01**	-0.00	0.00	-0.01	-0.01**
	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)
CPOE for radiology orders	0.00	0.00	-0.00	-0.00	-0.00	-0.00
	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)
CPOE for medication orders	0.01	0.01	0.01**	0.01*	0.02***	0.03***
	(0.01)	(0.01)	(0.00)	(0.00)	(0.01)	(0.01)
Operating margin	0.04***	0.02***	0.02***	0.02***	0.03***	0.03***
	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)
Wage index	-1.51***	-1.57***	-0.68**	-1.36***	-1.44***	-1.63***
	(0.56)	(0.48)	(0.29)	(0.31)	(0.43)	(0.56)
CMS Case Mix Index	2.35***	2.63***	1.45***	1.56***	2.87***	4.44***
	(0.32)	(0.28)	(0.17)	(0.17)	(0.25)	(0.35)
Saidin Index	-0.02	-0.01	-0.02***	-0.02***	-0.03***	-0.03***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
HHI	0.54**	0.29	-0.24*	0.08	-0.57***	-1.06***
	(0.23)	(0.23)	(0.13)	(0.13)	(0.18)	(0.25)
Adjusted Occupancy Rate	-0.03***	-0.02***	-0.01***	-0.02***	-0.01***	-0.01
	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
Magnet Designated Hospital	0.66***	0.48***	0.51***	0.52***	0.91***	1.18***
	(0.17)	(0.17)	(0.09)	(0.09)	(0.13)	(0.17)
Trauma level 1 Hospital	-0.26	-0.34	-0.32**	-0.16	-0.21	-0.36
	(0.22)	(0.23)	(0.13)	(0.13)	(0.17)	(0.23)
Nursing Care Registry	0.87***	0.74***	0.41***	0.45***	0.48***	0.63***
	(0.16)	(0.13)	(0.09)	(0.09)	(0.12)	(0.16)
Major teaching hospital	-0.54*	-0.77***	-0.95***	-0.57***	-0.63***	-0.82***
	(0.28)	(0.27)	(0.16)	(0.17)	(0.21)	(0.28)
Teaching hospital	-0.31**	-0.33**	-0.24***	-0.14	-0.32***	-0.43***
	(0.16)	(0.14)	(0.09)	(0.09)	(0.12)	(0.16)
Safety net hospital	0.09	-0.60***	-0.38***	-0.46***	-0.47***	-0.96***
	(0.18)	(0.17)	(0.10)	(0.10)	(0.13)	(0.18)
Medium-size hospital (100-399 beds)	-2.11***	-1.34***	-0.88***	-1.02***	-1.28***	-1.28***
	(0.19)	(0.15)	(0.11)	(0.10)	(0.15)	(0.19)

Large hospital (400+ beds)	-2.36***	-1.83***	-0.83***	-1.01***	-1.24***	-0.89***
	(0.28)	(0.26)	(0.16)	(0.16)	(0.23)	(0.30)
Standalone hospital	-0.00	0.21*	-0.01	-0.06	0.04	-0.04
	(0.14)	(0.13)	(0.08)	(0.08)	(0.10)	(0.14)
For profit	-1.15***	-0.83***	-0.94***	-1.02***	-0.94***	-1.56***
	(0.19)	(0.15)	(0.11)	(0.11)	(0.13)	(0.18)
Government	-0.19	-0.29	0.00	-0.09	-0.04	0.01
	(0.18)	(0.18)	(0.11)	(0.11)	(0.14)	(0.19)
Change of ownership	-0.34*	0.09	-0.02	-0.16	-0.53***	-0.63***
	(0.20)	(0.19)	(0.13)	(0.12)	(0.16)	(0.21)
Change of ownership count	0.01	-0.00	-0.03	-0.01	-0.05	-0.09**
	(0.04)	(0.04)	(0.03)	(0.02)	(0.03)	(0.04)
Medicaid expansion state	-0.51***	-0.70***	-0.28***	-0.29***	-0.62***	-0.36*
	(0.17)	(0.15)	(0.10)	(0.10)	(0.14)	(0.18)
Unemployment Rate	-0.14***	-0.19***	-0.07**	-0.03	-0.11***	-0.26***
	(0.05)	(0.04)	(0.03)	(0.03)	(0.04)	(0.05)
Below 65 Uninsured	-0.09***	-0.19***	-0.05***	-0.07***	-0.07***	-0.07***
	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)
Rural Hospital	0.55***	0.26	0.34***	0.25**	-0.09	-0.55***
	(0.20)	(0.17)	(0.12)	(0.10)	(0.15)	(0.20)
South	0.56**	0.76***	0.22*	0.13	1.07***	0.93***
	(0.22)	(0.21)	(0.13)	(0.12)	(0.18)	(0.24)
Midwest	0.91***	0.73***	0.29*	-0.03	1.12***	0.99***
	(0.27)	(0.24)	(0.15)	(0.15)	(0.21)	(0.28)
West	1.01***	1.61***	0.14	-0.34**	0.97***	0.86***
	(0.27)	(0.25)	(0.15)	(0.15)	(0.21)	(0.29)
Constant	78.76***	89.05***	87.23***	91.71***	87.82***	85.27***
	(1.36)	(1.15)	(0.82)	(0.76)	(1.10)	(1.42)
N	2406	2406	2406	2406	2406	2406
R^2	0.2932	0.3451	0.2995	0.3447	0.3606	0.4170

Table 3-2: The association between MU patient engagement, care coordination activities and patient experience

Standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 3.3: Association between meaningful use performance on patient engagement and care coordination domains and hospital readmission rates

	(1)	(2)	(3)	(4)	(5)	(6)
	Heart failure readmission rate	Stroke readmission rate	Hip & Knee readmission rate	COPD readmission rate	Pneumonia readmission rate	Hospital-wide readmission rate
Patient eAccess: Patients who VDT	0.00	-0.00	0.00	-0.00	0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Patient-specific education resources	0.00**	0.00	0.00	0.00	0.00*	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Medication Reconciliation	0.00	-0.00	-0.00	-0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Health Information Exchange	-0.00	0.00	0.00	0.00***	0.00	0.00**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
EHRs stage 1	0.07	-0.06	-0.11	-0.04	-0.06	-0.13
	(0.25)	(0.17)	(0.11)	(0.24)	(0.29)	(0.14)
EHRs stage 2	0.12	-0.14	0.07	-0.06	-0.44	-0.20
	(0.26)	(0.22)	(0.11)	(0.27)	(0.32)	(0.20)
EHRs stage 3	-0.08	-0.18	0.12	-0.15	-0.49	-0.28
	(0.28)	(0.23)	(0.12)	(0.28)	(0.34)	(0.20)
EHRs stage 4	-0.12	-0.21	0.19	-0.16	-0.79**	-0.34
	(0.32)	(0.25)	(0.13)	(0.31)	(0.37)	(0.22)
EHRs stage 1 years	-0.00	0.00	-0.00	0.01	-0.03	-0.00
	(0.03)	(0.02)	(0.01)	(0.02)	(0.02)	(0.01)
EHRs stage 2 years	-0.05*	0.02	-0.01	0.01	-0.04	-0.00
	(0.03)	(0.02)	(0.01)	(0.02)	(0.02)	(0.01)
EHRs stage 3 years	-0.02	-0.02	-0.06***	-0.01	-0.08*	-0.04
	(0.06)	(0.03)	(0.02)	(0.05)	(0.05)	(0.03)
EHRs stage 4 years	-0.05	0.04	-0.11***	-0.00	0.06	-0.01
	(0.09)	(0.06)	(0.04)	(0.08)	(0.09)	(0.05)
eMAR	0.12	0.07	-0.17**	-0.03	0.57**	0.14
	(0.20)	(0.15)	(0.07)	(0.17)	(0.24)	(0.15)
CDSS	0.21	0.12	-0.09	-0.06	0.31	-0.05
	(0.19)	(0.10)	(0.07)	(0.16)	(0.20)	(0.11)
Infection surveillance system	-0.11	-0.07	-0.01	-0.03	-0.13*	-0.05

	(0.07)	(0.04)	(0.03)	(0.06)	(0.07)	(0.04)
Outcome quality management system	-0.01	0.10*	0.01	0.07	-0.07	-0.05
	(0.10)	(0.06)	(0.04)	(0.08)	(0.10)	(0.05)
CPOE for laboratory orders	0.01**	-0.00	-0.00	0.00	0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
CPOE for radiology orders	-0.01**	0.00	0.00**	-0.00	-0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
CPOE for medication orders	0.00	-0.00	0.00	-0.00	-0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Operating margin	0.00	0.00	-0.00	-0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Wage index	-0.35	0.25	-0.03	0.45*	-0.25	0.24
	(0.29)	(0.17)	(0.11)	(0.24)	(0.30)	(0.15)
CMS Case Mix Index	-1.61***	-0.82***	-0.56***	-1.19***	-0.90***	-0.76***
	(0.20)	(0.13)	(0.08)	(0.17)	(0.20)	(0.11)
Saidin Index	-0.01**	-0.01	-0.00*	-0.01	-0.00	-0.01*
	(0.01)	(0.00)	(0.00)	(0.01)	(0.01)	(0.00)
HHI	-0.36***	-0.29***	0.02	-0.11	-0.04	-0.02
	(0.13)	(0.08)	(0.05)	(0.11)	(0.13)	(0.07)
Adjusted Occupancy Rate	0.01***	0.01***	0.00***	0.01***	0.01***	0.01***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Magnet Designated Hospital	-0.39***	0.03	-0.03	0.05	-0.14	-0.09
	(0.10)	(0.07)	(0.04)	(0.09)	(0.09)	(0.06)
Trauma level 1 Hospital	0.13	0.06	0.02	-0.14	-0.22*	-0.09
	(0.14)	(0.10)	(0.06)	(0.11)	(0.13)	(0.08)
Nursing Care Registry	-0.12	-0.13**	0.02	0.07	-0.00	-0.06
	(0.08)	(0.05)	(0.03)	(0.07)	(0.08)	(0.04)
Major teaching hospital	0.65***	0.51***	0.09	0.25*	0.81***	0.80***
	(0.17)	(0.11)	(0.07)	(0.14)	(0.16)	(0.09)
Teaching hospital	-0.02	0.09	0.04	0.11	-0.06	0.00
	(0.09)	(0.06)	(0.03)	(0.08)	(0.08)	(0.05)
Safety net hospital	0.41***	0.11*	0.02	0.09	0.24***	0.21***
	(0.09)	(0.06)	(0.04)	(0.08)	(0.09)	(0.05)
Medium-size hospital (100-399 beds)	0.17	0.05	0.07**	0.28***	0.39***	0.27***
	(0.10)	(0.06)	(0.04)	(0.09)	(0.10)	(0.06)

