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Adoption of Electronic Health Records by Admitting Physicians: A Heuristic Model

John Sharon Hudson
Old Dominion University

ADOPTION OF ELECTRONIC HEALTH RECORDS BY ADMITTING PHYSICIANS: A HEURISTIC MODEL

by

John Sharon Hudson
B.S.N. June 1982, Michigan State University
M.S.N. January 1986, Case Western Reserve University

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Approved by:

James A. Neff (Director)

Qi Zhang (Member)

Larry T. Mercer (Member)

Miguel Padilla (Member)

ABSTRACT

ADOPTION OF ELECTRONIC HEALTH RECORDS BY ADMITTING PHYSICIANS: A HEURISTIC MODEL

John Sharon Hudson
Old Dominion University, 2011
Director: Dr. James A. Neff

Background: Although hospital electronic health records (EHRs) are generally perceived to improve care, physician resistance may hinder EHR adoption.

Purpose: This study uses constructs from diffusion of innovations and resource dependence theories to predict adoption and rate of adoption of an EHR by admitting physicians from three of ten hospitals in a highly integrated health system in Virginia. Functions evaluated: computerized physician order entry (CPOE), electronic history and physical (EH&P) and electronic discharge summary (EDS). The study tested hypotheses that adoption would be associated with: working at larger, academic hospitals; financial alignment; larger physician groups; office EHR; youth; males; medical specialty; high volume; hospital-based; high inpatient ratio; and high loyalty.

Methods: Administrative data collected for 326 physicians admitting at least ten patients during the six months following EHR activation represented over 80% of the total admissions. Logistic Regression and Cox Regression were

used to evaluate how well variables predicted adoption (80% utilization) and adoption rate.

Results: The Logistic Regression model predicted significant proportions of variation in adoption of CPOE (66%), EH&P (34%) and EDS (40%). CPOE adoption was more likely ($p < .05$) for physicians who were male, had a high inpatient ratio, lower patient volume and community hospital setting. EH&P and EDS adoption was more likely for physicians with financial alignment and large, academic hospital setting.

The Cox Regression model predicted significant proportions of variation in rate of adoption of CPOE (10%), EH&P (14%) and EDS (19%). The overall model for CPOE was significant ($p=.006$); no individual predictors were significant. Physicians who were financially aligned or worked at the large, academic hospital adopted EH&P and EDS faster.

Conclusion: Personal factors: loyalty, age and gender were generally not predictive. Organizational factors: hospital setting and financial alignment were most predictive of adoption. Study results may help administrators improve EHR installations.

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CHAPTER I

INTRODUCTION

The use of hospital electronic health records (EHRs) is perceived to significantly improve health care processes, yielding safer, more cost effective care (Callen, Westbrook, & Braithwaite, 2006; Furukawa, Raghu, Spaulding, & Vinze, 2008; N. Menachemi & R. Brooks, 2006; Menachemi, Ford, Beitsch, & Brooks, 2007; Ohsfeldt, et al., 2005; Poon, et al., 2004; Saginur, 2005; Wu, Abrams, Baker, & Rossos, 2006). Physicians are key users of the systems and hold significant power to reduce hospital costs and improve quality (Miller & Sim, 2004; Stone, Smith, Shaft, Nelson, & Money, 2009). The EHRs are complex, integrated systems and cost millions of dollars to develop and implement. An estimated 19% of EHRs implemented by hospitals are failing and being uninstalled, in part, due to the resistance of physicians (Conn, 2007). The lack of use of the applications in EHRs by physicians is becoming a hurdle to the adoption of hospital EHRs (Abdolrasulnia, et al., 2008; Conn, 2007; Dephillips III, 2007).

Computerized Physician Order Entry (CPOE), augmented by computerized clinical decision support, is one of the processes with the greatest influence within the many EHR applications used by physicians (Chaudhry, et al., 2006). The measurement of percentage of orders entered directly by the physician via the computer is advocated by the Agency for Healthcare Research and Quality as an important measure of EHR use (AHRQ, 2009; Tang &

Hripcsak, 2009). The Healthcare Information Management Systems Society (HIMSS) set entry of 80% of all medical and procedural orders using CPOE as the benchmark for hospitals (HIMSS, 2009). The remaining 20% of orders may be given verbally to a nurse or hand-written and scanned into the EHR. Verbal and scanned orders do not receive the same computerized clinical decision support or error checking as those entered using CPOE. The percentage of orders entered directly, however, varies widely from hospital to hospital and physician to physician (Lindenauer, et al., 2006).

The history and physical document contains the current and past conditions of the patient. The history is a summary of the patient's illness based on interviews, the patient's perspective. The physical examination portion of the report contains the physician's assessment of the patient. Together, the history and physician serves as the basis for the clinical impression and initial treatment plan (LaTour & Eichenwald, 2006). The discharge summary provides information about the patient's condition prior to treatment and information about tests, examinations, procedures and the results of treatment (LaTour & Eichenwald, 2006).

Joint Commission (2005) standards recommend defined organizational policies and procedures regarding the specific data that should be included in history and physical and discharge summary documents including the chief complaint; history of present illness; review of systems; past, family, and social history; physical examination; and impressions. The Joint Commission recommends a discharge summary should provide information to other

caregivers including the reason for hospitalization; significant findings; procedures performed and care, treatment, and services provided; the patient's condition at discharge; the final (principal) diagnosis and any other diagnoses and procedures, and information provided to the patient and family. The Medicare Conditions of Participation require that the medical record have a discharge summary with outcome of hospitalization, disposition of case, and provisions for follow-up care (CMS, 2004).

Structured data entry in an EHR can prompt completeness, provide greater accuracy and readability, and improve searching and retrieval of data (Roukema, et al., 2006). Completion of the history and physical and discharge summary in a standardized manner helps in the effective management of health information for quality patient care (Kallem, Burrington-Brown, & Dinh, 2007). Inclusion of these variables also assists in coding and extraction of data for future health services research.

This study evaluates the adoption and rate of adoption of an EHR by admitting physicians. The rate of adoption was based on the number of months it takes physicians to achieve an 80 percent level of use for each measure of use. There are numerous functions included in an integrated EHR intended to improve the quality, safety or efficiency of care. Three of the important functions recognized are Computerized Physician Order Entry (CPOE), Electronic History and Physical (EH&P) documentation and Electronic Discharge Summary (EDS) documentation (Tang & Hripcsak, 2009). All three of these functions are required processes for the care of every patient treated in a hospital setting (CMS, 2004).

The benefits and rates of use of CPOE have been documented to a limited degree, however, there is limited documentation of the benefits of the other two measures of EHR use.

The variables CPOE, EH&P and EDS were measured to gain an understanding of the adoption and rate of adoption of three different functions in the EHR software. The study methodically seeks the most parsimonious model using a heuristic combination of constructs from Diffusion of Innovations Theory and Resource Dependence Theory. The analysis begins with overall hypothesis that adoption and the rate of adoption will be positively associated with young age, high volume, physician-hospital alignment, high levels of loyalty, hospital-based practice, medicine specialties, from large groups, having office based EHRs, admission of a high proportion of inpatients versus outpatients, at larger, teaching hospitals. Variables shown not to be significant to the overall model may be eliminated to achieve the most parsimonious model.

In addition to seeking a model predicting which groups adopt the EHR by six months after activation, the study evaluates the rate of adoption. The six-month adoption contrasts those who achieve an 80 percent level of use by the end of the six months to those who do not. The rate of adoption analysis seeks to predict which groups reached the pre-defined threshold fastest.