Large hospital (400+ beds)	0.44***	0.39***	0.13**	0.72***	0.66***	0.38***
	(0.16)	(0.11)	(0.06)	(0.14)	(0.16)	(0.09)
Standalone hospital	-0.05	-0.01	-0.07***	-0.04	-0.01	-0.02
	(0.08)	(0.05)	(0.03)	(0.07)	(0.07)	(0.04)
For-profit	0.38***	0.19***	0.12***	0.28***	0.31***	0.25***
	(0.09)	(0.06)	(0.04)	(0.08)	(0.10)	(0.05)
Government	-0.01	-0.01	0.10**	-0.00	0.02	0.02
	(0.10)	(0.06)	(0.04)	(0.08)	(0.10)	(0.05)
PN Mortality rate	0.05***	0.01	0.00	0.05***	0.09***	0.03***
	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)
HF Mortality rate	-0.02	-0.04**	-0.02**	-0.01	-0.09***	-0.03*
	(0.03)	(0.02)	(0.01)	(0.02)	(0.03)	(0.01)
COPD Mortality rate	-0.06**	-0.04**	-0.03**	0.07**	-0.04	-0.03*
	(0.03)	(0.02)	(0.01)	(0.03)	(0.03)	(0.01)
Stroke mortality rate	-0.05**	-0.02	0.02*	-0.02	-0.05**	-0.02
	(0.02)	(0.01)	(0.01)	(0.02)	(0.02)	(0.01)
Change of ownership (2007-2015)	-0.03	-0.10	0.07	0.16	-0.10	-0.09
	(0.12)	(0.07)	(0.05)	(0.10)	(0.13)	(0.06)
Change of ownership count	0.05*	0.02	-0.02*	0.03	0.01	0.01
	(0.02)	(0.01)	(0.01)	(0.02)	(0.02)	(0.01)
Medicaid expansion state	0.40***	0.05	-0.08**	0.14*	0.43***	0.13***
	(0.10)	(0.06)	(0.04)	(0.08)	(0.09)	(0.05)
Unemployment Rate	0.11***	0.06***	0.01*	0.07***	0.14***	0.07***
	(0.02)	(0.02)	(0.01)	(0.02)	(0.02)	(0.01)
Below 65 Uninsured	0.01	0.01**	-0.01**	-0.02***	-0.00	0.01***
	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)	(0.00)
Rural Hospital	-0.11	0.03	-0.08**	-0.27***	-0.06	-0.11**
	(0.11)	(0.06)	(0.04)	(0.09)	(0.11)	(0.06)
South	-0.05	0.10	0.10**	-0.05	0.09	-0.15**
	(0.14)	(0.08)	(0.05)	(0.10)	(0.13)	(0.07)
Midwest	-0.09	0.06	0.16***	-0.13	0.02	-0.13
	(0.16)	(0.09)	(0.05)	(0.11)	(0.15)	(0.08)
West	-0.59***	-0.28***	0.03	-0.48***	-0.60***	-0.64***
	(0.16)	(0.09)	(0.05)	(0.12)	(0.15)	(0.08)
Constant	23.03***	13.66***	5.58***	20.22***	17.09***	15.76***

	(0.78)	(0.49)	(0.31)	(0.66)	(0.80)	(0.42)
N	2072	2040	1852	2072	2072	2072
R^2	0.2086	0.1814	0.1097	0.1548	0.2037	0.2926

Table 3-3: Association between MU patient engagement, care coordination activities and hospital readmission

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 3. 4: Association between the patient experience of care and hospital readmission controlling for meaningful use performance on patient engagement and care coordination domains.

	(1)	(2)	(3)	(4)	(5)	(6)
	Heart failure readmission rate	Stroke readmission rate	Hip & Knee Readmission rate	COPD readmission rate	Pneumonia readmission rate	Hospital-wide readmission rate
Nurse Communication	-0.02	-0.05**	0.00	0.05	0.04	0.03
	(0.04)	(0.02)	(0.02)	(0.03)	(0.04)	(0.02)
Doctor Communication	-0.03	0.05***	-0.00	-0.03	0.01	-0.04***
	(0.03)	(0.02)	(0.01)	(0.02)	(0.03)	(0.01)
Pain Management	-0.01	-0.00	-0.01	-0.01	-0.02	-0.03*
	(0.03)	(0.02)	(0.01)	(0.03)	(0.03)	(0.02)
Meds Communication	0.02	0.02**	0.01	0.02	0.00	0.02**
	(0.02)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)
Discharge Information	-0.04***	-0.02**	-0.00	-0.02	-0.03**	-0.02**
	(0.02)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Recommend Hospital	-0.01	-0.00	0.00	-0.00	-0.04**	-0.00
	(0.02)	(0.01)	(0.01)	(0.02)	(0.02)	(0.01)
Care Transition	-0.07**	-0.04**	-0.03**	-0.05*	-0.05*	-0.05***
	(0.03)	(0.02)	(0.01)	(0.03)	(0.03)	(0.02)
Patient eAccess: Patients who VDT	0.00	-0.00	0.00	-0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Patient-specific education resources	0.00**	0.00	0.00	0.00	0.00*	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Medication Reconciliation	0.01	-0.00	-0.00	-0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Health Information Exchange (HIE)	-0.00	0.00	0.00	0.00***	0.00	0.00**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
EHRs stage 1	-0.07	-0.18	-0.12	-0.10	-0.08	-0.21*
	(0.26)	(0.17)	(0.11)	(0.22)	(0.29)	(0.13)
EHRs stage 2	0.09	-0.38	0.05	-0.13	-0.47	-0.27
	(0.28)	(0.23)	(0.11)	(0.26)	(0.33)	(0.19)
EHRs stage 3	-0.13	-0.39	0.11	-0.24	-0.55	-0.36*

	(0.29)	(0.24)	(0.12)	(0.27)	(0.35)	(0.20)
EHRs stage 4	-0.13	-0.43*	0.19	-0.31	-0.88**	-0.36*
	(0.33)	(0.26)	(0.13)	(0.30)	(0.38)	(0.22)
EHRs stage 1 years	0.00	0.00	-0.00	0.01	-0.04	-0.01
	(0.03)	(0.01)	(0.01)	(0.02)	(0.02)	(0.01)
EHRs stage 2 years	-0.05**	0.02	-0.01	0.00	-0.04	-0.00
	(0.03)	(0.01)	(0.01)	(0.02)	(0.02)	(0.01)
EHRs stage 3 years	-0.01	-0.03	-0.06***	-0.01	-0.08*	-0.02
	(0.05)	(0.03)	(0.02)	(0.05)	(0.05)	(0.03)
EHRs stage 4 years	-0.05	0.04	-0.11***	0.01	0.06	-0.03
	(0.08)	(0.06)	(0.04)	(0.07)	(0.09)	(0.05)
eMAR	0.10	0.18	-0.16**	0.02	0.55**	0.11
	(0.21)	(0.16)	(0.08)	(0.17)	(0.26)	(0.15)
CDSS	0.29	0.12	-0.07	0.01	0.33	0.09
	(0.20)	(0.12)	(0.08)	(0.17)	(0.21)	(0.11)
Infection surveillance system	-0.08	-0.07*	0.00	-0.01	-0.10	-0.03
	(0.07)	(0.04)	(0.03)	(0.06)	(0.07)	(0.04)
Outcome quality management system	0.00	0.11*	0.01	0.09	-0.04	-0.05
	(0.10)	(0.05)	(0.04)	(0.08)	(0.10)	(0.05)
CPOE for laboratory orders	0.01*	-0.00**	-0.00	0.00	0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
CPOE for radiology orders	-0.01**	0.00*	0.00*	-0.00	-0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
CPOE for medication orders	0.00	-0.00	0.00	-0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Operating margin	0.01	0.00	0.00	0.00	0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Wage index	-0.51*	0.20	-0.08	0.45*	-0.35	0.11
	(0.29)	(0.18)	(0.11)	(0.24)	(0.31)	(0.14)
CMS Case Mix Index	-1.38***	-0.70***	-0.51***	-1.03***	-0.59***	-0.62***
	(0.20)	(0.13)	(0.09)	(0.18)	(0.20)	(0.11)
Saidin Index	-0.01**	-0.01**	-0.00*	-0.01	-0.00	-0.00*
	(0.01)	(0.00)	(0.00)	(0.01)	(0.01)	(0.00)

HHI	-0.34**	-0.29***	0.01	-0.15	-0.05	-0.02
	(0.14)	(0.08)	(0.05)	(0.11)	(0.13)	(0.07)
Adjusted Occupancy Rate	0.01***	0.01***	0.00***	0.01***	0.01***	0.01***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Magnet Designated Hospital	-0.34***	0.09	-0.03	0.04	-0.07	-0.06
	(0.10)	(0.07)	(0.04)	(0.09)	(0.09)	(0.05)
Trauma level 1 Hospital	0.08	0.02	0.02	-0.15	-0.30**	-0.14*
	(0.14)	(0.10)	(0.06)	(0.11)	(0.12)	(0.07)
Nursing Care Registry	-0.07	-0.09*	0.03	0.07	0.07	-0.04
	(0.08)	(0.05)	(0.03)	(0.07)	(0.08)	(0.04)
Major teaching hospital	0.51***	0.44***	0.09	0.31**	0.78***	0.77***
	(0.17)	(0.10)	(0.07)	(0.14)	(0.16)	(0.09)
Teaching hospital	-0.08	0.07	0.04	0.10	-0.09	-0.03
	(0.09)	(0.06)	(0.03)	(0.08)	(0.08)	(0.05)
Safety net hospital	0.32***	0.07	0.01	0.10	0.22**	0.16***
	(0.09)	(0.06)	(0.04)	(0.08)	(0.09)	(0.05)
Medium-size hospital (100-399 beds)	0.07	0.03	0.05	0.25***	0.28***	0.20***
	(0.10)	(0.06)	(0.04)	(0.09)	(0.10)	(0.05)
Large hospital (400+ beds)	0.39**	0.37***	0.10	0.63***	0.58***	0.32***
	(0.16)	(0.11)	(0.07)	(0.14)	(0.16)	(0.09)
Standalone hospital	-0.04	-0.01	-0.07**	-0.02	-0.00	-0.02
	(0.07)	(0.04)	(0.03)	(0.07)	(0.07)	(0.04)
For profit	0.19**	0.10	0.08**	0.19**	0.14	0.17***
	(0.10)	(0.06)	(0.04)	(0.08)	(0.10)	(0.05)
Government	0.02	-0.02	0.10**	-0.02	-0.00	0.03
	(0.10)	(0.06)	(0.04)	(0.08)	(0.10)	(0.05)
PN Mortality rate	0.05***	0.01	-0.00	0.04***	0.09***	0.03***
	(0.02)	(0.01)	(0.01)	(0.02)	(0.02)	(0.01)
HF Mortality rate	0.00	-0.03*	-0.02*	0.00	-0.08***	-0.02
	(0.03)	(0.02)	(0.01)	(0.02)	(0.03)	(0.01)
COPD Mortality rate	-0.07**	-0.05***	-0.03***	0.06**	-0.05	-0.03**
	(0.03)	(0.02)	(0.01)	(0.03)	(0.03)	(0.01)
Stroke mortality rate	-0.06***	-0.02	0.01	-0.02	-0.06**	-0.02
	(0.02)	(0.01)	(0.01)	(0.02)	(0.02)	(0.01)

Change of ownership (2007-2015)	-0.07	-0.12*	0.07	0.19*	-0.17	-0.13**
	(0.12)	(0.07)	(0.05)	(0.10)	(0.13)	(0.06)
Change of ownership count	0.04*	0.02	-0.02*	0.02	0.01	0.00
	(0.02)	(0.02)	(0.01)	(0.02)	(0.02)	(0.01)
Medicaid expansion state	0.30***	0.02	-0.09**	0.12	0.37***	0.08
	(0.10)	(0.06)	(0.04)	(0.08)	(0.09)	(0.05)
Unemployment Rate	0.08***	0.06***	0.01	0.06***	0.11***	0.06***
	(0.02)	(0.02)	(0.01)	(0.02)	(0.02)	(0.01)
Below 65 Uninsured	-0.00	0.00	-0.01***	-0.02***	-0.01*	0.00
	(0.01)	(0.01)	(0.00)	(0.01)	(0.01)	(0.00)
Rural Hospital	-0.09	0.01	-0.07*	-0.23**	-0.06	-0.10*
	(0.11)	(0.06)	(0.04)	(0.10)	(0.11)	(0.06)
South	0.05	0.08	0.11**	-0.02	0.18	-0.08
	(0.14)	(0.08)	(0.05)	(0.10)	(0.13)	(0.07)
Midwest	-0.00	0.07	0.17***	-0.08	0.12	-0.06
	(0.16)	(0.09)	(0.06)	(0.12)	(0.15)	(0.08)
West	-0.49***	-0.27***	0.05	-0.46***	-0.45***	-0.57***
	(0.16)	(0.10)	(0.06)	(0.13)	(0.15)	(0.08)
Constant	37.58***	18.40***	8.70***	23.80***	24.79***	24.56***
	(2.57)	(1.65)	(1.08)	(2.22)	(2.53)	(1.41)
N	2068	2036	1850	2068	2068	2068
R^2	0.2357	0.2052	0.1146	0.1546	0.2279	0.3251

Table 3-4: Association between patient experience and hospital readmission

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

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CHAPTER 4: DETERMINING THE EFFECTS OF ELECTRONIC HEALTH RECORDS (EHRS) SOPHISTICATION ON HOSPITAL PROFITABILITY

Introduction

Acute care hospitals across the nation have moved to rapidly to adopt and implement Electronic Health Records (EHR) in the last decade. The percentage of hospitals with at least a basic EHR system rose from 9.4% in 2008 to 83.8% in 2015 [1]. In 2015, 96% of the hospitals with a basic EHR system reported possessing a certified EHR [1]. The adoption and implementation growth, in part, can be attributed to the incentives and penalties included in the 2009 Health Information Technology for Economic and Clinical Health (HITECH) Act [2]. As of August 2016, the Centers for Medicare and Medicaid Services (CMS) had paid over $34.7 billion to over 508,000 providers under the incentive program to encourage hospitals and other providers to "adopt, implement and meaningfully use of EHRs" [3]. This is good news for patients and the nation as whole because the EHRs' potential to improve health care quality and cut cost. However, EHR systems can cost individual hospitals millions of dollars[4-6].

Financial performance is major challenge hospitals face as they react to new policies and reimbursement incentives. Some hospitals struggle to keep afloat while others are worried of the changing policy and market landscape that might put them at risk of closure. The investment in EHRs can negatively impact hospitals' financial performance or, alternatively, increase profitability by supporting superior health services, increasing revenue, reducing costs, and eliminating waste. Whether EHRs improve hospital profitability is unclear as several factors make it challenging to estimate the impact of EHRs on financial performance in acute care hospitals[7-9]. First, there is a potential confounding effect of unobservable factors such as hospital and patient characteristics.

Second, few hospitals measure the impact of EHRs at all. Only 40% of hospitals measure the impact of EHRs, and 35% of those are not happy with their measures, according to a recent survey of healthcare executives by Beacon Partners, a Boston-based healthcare consulting firm [10].

Nevertheless, EHRs are not all created equally; there is tremendous variability level of sophistication. This study defines sophistication based on early work and an adaptation of the HIMSS EMR Adoption Model[11, 12]. Largely there are two dimensions of EHRs sophistication: (1) capabilities offered (sophisticated versus basic), and (2) integration of applications. A hospital is considered to be on the lowest EHRs sophistication level; EHRs stage 0 if it has not adopted and implemented one or more of the laboratory, radiology or pharmacy systems. It is considered on Stage 1 if it has implemented laboratory, radiology, pharmacy and clinical data repository (CDR), but not necessarily integrated. Therefore, for a hospital to be considered to be on the highest level of EHRs sophistication, it must have implemented systems comprising laboratory, radiology, pharmacy, CDR, nursing documentation, electronic medication administration record (eMAR), Clinical Decision Support Systems (CDSS), Computerized Provider Order Entry (CPOE) and physician documentation. More importantly, eMAR must include closed loop medication administration, in addition to the hospital having implemented electronic transactions to share data and integrated the picture archiving and communication system (PACS). In other words, the hospital at this stage is entirely paperless, and its critical systems are integrated, and therefore more likely to reap financial benefits from revenue gains, cutting cost or both.

The EHRs categorization used in this study, even though developed over the years before, is similar to the meaningful use framework that required hospitals progressively attest to and meaningfully use EHRs. For example, under the meaningful use regulations, participating hospitals are required to attest to their EHRs capabilities: In Stage 1, hospitals were required to attest to data capture and sharing, Stage 2, attest to advanced clinical processes capabilities and in Stage 3 attest to the applications of EHRs to improve outcomes [13]. The difference between the two, though, is that meaningful use requires the use of the systems i.e. it has a minimum threshold for meaningfully using the systems, while the categorization in this study just requires that the systems be implemented and be live. The core objectives of the meaningful use program, similar to the categorization of EHRs sophistication, were based on the theory that as hospitals adopt and implement more EHRs that are sophisticated; they will begin to realize "the true potential of EHRs to improve the safety, quality, and efficiency of care."[14] Hospital profitability is a possible outcome of the adoption, implementation and meaningful use of sophisticated EHRs.

Therefore, the purpose of this study is to examine the impact of EHR sophistication on hospital financial performance. Specifically, the aims are to:

a. Estimate the effects of EHRs sophistication on hospital profitability, i.e. operating margin;
b. Determine whether hospitals that have more years of experience with sophisticated EHRs also perform better on operating margin.
c. Investigate the pathways by which EHRs sophistication impacts operating margin by:
    i. estimating the effects of EHRs sophistication on hospital adjusted operating revenue per inpatient day, and
    ii. assessing the effects of EHRs sophistication on hospital adjusted operating expense per inpatient day;
d. Determine whether hospitals those have more years of experience with sophisticated EHRs also perform better in adjusted operating revenue, and expenses per inpatient day.

Understanding the impact of EHR sophistication on hospital financial performance is important because of policy and practical reasons. First, a recent systematic review concluded that "although health information technology (HIT) interventions are associated with financial effects, including cost savings and revenue gains, there are a few articles on this topic, especially ones with strong study designs and financial analyses" [15]. There are even fewer articles focusing on inpatient care and EHRs sophistication. The authors call for more research in this area, especially under the emerging trends in health care delivery – e.g., value-based purchasing, bundled payments [16, 17] – which require hospitals to report electronically massive amounts of data and face penalties if they do not perform on key metrics.

Second, hospital financial performance has health care quality, access and economic implications on communities across the country. Studies have shown that there is a link between financial performance and quality of care[18-21]. Often, hospitals under distress lay off employees and reduce resources allocated to quality improvement to focus on survival. The domino effects are not limited to quality concerns but also mergers and acquisition in addition to hospital closures, which may have devastating effects on the local economy [22-25] [26-29]. In other words, the financial viability of a hospital and the expected effects of EHRs sophistication on financial performance, are areas of interest to policymakers, hospital administrators, hospital owners and communities.