The study evaluates the adoption rate of adoption of a HIMSS Stage 7 EHR by physicians who care for patients at Sentara Healthcare, an integrated healthcare system in Southeastern Virginia. Currently, only eight health systems

in the United States (40 hospitals) have implemented EHRs of this, the highest level (HIMSS, 2010). The study evaluates the adoption of the EHR by physicians in three hospitals and develops a predictive model for the adoption and rate of adoption using three levels of predictor variables: hospital, physician group and personal physician variables. The three levels correspond to the constructs in the theoretical frameworks selected to support and guide the research. Diffusion of Innovations Theory (DI) suggests larger, academic hospitals and larger physician groups may provide an environment that encourages greater networking, risk-taking, innovation and faster adoption of innovations. Resource Dependence Theory (RDT) includes propositions suggesting physician groups that are more dependent on the hospital for resources will be more likely to be agreeable with changes the hospital makes. DI also provides propositions about the personal characteristics of innovators.

Pragmatic and parsimonious predictive models for assessing the variables affecting the acceptance of the system were developed. The overall model tested readily available administrative data from a healthcare system that implementing an EHR in multiple hospitals. This chapter introduces the problem, theoretical framework, research questions, assumptions, limitations, delimitations and significance of the study.

Problem and Purpose

The purpose of this study was to find a valid and reliable model with readily available information from administrative databases to predict the

adoption and rate of adoption of an EHR by admitting physicians. Integrated EHRs are being implemented by large health systems in the United States at an increasing rate. While the adoption of many individual low-level EHR software applications have been studied in detail, the variables associated with rapid adoption and high rates of physician use remain unclear. More specifically, the health system being studied invested over $200 million for the EHR it developed and implemented. It expects to implement their EHR at additional hospitals, physician offices and other care sites. The leaders of the implementation team would like to be able to evaluate administrative data for physicians at each hospital prior to implementation to predict the level and rate of acceptance and identify physicians or groups who may need additional training or convincing to adopt the EHR. Existing research focuses on surveys that measured attitudes to predict physician adoption of innovations. Most physician surveys have response rates of less than 50% and it is possible the physicians who do not respond to the surveys are also the physicians who are slow to adopt EHRs.

Background

Many variables inhibit the adoption of innovations of all types and there is a large body of literature regarding "the diffusion of innovations" (Dearing, 2008). While the cost of technological innovation has been blamed for over half of healthcare cost increases (Goldman, 2007), some innovations reduce the cost and improve the quality and safety of healthcare. Electronic health record systems are considered essential to future improvements in care (Anderson, 2007; Lee, Cain, Young, Chockley, & Burstin, 2005). In systematic reviews of

the literature (Aziz, McKenzie, & Clark, 2009; Chaudhry, et al., 2006), health information technology was shown to improve quality by increasing guideline adherence, decreasing medication errors and enhancing disease surveillance. The review also showed improved efficiency through decreased utilization of healthcare resources, such as redundant diagnostic tests. The integrated EHR, seamlessly connecting primary, secondary and tertiary providers of care is regarded as the ultimate goal but has only been attempted by a few large health systems in the U.S. (Bernier, Detmer, & Simborg, 2005; Chaudhry, et al., 2006).

According to the Advisory Board Company (2007), the adoption of information technology is focused on error reduction and patient safety improvements. A Healthcare and Information Management Systems Society (HIMSS) leadership survey of 360 hospital executives reported the two main justifications for future purchases of information technology equipment would be reduction of medical errors and replacement of aging information technology infrastructure (Monegain, 2007, HIMSS News Release). The RAND Corporation estimates U.S. annual savings of $77 billion from efficiency gains and $4 billion from error reduction. Previous studies showed $300 billion per year is wasted on healthcare that does not improve outcomes (G. Bush, 2004). The Institute of Medicine estimates $37 billion per year is spent on additional health services due to medical errors and there are between 44,000 and 98,000 iatrogenic deaths per year (Crane & Crane, 2006).

Physicians hold the power to reduce hospital costs and improve quality (Chaudhry, et al., 2006; Taheri, Butz, Griffes, Morlock, & Greenfield, 2000).

Physician use of EHR systems is considered key to their success (Grossman & Cohen, 2008). Adoption of EHRs by physicians has been slow (Abdolrasulnia, et al., 2008). The adoption of hospital CPOE applications have been evaluated, however, the adoption of fully integrated EHRs have not been evaluated (Bernier, et al., 2005). The barriers to adoption have been studied in individual physician offices and smaller scale EHR or stand-alone CPOE applications (Dephillips III, 2007). Institutional, governmental, hospital, environmental, and individual physician characteristics are some of the factors shown to affect the adoption of innovations (Bikson, 2007; Castle, 2001; Proenca, Rosko, & Zinn, 2003). These existing studies suggest physicians who are of young age, from large groups, use office based EHRs or practice at larger or teaching hospitals adopt more readily than physicians who do not have these characteristics.

Physicians provide services at hospitals by belonging to a hospital's "medical staff". Joining the medical staff involves an application and approval process that assures physicians are qualified to perform the services they request to provide. Concurrent with the rising rate of EHR implementation, physicians have increasingly aligned with hospitals (Terry, 2009). Many physicians today are more focused on lifestyle than independence and seeking a work environment that provides security and stability (MacNulty & Reich, 2008). Hospitals seek alignment to build high-performance organizations, leverage EHR operating platforms and meet the expected future healthcare payment system requirements (Thomas, 2009). There are many different types and levels of physician–hospital alignment (Lake, Devers, Brewster, & Casalino, 2003). The

following four levels of physician-hospital alignment are common. 1) Physicians may be employed by a competing health system and still work at several hospitals. 2) Physicians may be independent and have no financial agreements with any health system, allowing them freedom of choice regarding which hospitals they use. 3) Physicians may have a financial contract with a hospital to provide needed services. 4) Physicians may be employed by the health system to provide services exclusively for that system. The most common employment strategies between hospitals and physicians are direct employment, professional service agreements for hospital-based practice, and income guarantees for physicians who are growing their practices (Grauman & Harris, 2008). Physicians in categories one through three may choose which hospitals they use, and the number of patients they admit to each hospital. Physicians who prefer to avoid employment or contractual alignment with a hospital may simply choose to provide hospital services at only one organization due to the convenience of working (and being on-call) at only one facility or the volume of patient referrals gained from other physicians at the hospital (Teska & Wolosin, 2006). The ratio of patients admitted to one hospital to the total number of patients the physicians admits to all hospitals is commonly used as a measure of physician "loyalty" (Burns & Wholey, 1992). Existing research does not describe the effects of physician-hospital alignment, loyalty and patient volume on the adoption of EHRs.

A newer alignment strategy is to implement an EHR that helps integrate information between the hospital and physician offices. Disease based

reimbursement and pay-for-performance programs provide incentives for hospitals and physicians to accomplish common goals; with an EHR strategy, they can be managed together rather than separately (Fera, 2007). Experts claim that EHRs may improve alignment and alignment may improve the adoption of EHRs (Casalino, November, Berenson, & Pham, 2008; Thomas, 2009). Quality research, supporting the relationship between alignment and adoption, is not available in the literature.