Furthermore, this study will contribute to the emerging evidence on the effects of EHRs sophistication. The study utilizes a panel data analysis, which has several advantages as compared to a cross section study. These include capturing the dynamics of the healthcare environment, offer more accurate inference and control for unobservable characteristics and behavior and thereby controlling for the impact of omitted variables [30]. The study results will guide hospitals administrators in having realistic expectations on whether implementing sophisticated EHRs will bear positive results on profitability and how long it takes to see those results. Also, this study may add to the evidence to help some hospitals decide whether they should invest in a more sophisticated EHRs system, which is usually a substantial financial investment. Moreover, hospital administrators would be interested in any tool that can enhance their financial performance given pressures from payers, patients, and regulators. Sophisticated EHRs might be an instrument to cut down costs and improve operating revenue that can be reinvested in the provision of care under these circumstances.

Conceptual framework

The implementation of sophisticated EHRs is intended to provide efficient, high-value care, improve revenue cycle processes such as reducing the number of days in account receivable while minimizing costs such as labor and administrative costs. There is evidence that improving revenue cycle management can lead to higher profitability through a faster collection of revenues, reduction in operating expenses and boosting operating revenue[31].

Revenue cycle is defined as "all administrative and clinical functions that contribute to the capture, management, and collection of patient service revenue."[32] It begins from the scheduling of a patient or in some instances admission/registration, and ends with the revenue collection. Sophisticated EHRs can be a useful tool on revenue cycle management steps such as documentation, charge capture, case management, billings and claims denial management. These are areas where accurate and timely information in critical. For example, several errors such as incomplete provider orders and supporting documentation of what exactly was done, patient eligibility for the service provided or lack of medical necessity, might lead to claim denial. These are errors that sophisticated EHRs can help root out and ensure "clean claim" submission and eventual reimbursement. The efficiencies achieved because of using sophisticated EHRs have the potential of boosting the hospital revenue and reduction of administrative costs.

Also, sophisticated EHRs can be a tool to foster patient-friendly billing, enable pre-services collections and management of information flow between the hospital and the patients. This is made more relevant following the rise and the prevalence of the high-deductible health plans (HDHPs). Some hospitals have used sophisticated EHRs as a tool to transform their revenue cycle management and increase price transparency, which has had a positive return on investment [33].

Another way hospitals can boost their revenue using sophisticated EHRs is to advance health care quality and avoid penalties under pay-for-performance programs such as Hospital Value-Based Purchasing, Hospital Readmission Reduction Program, and Hospital-Acquired Condition (HAC) Reduction Program[34-36]. These programs require hospitals to not only improve overall health care quality but also report the required measures promptly. EHRs can exploit these opportunities and benefit the hospitals to gain revenue while also reducing the administrative and personnel costs associated with such programs.

Nevertheless, there are risks to implementing sophisticated EHRs, more so in the revenue cycle management. Poorly implemented sophisticated EHRs with can lead to "gross revenue losses, spikes in accounts receivable (A/R) days, and steep declines in cash flow."[37] In other words, there might be disruptions that may adversely affect revenue.

The study also hypothesizes that the more years of experience using an EHR system will enable the hospital to gain more as opposed the fewer years of experience. In summary, this study was based on the following hypotheses.

a. Other things being equal, when a hospital moves from less to the more sophisticated EHRs system, it will experience higher operating margin as opposed when the hospital stays in the less sophisticated EHRs system.
b. Other things being equal, when a hospital has greater experience, i.e., more years, in higher EHRs sophistication stages (stage 3 and 4) it will be associated with greater operating margin.
c. Other things being equal, when a hospital moves from less to the more sophisticated EHRs system; it will gain adjusted operating revenue per inpatient days as compared if it stays in a less sophisticated EHRs system.
d. Other things being equal, when a hospital moves from less to the more sophisticated EHRs system, it will reduce adjusted operating expenses per inpatient days as compared to if it stays in a less sophisticated EHRs system.
e. Other things being equal, when a hospital has greater experience, i.e., more years, in higher EHRs sophistication stages (stage 3 and 4) it will be associated with higher adjusted operating revenue and reduced operating expenses per inpatient day than when a hospital has less experience with higher sophisticated EHRs systems.

Methods

Data Sources

The financial performance data for this aim were derived from CMS' hospital cost reports (2005-2014). All Medicare-certified institutional providers, including hospitals, are required to file cost reports each year with a CMS intermediary. The report contains "provider information such as facility characteristics, utilization data, cost and charges by cost center (in total and for Medicare), Medicare settlement data, and financial statement data"[38]. The data on EHRs sophistication came from Healthcare Information and Management Systems (HIMSS) (2005-2012), through The Dorenfest Institute for Health Information database. The Dorenfest Institute provides "data, reports, white papers and other tools regarding adoption, implementation and the use of IT in hospitals and integrated healthcare delivery networks" [39].

Sample

The analysis used data from 2005 to 2012 in both the EHRs and cost report data. 32,944-hospital year observations were successfully merged. After dropping hospitals with fewer than 360 days in their cost report, and general data cleaning, we retained a sample of 30,829 (94%) hospital-year observations.

Study design

The study used a panel data analysis employing ordinary least squares with hospital and year level fixed effects. The unit of analysis was a US acute care hospital certified as Medicare institutional provider.

Measures

Dependent variables: The primary dependent variable was operating margin, which is a measure of profitability, indicating the proportion of revenue left over after the operating expenses have been paid. This is an appropriate measure since the study hypothesized that a more sophisticated EHRs would influence hospital operations and as a result profitability. Operating margin is defined as net operating revenue divided by operating revenue. The study also used two other dependent variables to estimate the pathway that a more sophisticated EHRs influenced operating margin through adjusted operating revenue and expenses per inpatient day. The study adjusted for outpatient revenue and expenses given the expected heterogeneity of the revenue mix among hospitals. The following formula was used to calculate the revenue and expenses per adjusted inpatient day:

$$\text{total inpatient days}*(1+\frac{\text{Outpatient revenue/expenses}}{\text{Inpatient revenue/expense}}).$$

All the amounts are inflation-adjusted to 2012 dollars.

Independent variables: The analytic variable was EHR sophistication, which is an ordinal variable that ranges from stage 0 to stage 4 using an adapted HIMSS EMR Adoption Model based on the complexity of the systems [11, 12]. The study defined a hospital's EHR as Stage 0 if it missed one or more of laboratory, radiology, pharmacy; Stage 1 if the hospital implemented laboratory, radiology, pharmacy and clinical data repository (CDR); Stage 2 if the hospital had attained stage 1 and implemented nursing documentation and electronic medication administration record (eMAR). A hospital was considered to be in Stage 3 if it implemented CDSS and CPOE and its eMAR included closed loop medication administration, in addition to having attained Stage 2. Finally, a hospital was in Stage 4 if it had achieved Stage 3, implemented physician documentation, electronic transactions to share data and the picture archiving and communication system (PACS) were integrated. The second analytic variable was the number of years a hospital spent in an EHR sophistication stage as earlier defined. This was to account for a possible learning curve or disruption following implementation of EHRs systems. The years range from 1 to 8 years for EHRs stages 0, 1 and 2; 1 to 5 years for stages 3; and 1 to 4 for stage 4. We also wanted to capture the overall EHRs experience that might not be captured in the years at a given stage, so we include the overall EHRs years ranging from 1 to 8 years.

Control variables: Hospital financial performance analysis, especially profitability has been a focus for hospital administrators, researchers, and creditors. Financial ratio analysis is a staple in the industry in gauging the financial health of hospitals. Other researchers have focused on determinants of hospital profitability [40, 41], characteristics of low and high performing hospitals [42, 43], financial health measures [44], while others recently have focused on the connection between EHRs and financial performance [8, 15, 45, 46]. From these and several other studies, we know that several managerial and patient mix variables, such as the age of plant, debt utilization, labor intensity, uncompensated care, Medicaid mix, subacute care mix, among others, are determinants of hospital profitability [40].

The study controlled for several measures that were expected to be determinants of hospital profitability based on the previous research above. These included patient mix variables such as Medicare inpatient mix, Medicaid mix, sub-acute mix, Intensive Care (ICU) mix, managed care (HMO) mix. These were calculated by taking the Medicare, Medicaid, sub-acute, ICU and HMO inpatient days and dividing them by the total inpatient days, respectively. The study controlled for these measures because they were possible determinants of profitability based on their resource utilization and reimbursement. Given the argument that EHRs that are more sophisticated are enablers to improved revenue cycle, the study controlled for days in patients accounts receivable. This was the number of days the hospital took to collect receivables [47]. Other measures included the age of plant, long-term debt to capital and equity financing which researchers have found to be determinants of profitability[40, 41, 48]. A lower age of plant indicates newer hospital's buildings and equipment. Long-term debt to capitalization variable measures the long-term financing mix. Equity financing variable measures the proportion of hospital's assets that is financed with equity.

We also expected hospitals, upon adopting and implementing more sophisticated EHRs, to add more employees especially Health Information Technology (HIT) specialists who might be costlier compared to regular employees. The study also controls for average salary per full-time equivalent (FTE) to account for possible regional employee cost variations. This variable was scaled by dividing it by $5,000. Also, the study controlled for labor intensity, which was defined as total FTE divided by inpatient days adjusted for outpatient visits.

For the models estimates the effects of EHRs sophistication on adjusted operating revenue and expenses per inpatient day, the study controls for two more variables, the outpatient mix, and patient deductions. The outpatient mix controls for the proportion of the patient revenue that is generated from outpatient services. It is defined as outpatient revenue divided by total patient services revenue. Patient deductions control for possible market power dynamics between payers and providers. For example, a hospital in a highly concentrated payer market might be force offer more contractual allowances which will affect its operating revenue and expenses. The patient deduction variable is calculated as total contractual allowances and discounts divided by gross total patient services revenue. Patient deduction variable enters the regression as a quadratic term. Finally, the study controlled for hospital size, medium hospital defined as hospitals with bed capacity of between 100 and 399 and large hospital with 400 and more beds, with a hospital with 100 beds or less being the referent category.

Empirical model

To estimate the effects of EHRs sophistication on hospital operating margin and whether years of experience at a given EHRs sophistication level has an effect on operating margin, the study employed the following ordinary least squares regression with time and hospital level fixed effects. The study also adjusted the standard errors for hospital level clustering.

$$y_{it} = \beta_1 x_{it1} + \beta_2 x_{it2} + \beta_3 x_{it3} + \beta_4 x_{it4} + \beta_5 x_{it5} + \beta_6 x_{it6} + a_i + u_{it} \qquad t=2005, 6, 7\ldots2012$$

<u>Equation 1</u>

Where i is for each hospital t is time. y_{it} are the dependent variables including operating margin, for each hospital across the eight years in the panel. x_{it1} is EHRs sophistication level ranging from stages 0 to stage 4, the referent category will be stage 0. x_{it2} is a vector of EHR years in each category, the referent category will be year 0 of each stage. x_{it3} is a vector of patient mix variables such as Medicare inpatient mix, Medicaid mix, subacute mix, ICU mix and managed care mix. x_{it4} is a vector of hospital financial and labor measures. These comprise liquidity indicators; current ratio, days accounts in receivable, capital structure measures; long-term debt to capital, equity financing, days, cost indicators; age of plant, average salary per FTE and labor intensity, x_{it5} is a Medicare market share. Lastly, the x_{it6} is the EHRs years of experience dummy variables.

The study employs the same regression model as in Equation 1, to determine the possible pathways by which EHRs sophistication influences operating margin, using adjusted operating revenue and expenses per inpatient day as the dependent variables. Also, the study added two control variables that were not in the previous model: outpatient mix and patient deductions.

The models are progressively built starting from the basic model i.e. regressing the EHRs sophistication stage against the dependent variable; operating margin, adjusted operating revenue and operating expenses per inpatient day, to the full model as specified in Equation 1.

Based on a Hausman test, which showed a significant difference between fixed effects and random effects results, fixed effects was selected. There are several advantages of using a fixed effects estimator and panel data. First, it helps to separate the effects of EHRs from other possible correlated factors that we usually do not observe, a challenge that has vexed previous research [49]. Second, the panel data enable us to capture the effects of EHRs over time and possibly avoid omitted variable bias.

Results

Summary statistics

Table 4.1 presents the summary statistics of the entire sample (N-30,829). The average operating margin was 2.78% with a minimum of -44.79% and a maximum of 33.34%. This suggests on average hospitals were profitable; however, some hospitals faced severe losses while others were doing well. The average hospital adjusted revenue per inpatient day was $2,371.24 with the minimum being $598.29 and maximum being $8515.20. The average hospital adjusted expenses per inpatient day were $ 2,279.07 with a minimum of $618 and a maximum of $7,541.30. On average, more than a fifth of the hospitals in the study sample was in the lowest EHR stage, meaning that these hospitals had not adopted and implemented one or more of the three systems: laboratory, radiology, pharmacy systems. Thirty-two percent of hospitals had implemented systems that were categorized as EHRs sophistication stage 1, 20.81% were on stage 2, 22.70% on stage 3, and 2.77% on stage 4.

Hospitals on stage 4 on average had been on the stage for about 1.75 years with a minimum of one year and a maximum of four years. Those on stage three averaged 2.17 years with a minimum of 1 and maximum of 5. The mean number of EHRs years of experience on stage two 2 was 2.44 with a minimum of 1 and max of 8. Similarly, stage zero and stage 1-averaged 2.57 and 2.62 years respectively, in both cases with a minimum of 1 year and a maximum of 8 years. Overall, hospitals had an average of 4 years EHRs experience.

The effects of EHRs sophistication on hospital operating margin

Table 4.2 presents results of five regression models that show the estimated effects of EHRs sophistication on operating margin. Model 1, shows the results of just the EHRs sophistication stages regressed against operating margin. Model 2 includes EHRs sophistication stages and number of years at each of the stage. Model 3 presents the full model. Models 1 to 3 are all ordinary regression models with a hospital and year level-fixed effects. Model 4 is a full model employing ordinary regression model with random effects. The study hypothesized that when a hospital moves from less to a more sophisticated EHRs system, it will experience higher operating margin as opposed when the hospital stays in the less sophisticated EHRs system. The results from Model 1 indicate that on average, a hospital moving from stage 0 to 2 is associated with a 0.70 (p<0.01) percentage point decrease in expected operating margin. On the other hand, a hospital moving from stage 0 to stage 4 is associated with a 0.69 (p<0.1) percentage point increase in expected operating margin. In Models 2 and 3, the results indicate that there is no statistical difference between a hospital in stage 0 and stages 1, 2 and 3. However, in the same models, a hospital moving from stage 0 to stage 4 is associated with negative expected operating margin, suggesting significant disruption to revenue cycle, patient care operations or both. After controlling for the number of years, a hospital is stage 4 is associated with 2.83 (p<0.01) percentage point decrease in expected operating margin. The effect decreases slightly once other factors are added to the regression in Model 3 (2.32 percentage point decrease (p<0.05)) and is consistent with the

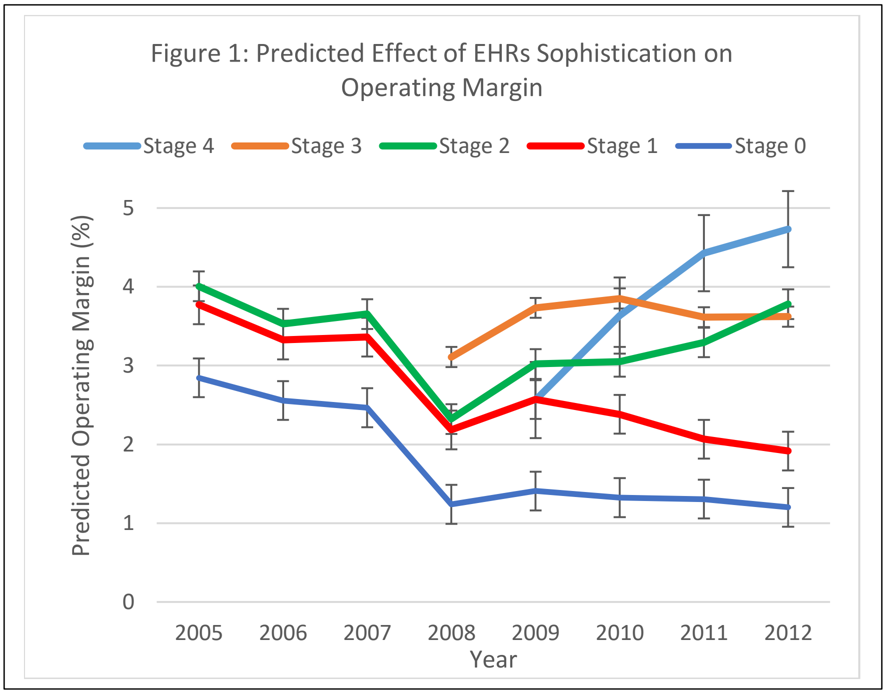

Figure 1: Predicted Effect of EHRs Sophistication on Operating Margin

random effects in Model 4 (1.91 percentage point decrease ($p<0.1$). This suggests that other factors have an influence on operating margin other than EHRs sophistication.

Figure 1 presents predicted effect of EHRs sophistication on operating margin. This strongly suggests that all things being equal, a hospital in stage 4 in 2012 was associated with 4.73 % in expected operating margin as compared to 1.20% in expected operating margin of a hospital in stage 0. Over time, it seems that stage 2 and stage 3 have a similar magnitude of effect on operating margin. In fact from Figure 1, stage 3 appears to be trending down while stage 2 is trending up. This is curious given that stage 3 is more sophisticated than stage 2. Given the results from Table 4.2 and Figure 1, it seems that hospitals face a major hurdle moving from stage 0 to stage 2. Overall, the predicted effects of EHRs sophistication on operating margin as presented in this figure suggests that other factors confound the effect of EHRs sophistication as will be highlighted below.

Effects of more years of experience with sophisticated EHRs on operating margin.

The results presented in Table 4.2 indicate that generally speaking, the longer a hospital remains in any given stage, the better a hospital's operating margin, that is except stage 1. For example, all things being equal, a hospital in stage 4 in the fourth year is associated with 5.09 ($p<0.01$) percentage points in operating margin more than a hospital in other stages (See Table 2, Model 3). This is a turn-around from a 2.32 ($p<0.01$) percentage point decrease in expected operating margin for advancing to stage 4, suggesting a disruption effect on revenue upon implementing stage 4 that dissipates over time. Further, the results show that it takes several years for some stages to see a positive effect on operating margin. For example, a hospital in stage 2 by the fifth year, is associated with a 1.17($p<0.01$) percentage point more in operating margin than a hospital in other stages. This increases to 3.31 percentage points by the eighth year. Higher stages such as stage 3 and 4 seem to take a shorter time to see a positive effect on operating margin. This suggests that there is a hurdle hospital have to get over and after that appear that they see almost immediate (after 1 year) effect on operating margin. The total number of years of EHRs experience did not seem to have an influence on operating margin. This suggests that the number of years at a given sophistication stage are better predictors of operating margin than the total number of years of EHRs experience. This probably shows that the total number of years might be diluted by the number of years in a lower EHRs sophistication stage that has less impact on the operating margin.

The pathways by which EHRs sophistication impacts operating margin

Table 4.3 presents results on the effects of EHRs sophistication on hospital adjusted operating revenue and expenses per inpatient day. These are based on the hypothesis that other things being equal when a hospital moves from less to the more sophisticated EHRs system; it will gain adjusted operating revenue and reduce adjusted operating expenses per inpatient days as compared if it stays in a less sophisticated EHRs system. Overall, there is substantial evidence that EHRs sophistication (stages 1-3) has a positive effect on adjusted operating revenue per inpatient day. Models 1 indicate that when a hospital moves stage 0 to stage 4, it is associated with a \$350.68 ($p<0.01$) dollars in expected adjusted operating revenue per inpatient day. Similarly, Model 4 results indicate that on average a hospital on stage 4 is associated with a \$303.90 ($p<0.01$) dollars increase in expected adjusted operating expenses per inpatient day. However, the results from Models 2, 3, 5 and 6, which control for the EHRs years of experience at a given EHRs stage and others factors, indicate that on average there is no statistical significance difference in adjusted operating revenue for a hospital moving stage 0 to stage 4. Stage 1, 2 and 3 are associated with an increase in expected adjusted revenue and expenses per inpatient day. This reinforces the early results of operating margin that suggests that there is a significant disruption to revenue and expenses associated with implementing stage 4.