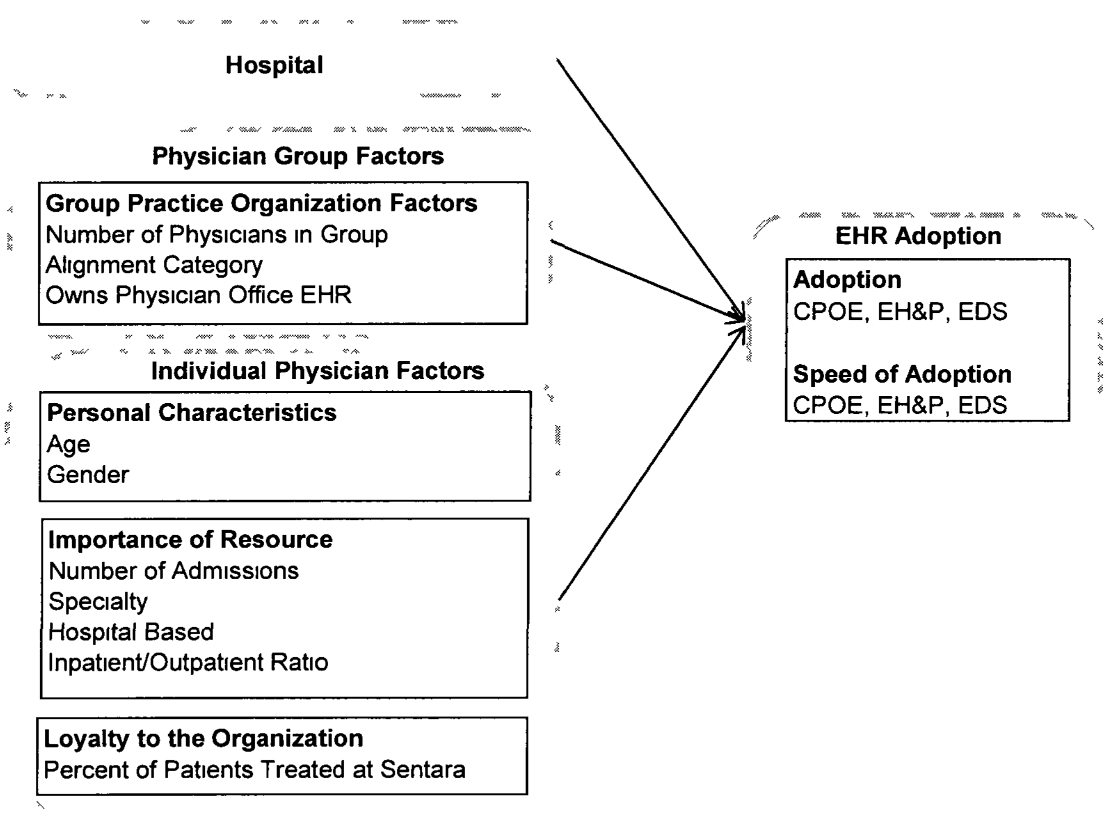
In summary, the rates of EHR activation and physician-hospital alignment are concurrently increasing. The use of EHRs is believed to improve health services and be a strong strategy for improving physician–hospital relations and achievement of mutual goals. The published literature does not evaluate if alignment, using any of the above strategies, improves the rate of EHR use. The use of CPOE has been studied in a variety of studies but the rate of adoption by admitting physicians has not been evaluated.

Theoretical Model

This study used a heuristic combination of dimensions from Resource Dependence Theory (RDT) and Diffusion of Innovations Theory (DI). DI theory includes dimensions regarding the innovation, innovator, places where innovation happens, the rate of innovation and how the innovation is introduced. RDT is an inter-organizational theory that provides propositions about how each of two organizations will behave when they do business with each other. The model seeks to understand how individual physicians respond to EHR activation at the

hospital where they provide care. Constructs from these two theories were selected because they may be used to evaluate the inter-organizational relationship between physician and hospital as the hospital asks the physician to adopt an innovation. Focus on factors associated with the importance of the resources provided by the hospital, physician-hospital alignment, loyalty and personal characteristics such as age, gender, and specialty A diagram of the basic model for this research is provided in Figure 1.

Figure 1: EHR Use and Adoption Model



Research Questions

Research Question One: What variables predict which physicians adopt (achieve an 80% use rate) of an electronic health record by six months after activation? Answering this question provides information for contrasting those who do and do not adopt by the end of a specific time and help administrators improve overall adoption of the EHR. If, for example, young, employed physicians do not achieve an 80% rate of use by the end of six months, the administration may want to evaluate and correct the reasons for low use or re-evaluate the value of employing physicians.

Research Question Two: What variables predict the rate of adoption (the number of months between activation and achievement of an 80% use rate) of an electronic health record by admitting physicians? Answering this question may help administrators expedite the adoption process.

Context

The study involved the physicians within a healthcare system in Southeastern Virginia. The healthcare system includes ten hospitals. Six of the ten had implemented the "eCare" EHR at the time of this study. The eCare system is a customized application of software provided by one of the largest EHR software vendors in the United States. The eCare application integrates the processes and data throughout this healthcare system, including physician offices, hospital and outpatient services. Physicians from the last three hospitals to activate eCare were included in the study.

Methods

This study sought pragmatic and parsimonious predictive models using retrospective data and quantitative analyses. All admitting physicians on the active or associate staff who admitted at least ten patients during the six months after activation of the EHR, were members of the medical staff the entire six months were included in the study. Physicians who admitted patients a hospital that activated the EHR earlier may have had the opportunity to use the system prior to activation at the hospital studied were excluded.

For practicality, de-identified administrative data were used. Administrative data regarding the CPOE, EH&P and EDS levels were collected from the EHR reporting systems after each activation. The EHR data was linked to the strategy department's database that provided information regarding the individual physicians, their medical groups and the hospitals to which they admitted patients.

Assumptions

Each hospital has a different number of beds, geographic location, teaching status and level of competition with other physicians for patients to serve. The three hospitals were compared in an attempt to evaluate differences in the results from hospital to hospital and adjust the remaining variables for hospital level influences. None of the current literature evaluated physician adoption at community hospitals. It is likely the trainers and implementation leaders learned from experiences of each implementation; however, the

implementation support and training at each site was similar. It was assumed any differences did not affect the physician behaviors. It is known that diseases and the volume of admissions to hospitals are often seasonal; however, it was be assumed seasonality does not affect the CPOE, EH&P and EDS use or rate of adoption. Since this study uses survival analysis techniques to develop inferences, it is assumed that once physicians reach the defined "event threshold" for adoption (80 percent use), they will maintain that level afterwards. In other words, it is assumed that once a physician adopts the EHR, that physician will continue to use it.

Limitations

Information was limited to administrative data obtained from existing sources. Many of the published studies and theories show a relationship between perceptions or attitudes and the adoption of innovations. Since this study seeks to find the most pragmatic model to evaluate the adoption of the EHR, complex and costly surveys of perceptions and attitudes were not performed. Elimination of perceptions and attitudes may result in a less predictive model.

Data were provided by employees of the health system. The database is updated quarterly based on information from the system's insurance company and web sites for physician groups, but the accuracy of the information provided by those sources cannot be assured. The alignment data regarding the percentage of patients admitted to a facility affiliated with this health system was

measured for the full calendar quarter prior to the implementation for each physician. There may be a lag time of nearly three months for some physicians. For example, if the hospital implements the software in September, the alignment percentage was measured from April to June. There may have been changes in admission patterns between the end of June and the implementation date in September.

Training sessions were held at different times of the day, in different locations, and provided by different trainers. Some trainers may have been more influential to change the behaviors of physicians than others. The three hospitals activated at different times. There is a period of up to nine months between the activations at the three hospitals studied. There may have been changes during these months that could affect the willingness of physicians to use the EHR. There was some mixing of the sample of physicians during the study period. Physicians who work at hospitals in this sample may have discussed their experiences with physicians who work at hospitals that activated the EHR earlier. The software did not change and was not updated during the period studied but individual methods to circumvent problems developed by physicians may have been shared.

Delimitations

The study was conducted by a health system in Virginia that may not be representative of other hospitals or healthcare systems. The sample is limited to a not-for-profit integrated health system in Southeastern Virginia that employs a

portion of its physicians and owns a health insurance plan. The hospital system is considered one of the most highly integrated health systems in the country based upon the ownership and interfacing of providers, information and systems of care (Bernd, 2010). The EHR being evaluated is considered highly integrated and essentially paperless. The EHR was awarded “HIMSS Analytics Stage 7” designation by the Healthcare and Information and Management Systems Society, the highest stage in the EHR scale. Most hospitals currently implement Stage 4 or below. The software used is a customized version of Epic™ and may not be representative of all EHRs. For these reasons, this study may be considered an evaluation of a model health system rather than a typical health system.

The study was performed during an “economic downturn” or recession. Additionally, during the study period, health care reform was being debated by the federal government. The results of this study may not be generalizable to physicians at hospitals that do not have similar characteristics.

The most recent hospital to activate may have been influenced by multi-study interference and or weather for the first week or two. The hospital activated the system the same week it was surveyed by The Joint Commission and hit by a storm that caused widespread flooding and residential property damage.

Significance of the Study

Electronic health records are being implemented at an increasing rate and at great expense to the hospital systems that lead the effort (Conn, 2007). The number of installations is expected to increase significantly with the approximate $17 billion dollar incentive program included in the United States government's economic recovery plan. Developing a predictive and pragmatic model for the assessment of current readiness for electronic health record implementation could significantly improve the success rate of adoptions across the United States. This study focuses on developing a model for evaluation of physician adoption that can affordably and practically be used by health care administrators.

According to a systematic review by Clamp and Keen (2005) current research regarding the use of EHRs "is scattered across many different clinical contexts and involves many different types of EHR" (p. 74). With the understanding EHRs have significant value but past research has not been easily generalized, this study intends to investigate the implementation of a version of the most commonly purchased EHR software. The software implemented by this health system was developed by Epic™ Systems Corporation. Epic™ continues to increase sales of software, capturing 40 percent of new sales (KLAS, 2009). An objective evaluation of variables associated with physician adoption for the largest vendor is useful. Results should be reasonably generalizable to other integrated health systems implementing Epic™ EHRs at the level of HIMSS Stage 6 or 7.

The study is also unique in several ways. Few EHRs of HIMSS Stage 6 and above have been implemented. Information about their success or failure is limited. While the implementation of EHRs at HIMSS Stage 6 and above and the level of physician-hospital alignment are both increasing, there are no studies of the association of all three levels of predictors used in this study. Hospital and individual physician level variables have been studied but no studies evaluated physician group level predictors such as the various types of physician alignment on the rate of adoption or levels of use of CPOE, EH&P or EDS.

The use of sophisticated modeling and survival analysis techniques, combining multiple theoretical approaches is lacking. While CPOE adoption has been evaluated to a limited degree, information regarding the adoption of EH&P and EDS is lacking. No studies detailing the use or adoption of EH&P or EDS were found in the peer reviewed literature. Understanding the variables that predict the use and rate of adoption of the EHR, and developing a method that allows reliable and valid assessment of a hospital's state of readiness will promote efficient optimization of EHR adoption.

CHAPTER II

LITERATURE REVIEW

This study focuses on physicians' adoption and levels of use of an integrated electronic health record system. A combination of theoretical perspectives on the adoption of innovations was used to identify models that predict the adoption and rate of adoption. This chapter reviews the definitions, history and research available related to Electronic Health Records (EHRs). The literature review focuses on variables related to the adoption of information technologies or EHRs. Since there is limited information published regarding physician adoption of EHRs, research reviewed includes studies of physician adoption of other technologies such as the Internet and personal digital assistants. Information regarding the adoption of EHRs in physician practices, nursing homes, and other settings where physicians work, is also be included in order to gain an understanding of predictors of adoption by physicians. The literature review concentrates on research performed within the last 10 years and published in peer-reviewed journals. Additionally, seminal research regarding the topic and theoretical perspectives is included.

The literature review begins with a review of EHR definitions, history and theories. Theories that include dimensions used in the development of the model for this study are emphasized. The theory review is followed by a review of studies that evaluated each variable, beginning with the dependent variables computerized physician order entry (CPOE), electronic history and physical

(EH&P) and electronic discharge summary (EDS), followed by hospital organizational variables, physician group factors and individual physician factors. The chapter concludes with a summary of the strengths of limitations of the current literature.

Electronic Health Record Definitions

The EHR definition has changed and continues to evolve as technology increases. The terms EHR and electronic medical record (EMR) are used interchangeably in the literature. The National Alliance for Health Information Technology, as noted in Thompson, Johnston, and Spurr (Thompson, Johnson, & Spurr, 2009), defined the EHR as "an electronic record of health-related information on an individual that can be created, gathered, managed, and consulted by authorized clinicians and staff within one health care organization (p. 444)." The Healthcare Information and Management Systems Society (HIMSS), as noted in Sidorov (2006), defined the EHR as "a longitudinal electronic record of patient health information generated by one or more encounters in any care delivery setting" (p. 1079). The EHR is an integration of various tools such as radiology and laboratory orders, electronic prescriptions, digital imaging, and decision-support tools that enables a safer more efficient health care system (Gagnon, et al., 2009).

HIMSS Analytics defines hospital and health system EHRs based on eight cumulative levels (stages) of adopted EHR capabilities. Stage One includes EHRs that interface with basic laboratory, radiology, and pharmacy information systems. Stage Two EHRs include clinical data repository, controlled medical

vocabulary, and clinical decision support system capabilities. Stage Three EHRs incorporate clinical documentation and digital radiology features. Stage Four EHRs include Computerized Physician Order Entry and clinical protocol functionalities. Stage Five EHRs feature closed loop medication administration. Stage Six EHRs integrate full physician documentation. Stage Seven EHRs offer an electronic and nearly paperless medical record (HIMSS Analytics, 2009). In 2009, less than 11% of 5,172 hospitals had achieved above Stage Four of EHR adoption. Only Stage Seven EHRs allows health care providers to electronically record, retrieve, integrate, analyze, and interpret data (HIMSS, 2009).

Not to be confused with the provider owned medical record, the Electronic Personal Health Records (EPHRs) are an Internet-based application that enables individual persons to create their own privately maintained record of received medical care (Flores, 2005). EPHRs help patients electronically store and transmit their medical information to doctors and hospitals. As a matter of convenience, in this study EHR refers to an electronic medical record that includes an electronic health record.

History of Electronic Medical Record Adoption

In 1901, Dr. Henry Plummer at the Mayo Clinic introduced the concept of a centralized medical record stored in a single repository and capable of traveling with the patient. In the 1960s, the Mayo Clinic began developing EHR systems. The centralized medical record supplied Mayo Clinic physicians with the data needed about each patient for medical care. The centralized medial record provided data to medical researchers that allowed researches to investigate

patient data by medical condition, date of treatment, physician name, and test category. In 1993, the Mayo Clinic advanced EHR development by adopting the first electronic physician's notes application. Today, Mayo Clinic physicians now document more than 60,000 notes per week. As a result, the EHR is critical to the Mayo Clinic's ability to provide collaborative, safe, and quality care (Libraries, 2009).

In the 1960s, Lawrence Weed first described the concept of computerized medical records. By 1967, Weed's work formed the basis of the Problem-Oriented Medical Information System (PROMIS) project at the University of Vermont, a collaborative effort between physicians and information technology experts. The project's objectives were to develop a system that would provide timely and sequential patient data for epidemiological studies as well as medical and business audits (Schultz, 1988). In the 1980s several EHR systems were developed and further refined by various academic and research institutions. Harvard Community Health Plan, a large prepaid clinic in Boston, Massachusetts, and the Indiana University Medical School created the Computer Stored Ambulatory Record (COSTAR), which was one of the earliest EHRs to combine inpatient and outpatient systems (Chaudhry, et al., 2006).

In 1999, the Institute of Medicine (IOM) (NIH, 1999) report *To Err Is Human* estimated from 44,000 to as many as 98,000 Americans die from medical errors incurred in hospitals. The IOM is a nonprofit organization that provides authoritative advice to health care decision-makers and the public on the urgent questions about health care. The IOM suggested that a promising strategy to

reduce medical errors and decrease health care spending is to transform current paper means of delivering health care information to electronic means.