Effects of more years of experience with sophisticated EHRs on adjusted operating revenue and expenses per inpatient day.

The results from Table 3 also generally indicate that the more years of experience a hospital has with a higher stage of EHRs i.e. stage 2, 3 and 4, the more operating revenue per inpatient day it gained. For example, a hospital in stage 4 by the end of the first year is associated with a \$120.09 ($p<0.05$) dollars in expected adjusted operating revenue per inpatient day more a hospital in other stages, all things being equal. The amount rise to \$177.56 ($p<0.05$) dollars by the end of the fourth year. Similarly, a hospital in stage 2 at the end of the second year is associated with an expected revenue gain of \$34.85 ($p<0.05$) as compared to other stages, holding everything else constant. This increase grows to \$137.58 in the sixth year, falling to \$103.50 in the seventh year and is not statistically significant in the eighth year. Overall, evidence from the regression indicates that hospitals with more sophisticated EHRs consistently performed better on operating revenue after at least a year of disruption, while the evidence is not so consistent on reducing operating expenses.

Discussion

The federal government and hospitals have spent an enormous amount of resources to encourage the adoption and implementation of sophisticated EHRs to improve health care quality and efficiency [3]. In acute care setting, sophisticated EHRs systems are thought to be tools that can also improve financial performance. Indeed previous systematic reviews have found a relationship between general EHRs and financial performance, in some case mixed results [15, 49, 50]. This study sought to add our knowledge on key areas.

The effects of EHRs sophistication on hospital operating margin

The study set out to test several hypotheses. First, the idea that when a hospital moves from less to the more sophisticated EHRs system, it will experience higher operating margin as opposed when the hospital stays in the less sophisticated EHRs system. We did not find a positive effect on operating margin when a hospital moves from a less sophistication stage to a more sophisticated stage. However, when we conducted the prediction of the effects of EHRs sophistication on operating, controlling for several factors, hospitals in higher stages were associated with higher operating margin. Second, we found substantial evidence that the more years of experience a hospital has on a higher EHRs sophistication stage, the better the hospital performed.

This has several implications for practice and policy. First, the effects of EHRs sophistication should not be looked in isolation, rather in combination with other factors. For example, liquidity, capital structure, and cost measures were all found to be reliable predictors of operating margin. This suggests that hospitals should use EHRs in a combination of looking how these factors affect profitability. There is evidence from early adopters that they used sophisticated EHRs to launch hospital-wide service and business transformation [51]. For example, Novant Health used sophisticated EHRs as a platform to reduce account receivable by 93 days, reduced revenue cycle services costs by reduced by 49 percent and increase gross collection by 2-6 percent

[52]. Second, it seems that hospitals should be prepared for disruption when they launch more sophisticated EHRs systems. For example, the results indicate there are possible hurdles for implementing EHRs systems comprising stages 2. In addition, after controlling for other factors, the results indicate major revenue disruption when a hospital moves to stage 4. There are two possible approaches to mitigate the expected disruptions. The first approach is that hospitals need to do a thorough planning and evaluation before, during and after major EHRs implementation. This includes not neglecting the revenue cycle functions while focusing on only on patient care EHRs conversion [53]. This might mean appointing revenue cycle point person in the planning, pre-live and post-live, in addition to pre-testing the system, having provider buy-in and having a revenue cycle management back-up plan [37, 53]. The second approach might be either installing system incrementally stage by stage or implementing hospital division by division.

The results also suggest that for hospitals to have full benefits of sophisticated EHRs, then they have to implement the more sophisticated systems i.e. stage 4. There are at least two reasons for this. There is consistent and financial gain from going all in as opposed to implementing few applications. Also, the time it takes to start seeing the benefits in this stage is shorter as compared to less sophistication stage. Lastly, for researchers, the study shows that it is important to control for years a hospital has spent at a given sophistication stage, otherwise, the results potentially will be biased. Lastly, some hospitals seem to be struggling, and these might need help, possibly through regional extension services to prepare for possible disruption and successfully implementation and utilization of sophisticated EHRs.

<u>The pathways by which EHRs sophistication impacts operating margin</u>

The study also examined whether when a hospital moves from less to the more sophisticated EHRs system, it will improve revenue and or reduce adjusted operating expenses per inpatient days as compared to if it stays in a less sophisticated EHRs system. There is evidence to conclude that EHRs sophistication is influencing operating margin by improving adjusted operating revenue. Also, there is evidence that EHRs that are more sophisticated slightly helped reduce the adjusted operating expenses per inpatient day. However, the fact that expenses did not rise as rapidly as revenue due to EHRs sophistication is good news for hospitals. Especially given previous studies that found that on aggregate sophisticated EHRs were associated with increase in hospital costs and nursing levels [54, 55]

The study also found evidence that other things being equal, when a hospital has greater experience, i.e., more years, in higher EHRs sophistication stages (stage 3 and 4) it was associated with higher operating revenue and reduced operating expenses than when a hospital has less experience with higher sophisticated EHRs systems. Again, this is in line with results from other studies which indicate successful hospital, over time, used the sophisticated EHRs to launch operational transformation, as a result, saw financial benefits [56-59]. This suggests that hospitals might see a financial gain if they use the sophisticated systems as a launching pad for robust healthcare quality improvement and as a tool to improve revenue cycle process and reduce costs.

Hospitals face limited avenues to increase revenues as they are being squeezed from decreasing reimbursement, shifting of risk from payers and competition from ambulatory centers [60]. Sophisticated EHRs might be one of the tools these hospitals might use to improve their revenue cycle management and improve operational efficiency. More so for hospitals that serve rural or low-income individuals, which traditionally have razor thin margins [61, 62]. These hospitals might need more support to successfully implement sophisticated EHRs and use the system to transform their operations.

<u>Limitations</u>

There are several limitations to this study. First, we are limited to the available data. This might lead to underestimation or overestimation of the effect of EHRs sophistication, especially given the results that EHRs years of experience are a predictor of profitability. For example, they study was limited to the eight years the data covered, while some hospital might have more years of experience. In addition, some hospitals might have switched from one vendor to another or from a homegrown system to an outside vendor, which might disrupt the hospital operations, and this might not be captured in the data. There is also the issue of endogeneity that might not be eliminated by the hospital level fixed effects.

Cleaning the data in some instances depends on a judgment call. For example, in this study, we recoded the extreme top and bottom one percent as missing. Other researchers might clean the data differently and hence arrive at different conclusions in their analysis. Lastly, past research has shown that hospitals with electronic medical records use the systems to boost their revenue through various practices including what is known as "upcoding," a practice of billing with a higher paying codes [63]. It is possible that the effect observed here especially on operating revenue will be in part due to revenue enhancing practices and not the hypothesized practices.

Conclusion

This study set out to estimate the effects of EHRs sophistication on hospital profitability i.e. operating margin and the pathway to that effect if any. Also, the study sought to determine whether hospitals that have more years of experience with sophisticated EHRs also perform better on operating margin, adjusted operating revenue and expenses per inpatient day. The results of this study led us to conclude that hospitals with a higher sophisticated EHRs system will perform better on operating margin, however, after some disruptions. Moreover, our analysis suggests that more sophisticated EHRs system influence revenue and not operating expenses. We conclude that it is important to consider the number of years of experience a hospital has at a given stage to evaluate the EHRs sophistication impact correctly.

Thus, it is important for hospitals to thoroughly plan for possible revenue cycle disruption and have plans to overcome or mitigate the disruptions. In addition, hospitals and researchers should consider the number of years in might take to see the results. More importantly, the financial viability of acute care hospitals, especially small hospital and those that serve rural and vulnerable communities, is of importance to the served communities and policy makers. For example, CMS and Congress have regulations that are geared to protecting such hospitals from going out of business, such as reimbursement for the cost for Critical Access Hospitals (CAH) [47]. While this study did not test specifically for CAH and rural hospitals, results indicate that larger hospitals performed better than small hospitals. The small, rural and hospitals that serve vulnerable populations typically have low operating margin might need government support over time to implement sophisticated EHRs which can help them to be more financially sustainable.

Chapter 4 Tables

Table 4.1: Summary statistics					
Dependent variables	**Observations**	**Mean**	**Std. Dev.**	**Min**	**Max**
Operating Margin (%)	29,861	2.78	9.86	-44.79	33.94
Adjusted Revenue per Inpatient Day	29,825	2371.24	1024.21	598.29	8515.20
Adjusted Expenses per Inpatient Day	29,825	2279.07	949.99	618.88	7541.30
Independent variables	**Observations**	**Percent**			
EHRs Stage 0	6,667	21.63			
EHRs Stage 1	9,894	32.09			
EHRs Stage 2	6,414	20.81			
EHRs Stage 3	6,999	22.70			
EHRs Stage 4	855	2.77			
	Observations	**Mean**	**Std. Dev.**	**Min**	**Max**
EHRs Stage 0 Years	6,667	2.57	1.70	1	8
EHRs Stage 1 Years	9,894	2.62	1.67	1	8
EHRs Stage 2 Years	6,414	2.44	1.56	1	8
EHRs Stage 3 Years	6,999	2.17	1.22	1	5
EHRs Stage 4 Years	855	1.75	0.94	1	4
Total EHRs Years	30,829	4.020792	2.227956	1	8
Continuous control variables	**Observations**	**Mean**	**Std. Dev.**	**Min**	**Max**
Age of plant (Years)	28,465	12.28	13.24	0	146.15
Equity financing (%)	30,487	52.09	51.62	-166.69	302.15
Long-term debt to capital (%)	30,534	35.66	56.91	-291.69	309.69
Days in Patient Accounts Receivable	30,448	53.01	18.16	9.04	159.01
Current ratio	30,405	2.65	2.21	0.16	17.29
Patient deductions (%)	29,746	55.59	17.03	5.90	84.69
Adjusted Occupancy Rate (%)	30,368	44.14	22.82	0.13	99.96
Medicare Mix (%)	30,559	51.55	18.29	0	95
Medicaid Mix (%)	30,463	11.50	9.39	0	49.97
Sub-acute Mix (%)	29,716	6.11	10.41	0	49.97
ICU Mix (%)	30,510	9.80	7.76	0	34.98
HMO Mix (%)	30,661	8.42	10.13	0	49.97
Average Salary per FTE Per $ 5,000	30,180	51.61	16.98	0	88.76
Labor Intensity	30,777	10.64	2.47	5.91	20.65
Medicare Market Share	29,769	1.58	0.91	0.04	43.27
Categorical control variables	**Observations**	**Percent**			
Small hospitals (1-99 beds)	14,160	45.93			
Medium Hospitals (100-399 beds)	13,530	43.89			
Large hospitals (400 + beds)	3,139	10.18			