Federal Government EHR Initiatives

Several key federal government activities were launched in 2004 to accelerate the nationwide EHR adoption time-line. According to Sensmeier (Sensmeir, 2008), President Bush, by executive order, created the position of a National Health Information Technology Coordinator (NHITC). NHITC's role was to facilitate EHR adoption with uniform technology standards by the year 2014 (W. G. Bush, 2004). This began the "Decade of Health IT" and initiated a series of activities designed to accelerate EHR development throughout America. The federal strategic framework focused on four strategic goals:

1. Inform clinical practice: incentivize EHR adoption, reduce risk of EHR investment, and promote EHR diffusion in rural and underserved areas.
2. Interconnect clinicians: foster regional collaborations, develop a nationwide health information network, and coordinate federal health information systems.
3. Personalize care: encourage use of personal health records, enhance informed consumer choice, and promote use of telehealth systems.
4. Improve the population's health: Unify public health surveillance architectures, streamline quality and health status monitoring, and accelerate discovery and dissemination (W. G. Bush, 2004).

More important, with the government's mandate for hospitals and physician practices to implement the EHR, reporting systems and safety features may prevent "near misses" as well as fatal occurrences (Leape & Berwick, 2005).

On February 2009, President Obama signed the $787 billion American Recovery and Reinvestment Act of 2009 (ARRA). Title XIII of Division A and Title IV of Division B of ARRA, together cited as the Health Information Technology for Economic and Clinical Health Act (HITECH), include provisions to promote the "meaningful use" of the EHR. The HITECH Act authorizes incentive payments for eligible Medicare and Medicaid providers to become meaningful users of certified EHR technology. In 2015, noncompliant providers will be subject to reduced Medicare payment ("Rules and Regulations," 2009).

The HITECH Act provides over $1.4 billion in grants to accelerate EHR adoption. The grants serve multiple purposes: (1) Start 70 Regional Extension Centers to assist primary care providers' efforts to become meaningful users of EHR. (2) Establish a national Research Center to help the Regional Centers. (3) Support HIT workforce development (workflow redesign specialists, clinical consultants, implementation specialists, implementation managers, technical support specialists, and trainers). (5) Increase the availability of individuals qualified to serve in HIT roles requiring university-level training. (6) Support research focused on problems that have impeded EHR adoption (HHS, 2009).

The Veteran's Health Administration (VHA) is the leading integrated health care system in the America. VHA provides public-sector care to honorably discharged veterans of the U.S. armed forces (Oliver, 2008). In the 1970s,

relevant stakeholders regarded VHA care as poor. Yet, within the last few years VHA's performance of care has improved, which has been attributed to a set of reforms introduced in 1995 as well as a mandated national EHR system in 1999. Today's EHR is accessible to all VHA's providers to capture clinical data such as pharmacy orders, progress notes, and lab results. Asch, McGlynn, and Hogan (Asch, McGlynn, & Hogan, 2004) compared VHA's performance against a national sample of non-VHA patients over a two-year period. Asch et al. reviewed 348 quality indicators across 26 conditions in a broad range of inpatient and outpatient services. Against these quality indicators VHA patients received much better care than did non-VHA patients (Asch et al., 2004). The advances in quality care are contributed to the VHA's development of EHRs (Kupersmith, et al., 2007).

Outcomes of Electronic Health Record Use

This study does not evaluate the quality of outcomes. A review of the outcomes of EHR use helps to clarify the value of this study. In a systematic review of the literature performed in 2005, Clamp and Keen (2005) summarized several studies evaluating EHRs including CPOE systems and radiology picture archiving and communication systems (PACS). Their study showed EHRs significantly improve safety, efficiency, quality and standardization of care. They concluded EHRs are important due to their inherent ability to allow sharing of information, with easy access, at multiple locations. Additionally, EHRs may include systems that assure protocols are followed, safety checks are performed (such as checking for drug interactions), and alerts for clinical values that may be

outside of normal parameters are noted. The integrated electronic health record pulls data from the full continuum of patient care: from physician office through hospital, pharmacy and other outpatient entities. This allows clinicians to gain rapid access to a patient's history, medications, laboratory values, allergies and other vital information for their care.

The research regarding outcomes is also summarized by Chaudhry and Jerome (2006). The authors systematically reviewed 257 English-language literatures from multiple online indexes between 1995 and 2005. Approximately 25% of the studies were from for academic institutions and only nine studies evaluated multi-functional commercially developed systems. The study showed improvements in adherence to guidelines based care, surveillance and monitoring, medication error rates, and preventive health. Additionally a decrease in the utilization of care was shown, but the efficiency of physicians' use of time showed mixed results.

Another multi-hospital study completed by Amarasingham, Plantinga, et al. (2009) evaluated 67,233 patients over the age of 50 years admitted to 41 hospitals in Texas. They found an increase in the automation of notes and records was associated with a decrease in the odds of fatal hospitalizations. They also found higher scores in order entry were associated with decreases in the odds of death for certain cardiac procedures. Overall, higher scores in the use of information technology showed significant reductions in the odds of complications. Higher scores on test results, order entry, and decision support were associated with lower costs for hospital admissions. They concluded,

"Hospitals with automated notes and records, order entry, and clinical decision support had fewer complications, lower mortality rates, and lower costs" (p. 113).

In 2009, Yu, Menachemi, et al. (2009) published "Full implementation of computerized physician order entry and medication-related quality outcomes: a study of 3364 hospitals." The study contrasts quality of care measures for hospitals with CPOE systems with hospitals that have not fully implemented such systems. The study linked hospital quality data from the Centers for Medicare and Medicaid Services to the Healthcare and Information and Management Systems Society Analytics database, which contains hospital CPOE adoption information. They found 8% of hospitals have fully implemented CPOE systems. Those with CPOE were more often larger, not-for-profit and teaching hospitals. The study showed significant positive associations between specific objective quality indicators in medication administration and CPOE implementation.

Theoretical Model

This study uses a heuristic combination of propositions from Resource Dependence Theory (RDT) and Diffusion of Innovations Theory (DI). The model evaluates the rate of adoption and levels of use of individual physicians and seeks to understand how they responded to EHR activation at a hospital where they provided care. It focuses on factors associated with the importance of the resources provided by the hospital, physician-hospital alignment, loyalty and personal characteristics such as age, gender, and specialty. Adoption and use of the EHR is measured by the proxy variables CPOE, EH&P and EDS. Rate of

adoption is a calculation of the amount of time it takes for physicians to reach a pre-defined level of use for each of the proxies. The next section reviews the theories to show the origin of each variable selected for the final model used in this study.

Many studies of the adoption of innovations focus on models in which attitudes mediate the effects of other variables. In an effort to develop a method that eliminates the effects of low response rates and maximizes the efficiency of data gathering, this study does not measure perceptions or attitudes but focuses on using reasonably available administrative data. The variables included attempt to represent appropriate parameters in DI and RDT.

Diffusion of Innovations Theory

Everett Rogers, often considered the father of innovation adoption theory, published five complementary adoption/diffusion theories (Rogers, 1995). Components of Diffusion of Innovations Theory (DI) are listed below (Dearing, 2008).

- The Innovation - One of the Diffusion of Innovation (DI) theories focused on perceived attributes of the innovation. The theory states there are five attributes upon which adoption of an innovation is judged: trialability, observability, relative advantage, complexity, and compatibility. Trialability is based on how well an innovation can be tried out. The observability is a measure of how well the results can be observed. Relative advantage measures the

advantage of the innovation over present techniques. Complexity measures whether the innovation is overly complex or too complex to learn or use. Compatibility measures whether the innovation fits with circumstances or current practice.

- The Adopter - Early adopters tend to be younger, more educated, have higher socio-economic status, have more tolerance for risk, be better networked with others, seek the advice of opinion leaders, work for larger organizations, be less rigid, have more lofty goals, and be more innovation-minded in general. Other research using DI correlated early adoption with successful adoption by peers (Walker, 1969).
- The Social System – Social norms and the structure of the informal opinion leaders create different levels of pressure to adopt.
- The Individual Adoption Process – Awareness, persuasion, decision, implementation and continuation are the theorized phases of normal adoption.
- The Diffusion System – The change agents who seek out adopters and intervene, especially with opinion leaders and champions affect the diffusion rate.

Rogers found that early adoption was primarily associated with importance, space, and time and supported the following propositions:

- Places where it is important to have the innovation adopt the innovation earlier,
- Places geographically closer to where an innovation is first developed tend to adopt earlier than places further away,
- The rate of adoption "follows an S-shaped logistic curve with slow increases in adoptions until a tipping point is reached when adoptions accelerate rapidly, then plateau and increase only slowly to reach the last adopters" (Brown & Cox, 1971, p. 559).

Adopters may be characterized in order as innovators, early adopters, early majority, late majority, and late adopters/"laggards".

In the healthcare system to be studied, the hospital had already successfully implemented the EHR in three hospitals and implementation at the fourth, fifth and sixth hospital is evaluated. Characteristics of the adopter are included in the model such as age, gender, and specialty. Use of an office based EHR are used as a proxy for personal innovativeness.

Resource Dependence Theory

Resource dependence theory is an inter-organizational, open systems theory, published originally by Pfeffer in Salancik (2003), that allows for the evaluation of how organizations interact when they are dependent on each other for resources. In this study, the symbiotic relationship between the hospital organization and physician organizations (individual physicians or groups of

physicians) is evaluated. The theory focuses largely on each organization's desire to be autonomous and is considered a theory about how organizations interact to avoid a loss of power to each other. The theory contains several propositions, one of which posits that the more dependent an organization is on another for its resources, the more likely the dependent organization will be to accept the providing organization's demands. This study includes the evaluation of "physician-hospital alignment" as a predictor of acceptance. It is believed that the physician is one organization/business entity and the hospital is another. It is proposed the more closely a physician is aligned to the hospital implementing the EHR, the more likely the physician is to be an early adopter of the EHR. A highly dependent physician may be an employee of the organization, dependent on the hospital for some or all new patient referrals, or dependent upon the hospital for a place to provide hospital services (e.g. surgery or inpatient care). If a physician provides services and gains referrals at several hospitals, however, the physician has a lower level of dependence on the hospital and may be less likely to accept the hospital's EHR.

Resource Dependence Theory has been applied to the relationship between organizations in many healthcare studies (Goes & Park, 1997; Lucas, et al., 2005; Tian, 2006) but not to evaluate the relationship between physicians and hospitals. In Resource Dependency Theory (RDT), organizations maximize their power based on the exchange of resources. RDT proposes that hospitals seek to gain essential resources by establishing relationships with other organizations. In doing so, they become more dependent on the organizations. Using this

perspective, organizations act as coalitions, adapting their structure and patterns of behavior to acquire and maintain needed resources (Pfeffer & Salancik, 1978). The model for the study is drawn from RDT and literature related to the adoption of innovations. The adoption of innovations may be viewed as an attempt of organizations to gain necessary resources, balancing autonomy with uncertainty. The hospital seeks to increase the volume of patients and procedures performed, whereas the physician seeks to have a place to perform those procedures and may have several hospitals from which to choose.

Resource Dependence Theory has been used to study the adoption of several innovations (Friedman, 1991; Kazley & Ozcan, 2007; Proenca, Rosko, & Zinn, 2000; Tian, 2006). However, only Kazley & Ozcan studied EHR adoption, and that was with respect to hospital adoption of EHR rather than physician adoption of EHR. The purpose of their study was to determine the national prevalence of EHR adoption in acute care hospitals and evaluate the organizational and environmental correlates. They did not describe the use of the theory in their selection of variables. They used a non-experimental, cross sectional design and Logistic Regression for analysis. EHR use was determined from public databases. They found hospital EMR adoption was significantly associated with environmental uncertainty, system affiliation, size, and urban location. Competition, munificence, not for profit status, teaching status, payer mix, and profit margin were not shown to be statistically significant. Institutional, governmental, hospital, environmental, and individual physician characteristics were some of the variables evaluated. Essentially, they concluded that cost and

time are among the most significant barriers to adoption, and HMO, academic or hospital alignment and financial wealth are related to EHR adoption by hospitals.

A study published in 2008 by Bartos (2008) evaluated the perceptions of personal power and their relationship to physician's resistance to CPOE. The researcher developed a semantic differential power perception survey to measure power perception in attitudes of CPOE. A sample of 276 healthcare workers from two hospitals was surveyed before and after implementation of CPOE. The study confirmed a relationship between power perceptions and CPOE attitudes. The study focused on instrument development rather than drawing inferences and suffered from a low response rate. The author, however, articulated the power relationship between physicians and hospitals, writing: "Although, there are some similarities between business and healthcare organizations, the social and working relationships are typically different. In healthcare, clinician work relationships are often more complex with both peer-to-peer and hierarchical structures. For example, a physician may be an independent practitioner at a hospital, which means he/she has no employment status in that hospital. However, the same physician has the authority to direct the work activity of employees of the hospital, to influence decisions made by that hospital, and to directly influence the financial well being of that hospital" (p. 46).

The combined model, integrating the concepts of DI and RDT is illustrated below; each variable is labeled with its theoretical base.

Table 1: EHR Adoption Theories and Predictor Variables Used

Theory/Proposition	Variable Category	Predictor Variables Used	Hypothesized Relationship
DI Theory - Environments with greater trialability, size, observability, or networking adopt earlier	Hospital	Hospital	large, teaching
	Physician Group	Owns physician office EHR	+
		Group Size	Larger
RDT - External Control increases compliance/adoption		Alignment	Higher levels
DI Theory - younger adopt earlier	Individual Physician	Age Group	Younger
		Gender	Male
RDT - Higher Importance of resource increases compliance/adoption		Hospital-based	+
		Discharge Volume	+
		Inpatient Ratio	+
RDT - Higher efficiency of resource increases compliance/adoption		Specialty	medical +
		Loyalty	+

Literature Regarding the Variables

This section reviews key studies on adoption and use of technologies by physicians. Most of the peer reviewed literature applicable to this topic falls into one of the following four categories: 1) hospital adoption of information technology, 2) physicians' outpatient office adoption of EHR, 3) physician acceptance/resistance to CPOE, and 4) physician adoption of innovations. The review begins with predictors of physician adoption, followed by physician group EHR adoption, and hospital (organization level) adoption. Studies of hospital adoption of EHRs are included in this review in order to explain the relationship between the physician and the hospital, which is key to understanding the dynamics from the RDT perspective.

Use of Computerized Physician Order Entry

Physician computer order entry (CPOE) has been the subject of debate since 1970 (Sittig & Stead, 1994). A review article provides an early summary of CPOE in the U.S. Sittig and Stead provide examples of early implementation efforts, review the rationale for CPOE, and summarize many sociologic barriers to CPOE. They provide an analysis of the existing technologies and designs at the time. They conclude that many systems have been implemented successfully while others have failed outright. The rationale for CPOE includes cost-conscious decision-making, physicians' time efficiency, and process improvement. Barriers result from the changes required in physicians' practice patterns, roles within the care team, training, and institutional policies. Sittig and Stead suggest key ingredients for successful implementation include system rate and ease of use, consistency of user interfaces, broad and committed involvement and direction by clinicians prior to implementation, commitment of top leadership, and regular meetings of problem solvers to work out procedural issues. The article summarizes 86 peer-reviewed articles published prior to 1995. While the articles reviewed were older, and generally limited to expert opinions or case studies, they provide a foundation for the remainder of this section.