Table 4-1: Summary statistics

Table 4.2: The effects of EHRs sophistication on hospital operating margin

	(1) FE	(2) FE	(3) FE	(4) RE
	Operating Margin (%)	Operating Margin (%)	Operating Margin (%)	Operating Margin (%)
EHR Stage 1	-0.15	0.25	0.29	0.44**
	(0.17)	(0.24)	(0.23)	(0.21)
EHR Stage 2	-0.70***	-0.35	-0.18	-0.02
	(0.20)	(0.28)	(0.28)	(0.27)
EHR Stage 3	-0.08	-0.54	-0.26	-0.08
	(0.20)	(0.43)	(0.42)	(0.41)
EHR Stage 4	0.69*	-2.83***	-2.32**	-1.91*
	(0.39)	(1.08)	(1.00)	(1.02)
EHR Stage 1 Year 1		-0.25	-0.20	-0.03
		(0.32)	(0.31)	(0.25)
EHR Stage 1 Year 2		-0.49	-0.42	-0.15
		(0.39)	(0.37)	(0.30)
EHR Stage 1 Year 3		-0.46	-0.46	-0.05
		(0.44)	(0.42)	(0.33)
EHR Stage 1 Year 4		-0.23	-0.22	0.25
		(0.52)	(0.49)	(0.39)
EHR Stage 1 Year 5		-0.13	-0.07	0.49
		(0.61)	(0.59)	(0.47)
EHR Stage 1 Year 6		0.50	0.66	1.29**
		(0.74)	(0.71)	(0.59)
EHR Stage 1 Year 7		-0.70	-0.74	-0.02
		(0.91)	(0.89)	(0.76)
EHR Stage 1 Year 8		-2.34**	-2.13*	-1.11
		(1.17)	(1.14)	(1.05)
EHR Stage 2 Year 1		0.15	0.20	0.35
		(0.28)	(0.27)	(0.24)
EHR Stage 2 Year 2		0.13	0.17	0.48*
		(0.34)	(0.32)	(0.29)
EHR Stage 2 Year 3		0.31	0.29	0.68**
		(0.42)	(0.39)	(0.34)
EHR Stage 2 Year 4		0.83*	0.71	1.21***
		(0.50)	(0.47)	(0.41)
EHR Stage 2 Year 5		1.53**	1.17**	1.83***
		(0.64)	(0.59)	(0.51)
EHR Stage 2 Year 6		2.51***	1.94**	2.61***
		(0.81)	(0.77)	(0.68)
EHR Stage 2 Year 7		2.87***	2.03**	2.88***
		(1.00)	(0.93)	(0.84)
EHR Stage 2 Year 8		4.28**	3.31**	4.20***
		(1.72)	(1.61)	(1.50)
EHR Stage 3 Year 1		0.63	0.48	0.50
		(0.42)	(0.41)	(0.39)
EHR Stage 3 Year 2		1.32***	1.10**	1.23***

		(0.47)	(0.45)	(0.43)
EHR Stage 3 Year 3		1.75***	1.49***	1.70***
		(0.53)	(0.51)	(0.47)
EHR Stage 3 Year 4		1.98***	1.61***	1.95***
		(0.60)	(0.57)	(0.53)
EHR Stage 3 Year 5		1.11	0.71	1.16*
		(0.73)	(0.70)	(0.64)
EHR Stage 4 Year 1		2.78***	2.42**	2.30**
		(1.03)	(0.94)	(0.98)
EHR Stage 4 Year 2		3.59***	3.05***	3.11***
		(1.11)	(1.03)	(1.05)
EHR Stage 4 Year 3		5.28***	4.70***	4.79***
		(1.30)	(1.20)	(1.22)
EHR Stage 4 Year 4		4.69***	5.09***	5.44***
		(1.69)	(1.53)	(1.57)
Total EHRs Years		-0.12	-0.46	-0.25**
		(0.43)	0.05	-0.08
2006		-0.12	(0.37)	(0.16)
		(0.39)	0.55	0.12
2007		0.26	(0.76)	(0.22)
		(0.81)	-0.19	-0.77***
2008		-0.74	(1.15)	(0.30)
		(1.22)	0.49	-0.28
2009		-0.13	(1.54)	(0.37)
		(1.65)	0.57	-0.23
2010		-0.19	(1.94)	(0.45)
		(2.06)	0.82	0.05
2011		-0.13	(2.34)	(0.53)
		(2.49)	1.38	0.54
2012		0.12	(2.73)	(0.61)
		-0.12	0.05	-0.08
Age of plant			0.02**	0.00
			(0.01)	(0.01)
Long-term debt to capital (%)			-0.00	-0.00
			(0.00)	(0.00)
Equity financing (%)			-0.04***	-0.04***
			(0.01)	(0.01)
Days revenue in accounts receivable			0.03***	0.04***
			(0.00)	(0.00)
Current ratio			0.46***	0.46***
			(0.05)	(0.04)
Adjusted occupancy rate			0.05***	0.05***
			(0.01)	(0.01)
Medicare Mix			0.01	-0.06***
			(0.02)	(0.01)
Medicaid Mix			-0.01	-0.05***
			(0.02)	(0.01)
Sub-acute mix			0.02	0.00

			(0.02)	(0.01)
ICU Mix			-0.02	-0.01
			(0.03)	(0.02)
HMO mix			0.01	-0.03***
			(0.01)	(0.01)
Outpatient Revenue Mix			-0.28***	-0.05
			(0.08)	(0.05)
Average Salary per FTE			-1.08***	-0.93***
			(0.25)	(0.16)
Labor intensity			0.08***	0.04***
			(0.01)	(0.01)
Medicare Market Share			0.87**	0.59**
			(0.43)	(0.27)
Medium Hospital (100-399 beds)			1.29**	0.59
			(0.65)	(0.39)
Large hospital (400+ beds)			0.02**	0.00
			(0.01)	(0.01)
Constant	2.98***	3.31***	1.72	4.71***
	(0.13)	(0.25)	(1.66)	(1.20)
N	26327	26327	25117	25117
R^2	0.0019	0.0107	0.0608	

Table 4-2: The effects of EHRs sophistication on hospital operating margin

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 4.3: The effects of EHRs sophistication on hospital adjusted revenue and expenses per inpatient day.

	(1)	(2)	(3)	(4)	(5)	(6)
	Revenue	Revenue	Revenue	Expenses	Expenses	Expenses
EHR Stage 1	103.44***	53.87***	41.80***	101.21***	40.55***	31.30***
	(11.08)	(14.31)	(9.91)	(10.72)	(13.83)	(9.23)
EHR Stage 2	172.69***	37.27**	27.93**	176.05***	36.20**	27.57**
	(11.96)	(16.54)	(11.84)	(11.48)	(15.88)	(10.89)
EHR Stage 3	280.08***	47.56**	36.80**	258.69***	48.82**	37.70***
	(12.57)	(23.62)	(16.70)	(11.93)	(21.62)	(14.34)
EHR Stage 4	350.68***	-26.56	-52.47	303.90***	32.71	7.45
	(26.05)	(84.82)	(60.86)	(23.02)	(77.55)	(54.43)
EHR Stage 1 Year 1		-24.56	-33.31**		-15.25	-25.21**
		(18.71)	(13.74)		(18.02)	(12.79)
EHR Stage 1 Year 2		-14.46	-23.11		-10.08	-21.20
		(23.14)	(16.67)		(22.79)	(15.57)
EHR Stage 1 Year 3		-10.15	-16.56		-8.46	-16.57
		(27.33)	(19.74)		(26.96)	(18.49)
EHR Stage 1 Year 4		9.78	10.89		-1.26	-8.51
		(33.42)	(23.92)		(32.48)	(21.87)
EHR Stage 1 Year 5		14.29	1.29		-10.44	-28.74
		(37.60)	(27.14)		(36.76)	(24.59)
EHR Stage 1 Year 6		7.85	8.24		-34.28	-46.45
		(44.12)	(32.04)		(43.77)	(29.42)
EHR Stage 1 Year 7		18.76	24.67		-35.76	-40.07
		(62.32)	(45.85)		(54.48)	(37.45)
EHR Stage 1 Year 8		-93.72	-28.03		-87.50	-69.67*
		(60.88)	(45.27)		(61.37)	(40.85)
EHR Stage 2 Year 1		15.02	7.59		10.42	3.85
		(16.84)	(12.07)		(16.18)	(11.12)
EHR Stage 2 Year 2		37.55*	34.85**		23.86	16.59