The results of a survey completed in 2002 attempted to determine the availability of CPOE in the U.S. and the degree to which physicians were using it (Ash, Gorman, Seshadri, & Hersh, 2004). The design combined mail and telephone surveys of 964 randomly selected non-government hospitals. Of the

626 hospitals responding, some form of CPOE was available at 16%. Of 91 hospitals reporting data about inducement, it was mandatory at 46%. At 46% of the hospitals, more than 90% of the physicians used CPOE; 47% reported that fewer than 50% of the physicians used CPOE. Saturation was bimodal, with 35% of the hospitals showing more than 90% of the orders were entered by physicians and 28% reporting that less than 10% of all orders were entered that way. The authors concluded that 9.6% of hospitals had CPOE fully available, and of those that did, less than a third of them had greater than 90% saturation. This study provided useful, although dated information about the use of CPOE. It helped establish "percentage of orders entered into the computer" as a key measure of saturation, or use. It did not, however, differentiate who entered the order or if the physician entered the order directly.

Sittig, Ash, and others, published the results of another survey of hospitals in the United States (2007). The survey focused on the concept of infusion, defined by the authors as "the degree to which one uses an innovation in a more complete and sophisticated manner" (p. 252). The survey had a response rate of 47% (176 hospitals). They found the length of time that CPOE had been in place ranged from six months to 25 years with a median of five years, and the percentage of orders entered electronically ranged from one to 100%, with a median of 91%. The authors concluded there was a high degree of infusion in the majority of institutions surveyed. While this study provides information regarding the level of infusion at hospitals, it does not measure the percentage of orders entered by the physician. Additionally, it does not attempt to describe or

predict the type of physicians who use CPOE. Evaluation of an integrated system remains to be published (Bernier, et al., 2005).

The Agency for Healthcare Research and Quality (AHRQ) published a methodology for measurement of the use of CPOE (AHRQ, 2009). The recommendation provides the formula for calculation, cost considerations and potential risks of using this measure. The formula is %CPOE=(A+C)/(A+B+C), where %CPOE is the percentage of orders entered directly by a physician; A is all CPOE orders entered by the physician; B is all CPOE orders entered based on verbal, face-to-face, or telephone communication with the provider; and C is orders that are standing or protocol orders that are predefined for any clinical or administrative event. The AHRQ set in place clear parameters for measurement of what they consider a benchmark metric.

One of the published studies evaluated order entry rates at two hospitals in 2003 (Lindenauer, et al., 2006). Researchers calculated order entry rates for orders entered directly by the physician and linked the results with a survey that assessed attitudes concerning the influence of CPOE on personal efficiency, quality of care, and patient safety. The CPOE system was implemented several years earlier, however, and the survey was completed years after CPOE implementation. The response rate was 71%, yielding 356 responses. The results showed 22% of physicians' the interfaces were compatible with their workflow, 34% perceived it was faster to enter orders by hand, and 41% perceived CPOE orders were carried out more rapidly. Gender and years since graduation from medical school were not significantly different for the three

categories. Specialty was strongly associated with the use of the system. Anesthesiology, pediatrics and surgery had the largest proportion of high users. Physicians who were trained in a CPOE environment and used computers for personal activities had the highest levels of adoption. Users in the high category were three times as likely to state the interface supported their workflow.

Information published by HIMSS Analytics (HIMSS, 2009) provides a current estimate of the percentage of hospitals with CPOE. They estimate that in 2009, 3.6% of hospitals have CPOE capability with clinical decision support systems (considered Stage 4 of 7 stages in the HIMSS EHR Adoption Model). Further, HIMSS claims that fewer than one percent of EHR systems are at Stage 6, which includes physician documentation using structured templates, full decision support and full Picture Archiving and Communication Systems (PACS) ("Analysis: Less than 1% of U.S. hospitals at stage 6 EMR adoption," 2009). As of July, 2010, the median score for the 5,217 hospitals evaluated by HIMSS was 3.192 (HIMSS, 2010).

In a dissertation published by Morton (2008), use and acceptance of an electronic health record was studied. An online survey of 802 faculty, fellow and resident physicians in a teaching hospital in the southeastern United States was completed. The response rate was 29.8%. The researcher used structural equation modeling to evaluate the variance in attitudes toward electronic health record. The model explains 73% of the variance. The author concluded the following perception variables contribute to physician acceptance of an electronic health record: management support, physician involvement in the selection and

implementation, perceptions of the EHRs influence on physician autonomy, physician-patient relationship, perceived ease of use and perceived usefulness. Training was not a significant predictor of attitudes. The study could not be generalized to a community hospital due to the population it studied. Additionally the response rate was low and the number of responses may limit the power of the conclusions.

Physician Adoption of Other Innovations

Physicians use of information technology, including e-mail communications with patients, clinical decision support using the Internet, and on-line access to professional journals was studied in 2004 (Grant, Campbell, Gruen, Ferris, & Blumenthal). In a survey with a response rate of 53%, CDS was reported as “frequent” in 41% of the physicians, online professional journal access was 39%, and e-mail communication with patients was only 3.4%. The following variables were found to have significant relationships (adjusted odds ratios in parentheses) with use of any of the information technology tools: primary care practice (1.34 to 2.26), academic practice setting (2.17 to 5.41), years since medical school graduation (0.85 to 0.87), and solo/2 person practice (0.21 to 0.55).

“E-detailing” involves using digital technology such as the Internet, video conferencing and interactive voice response. To test a model of physicians adoption of e-detailing and to describe physicians using e-detailing, a mail survey was sent to a random sample of 2000 physicians practicing in Iowa (Alkhateeb &

Doucette, 2009). Binomial Logistic Regression was used to test the model on physician adoption of e-detailing. The independent variables followed Diffusion of Innovations (DI) theory and included relative advantage, compatibility, complexity, peer influence, attitudes, years in practice, presence of restrictive access to traditional detailing, type of specialty, academic affiliation, type of practice setting and control variables. A total of 671 responses were received giving a response rate of 35%. A total of 141 physicians (21%) reported using of e-detailing. The overall adoption model for using either type of e-detailing was found to be significant. Relative advantage, peer influence, attitudes, type of specialty, presence of restrictive access and years of practice had significant influences on physician adoption of e-detailing. The final model of adoption of innovation is useful to explain physicians' adoption of e-detailing.

A systematic review of personal digital assistant (PDA) usage surveys was conducted by Garritty and Emam (Garritty & El Emam, 2006). Reports from eight databases covering both biomedical sciences and engineering were evaluated and verified in a standardized way. Twenty-three relevant surveys were identified, 15 from peer-reviewed journals published between 2000 and 2005. There is clear evidence of an increasing trend in PDA use. The authors summarized their conclusions regarding predictors of use listing the following variables: Younger physicians, residents, and those working in large and hospital-based practices are more likely to use a PDA. They concluded, however, that professional PDA use in health care settings involves more administrative and organizational tasks than those related to patient care.

Shengan et al. collected information from 151 physicians working in the healthcare sector in Finland to evaluate physicians' acceptance of mobile communication technologies (Shengnan, Mustonen, Seppanen, & Kallio, 2006). The authors used concepts from the technology acceptance model plus personal dispositional innovativeness toward information technology (PIIT). The model explained a large portion of the variance in physicians' intentions to use the mobile system (Nagelkerke $R^2 = 0.654$). Specifically, perceived usefulness, the interaction effects of PIIT and age on ease of use, and of age on compatibility were shown to be predictive.