		(20.74)	(15.02)		(19.58)	(13.73)
EHR Stage 2 Year 3		50.29*	57.60***		21.57	22.38
		(25.98)	(19.11)		(24.36)	(16.98)
EHR Stage 2 Year 4		55.62*	78.64***		12.12	24.08
		(33.35)	(24.04)		(31.27)	(21.27)
EHR Stage 2 Year 5		79.10**	101.45***		9.37	21.68
		(39.94)	(28.35)		(39.25)	(26.39)
EHR Stage 2 Year 6		121.98**	137.58***		9.22	18.57
		(51.09)	(36.53)		(48.25)	(33.22)
EHR Stage 2 Year 7		24.10	103.50**		-80.50	-15.74
		(67.14)	(43.59)		(60.33)	(38.81)
EHR Stage 2 Year 8		-35.70	90.10		-170.98***	-77.10
		(72.68)	(56.15)		(66.34)	(53.09)
EHR Stage 3 Year 1		-5.47	-6.95		-22.64	-24.07*
		(22.83)	(16.09)		(20.70)	(13.90)
EHR Stage 3 Year 2		36.51	33.49*		-8.81	-10.28
		(26.78)	(19.17)		(24.68)	(16.76)
EHR Stage 3 Year 3		49.98	44.69*		-10.18	-15.64
		(32.33)	(23.19)		(29.65)	(20.24)
EHR Stage 3 Year 4		45.83	49.95*		-36.12	-33.51
		(37.97)	(28.97)		(34.64)	(24.45)
EHR Stage 3 Year 5		57.43	34.30		-8.84	-27.84
		(45.26)	(33.72)		(44.40)	(31.93)
EHR Stage 4 Year 1		109.75	120.09**		32.68	43.92
		(84.97)	(60.06)		(76.82)	(52.83)
EHR Stage 4 Year 2		84.07	117.25*		-33.77	4.45
		(84.45)	(61.75)		(76.71)	(54.94)
EHR Stage 4 Year 3		128.27	166.48**		-23.07	16.42
		(97.11)	(66.65)		(90.56)	(59.56)
EHR Stage 4 Year 4		176.26	177.56**		50.44	40.88
		(123.92)	(79.71)		(137.70)	(88.00)
Total EHRs Years		-61.18***	-11.38		-51.04**	-5.32

		(19.46)	(14.71)		(20.39)	(14.90)
2006		80.58***	56.35***		75.51***	37.39**
		(17.19)	(15.55)		(17.77)	(16.22)
2007		168.15***	108.56***		154.58***	66.55**
		(35.37)	(30.89)		(37.41)	(32.31)
2008		231.09***	133.34***		232.97***	92.48*
		(53.11)	(47.54)		(56.41)	(49.82)
2009		395.23***	281.48***		372.38***	201.83***
		(71.76)	(64.56)		(76.12)	(67.59)
2010		510.26***	360.10***		482.78***	264.72***
		(90.23)	(81.17)		(95.70)	(84.96)
2011		576.09***	399.84***		546.60***	287.40***
		(108.83)	(97.24)		(115.49)	(102.07)
2012		647.48***	461.85***		616.01***	327.18***
		(127.69)	(114.06)		(135.12)	(119.30)
Age of plant			-0.75**			-1.11**
			(0.38)			(0.48)
Long-term debt to capital (%)			-0.15			-0.05
			(0.11)			(0.09)
Equity financing (%)			-1.60***			-0.70***
			(0.24)			(0.20)
Days revenue in accounts receivable			0.54***			-0.30**
			(0.15)			(0.13)
Current ratio			3.03*			-5.45***
			(1.68)			(1.53)
Patient Deductions			-0.21***			-0.10***
			(0.02)			(0.01)
Adjusted occupancy rate			-4.04***			-4.88***
			(0.63)			(0.68)
Medicare Mix			-0.85			-0.68

			(0.83)			(0.77)
Medicaid Mix			-1.98***			-1.26*
			(0.76)			(0.71)
Sub-acute mix			6.39***			5.57***
			(0.92)			(0.94)
ICU Mix			6.46***			5.76***
			(1.29)			(1.20)
HMO mix			-0.69			-0.70
			(0.50)			(0.46)
Outpatient Revenue Mix			-24.99***			-21.40***
			(2.48)			(2.56)
Average Salary per FTE			70.86***			77.93***
			(8.40)			(9.08)
Labor intensity			426.74***			467.65***
			(85.01)			(94.98)
Medicare Market Share			-4.11***			-5.50***
			(0.93)			(0.87)
Medium Hospital (100-399 beds)			-101.35***			-111.34***
			(20.79)			(20.06)
Large hospital (400+ beds)			-141.90***			-140.89***
			(35.67)			(36.80)
Constant	2164.59***	2154.98***	3059.42***	2080.86***	2065.86***	2437.42***
	(8.18)	(12.98)	(361.47)	(7.96)	(12.70)	(394.11)
N	24529	24529	24529	24530	24530	24530
R^2	0.0539	0.1130	0.5102	0.0524	0.1081	0.5174

Table 4-3: The effects of EHRs sophistication on hospital adjusted revenue and expenses per inpatient day.

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

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CHAPTER 5: CONCLUSION

The overarching goal of the dissertation study was to evaluate in a comprehensive manner the multifaceted impact of Electronic Health Records (EHRs) sophistication in U.S. hospitals. The outcomes of interest included hospital health care quality, patient experience, hospital readmissions, and hospital profitability. The results indicated that EHRs sophistication was associated with improved healthcare quality and profitability, while patient engagement, care coordination was associated with improved patient experience. However, there were unexpected findings. For example, EHRs sophistication was found to be associated with improved clinical process of care but not the patient outcomes. Meaningful use patient engagement and care coordination dimensions were found to influence the patient experience and not readmission directly. Moreover, the study found EHRs sophistication to have an impact on operating margin through gain on operating revenue and not through the reduction of operating expenses. Another unexpected finding had to do with the EHRs stages and years of experience with a specific EHRs sophistication stage. It appears that Stage 2 is more difficult for hospitals to overcome, suggesting some kind of a hurdle for hospitals. It also looks like it takes longer for a hospital in Stage 2 to see a gain in performance as compared to Stage 3 and 4.

The results suggest that overall, programs such as meaningful use have helped hospitals to implement and use sophisticated EHRs to improve health care quality and hospital outcomes. As shown in the study, in some cases, EHRs are having the expected impact and yet in others they are not. There are several possible reasons why sophisticated EHRs and meaningful use dimensions are not having the expected impact. For example, it is possible that it takes a long time for the EHRs effects to trickle down from improving clinical process measures to enhancing patient outcomes and reducing operating expenses. This possibility is supported by the results that show that across different measures, the length of a hospital's experience with more sophisticated EHRs was associated with improved clinical process of care and profitability. It is also plausible that the areas sophisticated EHRs did not have the expected effect require concerted efforts. For example, patient outcomes and adjusted operating expenses might require hospitals to apply advanced analytics to pinpoint specific areas of improvement and "transform healthcare big data into actionable knowledge" [1, 2]. For example, applying predictive analytics, hospitals may identify patients who are likely to be readmitted and once identified a hospital may focus efforts on those patients to reduce and mitigate their likelihood of readmission. Other examples include looking for patterns of overuse and misuse of resources with the intention of reducing waste and improving efficiency. These points to possible future study questions in areas such as the role of advanced analytics in the age of sophisticated EHRs, the effects of internal hospital environment on the operating expenses, hospital readmissions and patient outcomes.

There are a couple of possible explanations for the surprising finding concerning the EHRs sophistication Stage 2. This stage requires a hospital to have adopted and implemented nursing documentation and electronic medication administration record, which may partly explain the findings. First, across the country, nurses "comprise the largest single component of hospital staff, are the primary providers of hospital patient care."[3] Second, there are reports of wide nurse dissatisfaction with electronic records, especially its usability and disruption of long-established and familiar workflow.[4-6] Some of the dissatisfaction rise from poor user interface design and lack of inclusion of nurses in choosing and implementing an EHRs platform that fit their work needs. [7, 8], Lastly, nurses are the health care providers who administer medications using the eMAR. Therefore, taken together, these three facts possibly explain why there seems to be a hurdle getting through Stage 2 and why it seems to take longer to see positive results.

Overall, hospitals face uncertainty in the current political climate. While the HITECH Act and ACA possibly helped hospital invest for the future, the two legislations also imposed expensive reconfiguration of care delivery. With the future of ACA being uncertain, hospitals need every tool possible to be sustainable in the future. There is no indication the modified meaningful use program is going to be abolished. Therefore, a clear understanding of how sophisticated EHRs can be used to optimize care, reduce operating expenses and improve patient experience is going to be more valuable than ever. For example, researchers can use the data to understand the role of internal and external contextual factors on the success of sophisticated EHRs. Most critical internal and external contextual factors such as organizational culture, readiness for change, leadership and management attributes, are not currently available. However, it is still possible that the new incoming administration will slow down or stop enforcing the modified meaningful use requirements. Even in that case, hospitals are unlikely to roll back the investment they have already made in the implementation of sophisticated EHRs. In addition, early adopters of sophisticated EHRs are unlikely to slow down their progress in using the systems to improve outcomes. To what extent hospitals may continue to invest in EHRs and successfully use the system to improve care and reduce costs may depend on the new administration's interest in pushing forward on such care models and payment reforms as ACOs and value-based purchasing. However, private payers and other stakeholders might lead the continued transformation whether the federal government is on board or not. For example, the Health Care Transformation Task Force, a consortium of patients, payers, providers, and purchasers, have committed to 75 percent of the members' businesses operating under value-based contract arrangement by 2020.[9] A 2016 report from the Transformation Task Force found that "41 percent of its provider and payer members' business were in value-based payment arrangements at the end of 2015, up from the 30 percent in 2014."[10] Thus, research efforts are needed to monitor policy changes and the impact on quality of care especially on EHR investment and utilization.

The possible danger to roll back EHR investment might be in small rural hospitals, safety net hospitals, and those hospitals that depend on support from regional extension services. In addition, the rollback will cause disruption and create uncertainty in the industry. Most hospitals, with the exception of early adopters, have gone through a painful process to adopt and implement sophisticated EHRs; most are less likely to reverse the process. Moreover, hospitals that depend on the government funded extension centers support still might need help to complete the process of implementing and using the EHRs to improve outcomes. In addition, EHRs that are more sophisticated are expensive to maintain and upgrade, not to mention the number of technical staff required and the cost of continuous training of providers and other staff members.

Whether or not hospitals and health care providers in general, continue to invest in EHRs may determine the success of population health. The possible societal benefit of sophisticated EHRs is to improve overall population health, which may reduce healthcare cost. However, this promise requires interoperability, which in turn requires investment in healthcare exchange platforms, sustained standardizations, and cooperation among provider systems, some cutting across state lines. The goal to improve population health may suffer if programs such as meaningful use are abolished. The study did not provide substantial evidence on the effect of health information exchange, which is critical in improving population health. Suggesting that more work needs to be done on issues such as interoperability to allow seamless information exchange. If the meaningful use program were to be terminated, then this work might also stall.

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