Outpatient Physicians' Office EHR Adoption

With respect to physician and hospital adoption of information technology, Nir Menachemi (2004) is one of the most prolific researchers, having published over 11 articles over the last six years. He published a discussion of variables potentially affecting the adoption of telemedicine. Summarizing these articles, large practice size, specialty practice, young physician age, multi-specialty practice affiliation and low managed care market penetration were significantly related to the adoption of information technologies. Additionally, in a 2007 study he concluded many physicians are only partially adopting EHR technologies, not taking advantage of key safety and cost control functionalities.

The table below summarizes the conclusions from several prominent published studies of physician adoption.

Table 2: Physician Adoption Explanatory Variable Summary

Variable	Positive	Negative	Publication
MD Age		4	(Abdolrasulnia, et al., 2008; Garritty & El Emam, 2006; Grant, et al., 2006; N. Menachemi & R. G. Brooks, 2006; Shengnan, et al., 2006)
Years in practice		3	(Alkhateeb & Doucette, 2009)
Solo practice		2	(Ford, Menachemi, & Phillips, 2006; S. R. Simon, et al., 2007)
Group size (physicians)	4		(Abdolrasulnia, et al., 2008; N. Menachemi & R. G. Brooks, 2006; S. R. Simon, et al., 2007; Steven R. Simon, et al., 2008)
Multispecialty group	2		(Kralewski, et al., 2008; Menachemi, Ford, Chukmaitov, & Brooks, 2006)
Primary care	2		(DesRoches, et al., 2008; Grant, et al., 2006)
Specialty care	1		((N. Menachemi & R. G. Brooks, 2006; Menachemi, Perkins, van Durme, & Brooks, 2006)
Hospital-based practice	1		(Garritty & El Emam, 2006)
Academic practice	2		(Russell & Spooner, 2004; S. R. Simon, et al., 2007)
Personal Innovativeness	2		(Buechner, Baier, & Gifford, 2008; Frank, Sanna, Puumalinen, & Sintonen, 2006; Roback, Nelson, & Persson, 2007; Shengnan, et al., 2006)
Perceived cost		1	(Buechner, et al., 2008)
Perceived compatibility	4		(Al-Gahtani & King, 1999; Alkhateeb & Doucette, 2009; Morton, 2008; Park, 2000; Shengnan, et al., 2006)
Physician-Hospital Alignment	1		(Randeree, 2007)
Admission volume			
Inpatient Ratio			
Loyalty			
Perceived loss of Autonomy		1	(Morton, 2008)

Hospital Organizational Variables and Hospital Adoption of EHR

Three variables in the literature regarding hospitals are considered organizational facilitators for adoption: hospital size, teaching status, and perceived organizational support. Hospital size (measured in number of beds) is evaluated in several studies regarding hospital adoption of information

technology but studies of bed number and teaching status, and their association with information technology adoption, generally focus on hospitals' adoption of information technology rather than the individual physician adoption that happens subsequent to each hospital's determination to adopt the information technology. Some of these studies showing a relationship between size, teaching status and hospital adoption of innovations are described below.

Cutler, Feldman and Horwitz (2005) completed a study of CPOE ownership from the Leapfrog Group's Hospital Patient Safety Survey between 2002 and 2003, provides information regarding hospital ownership but also suggests that ownership and physician resistance are related. The researchers considered two broad theories for low CPOE ownership: financial theories and ownership theories. The survey included 751 hospitals from 19 states. Results showed that teaching hospitals are three times as likely as non-academic hospitals to be progressing towards implementing CPOE systems. They also found that government owned community hospitals were almost three times as likely as nonprofit hospitals, and seven times as likely as for-profit hospitals, to be progressing. This was remarkable since the government owned hospitals included were community hospitals, not federal hospitals, such as the Veterans Affairs Hospitals. System membership and income per admission were not significant predictors. The authors rejected the financial theory and discussed the ownership theory in detail. The results regarding teaching status were not discussed in detail. They suggested one explanation for high government owned facility implementation might be due to the lack of resistance by physicians at

those facilities, due to their beliefs the systems are too complicated or diminish the clinical experience. The authors further suggested that physicians at private institutions might be powerful enough to prevent the adoption at private hospitals.

In another study, Ford and Short used Leapfrog Group data from 2003-2005, linked with 2002 American Hospital Association survey data (2008) to assess group membership and the adoption of CPOE. The researchers found significantly higher rate of adoption of CPOE among health systems with centralized physician/insurance health systems.

One study (Hikmet, Bhattacherjee, Menachemi, Kayhan, & Brooks, 2008) examined how organizational characteristics such as size, geographic location, system membership and tax status affect adoption of healthcare information technology in hospitals. They collected information from 98 Florida hospitals. Results demonstrated the hospital size and system membership, but not geographic location, have a systematic and significant relationship to the level of health information technology adoption, explaining between 28 and 41% of variance.

Ohsfeldt, Ward, et al. (2005), in "Implementation of hospital computerized physician order entry systems in a rural state: feasibility and financial impact," evaluated the costs associated with the implementation of CPOE in hospitals in a rural state. They concluded that the relatively modest benefits in the form of patient care cost savings or revenue enhancement may not be sufficient to offset the costs of implementation for smaller hospitals.

One recently published, large scale study of CPOE adoption by hospitals focused on pediatric care as a predictor (Teufel, Kazley, & Basco, 2009). In 2003, early adoption of CPOE was associated with children's hospitals, private hospitals, urban-teaching hospitals, and hospitals outside of the western region.

Several studies used Resource Dependence Theory (RDT) to evaluate the adoption of various innovations by hospitals (Friedman, 1991; Kazley & Ozcan, 2007; Proenca, et al., 2000; Tian, 2006). Kazley & Ozcan studied hospital adoption of EHR. The purpose of their study was to determine the national prevalence of EHR adoption in acute care hospitals and evaluate the organizational and environmental correlates. They used a non-experimental, cross sectional design and Logistic Regression for analyses. EHR use was determined from public databases. They found hospital EHR adoption was significantly associated with environmental uncertainty, system affiliation, size, and urban location. Competition, not-for-profit status, teaching status, payer mix, and margin were not shown to be statistically significant.

The above studies were generally well designed, but based on information over 5-years old and focused on organizational level adoption. Only one study suggests bed size may be associated with increased information technology use by physicians. The studies evaluated systems at HIMSS Stage 4 and below.

Other Studies Focused on Identified Variables

Physician-Hospital Alignment

No study specifically evaluated physician-hospital alignment and information technology adoption, however, two recent studies evaluated the effects of similar concepts. Hier, Rothschild, et al. (2005) studied "Differing faculty and house staff acceptance of an electronic health record." The authors surveyed 330 faculty and house staff physicians regarding attitudes towards new electronic health record at the University of Illinois at Chicago. House staff physicians perform the majority of their duties in a hospital setting whereas faculty works only a portion of their worked time in a hospital. User acceptance of the EHR was high for both faculty physicians and house staff, but there was a significant difference in the acceptance between the groups. Eighty-eight percent of the house staff and 64.7% of the faculty preferred the EHR to a paper record. The study suggests that physicians who spend a larger proportion of their time in the hospital have a higher likelihood of adoption and adopting faster.

The second study evaluated the role of "perceived threat to professional autonomy" (Zhiping & Lopez, 2008). The author mail surveyed a random sample of 1000 physicians. The response rate was 20% for the EHR portion of the survey and 13% for the clinical decision support (CDS) survey. They concluded that threat to autonomy diminishes perceived usefulness and the intention to use EHRs and CDS. While alignment and autonomy are different concepts, several

studies have concluded that employed physicians are less concerned with autonomy than those in private practice (Hoff & McCaffrey, 1996) .

Summary of Literature Reviewed

The literature regarding the adoption of innovations is extensive, with studies dating back into the 1980s using a variety of theoretical models. The majority of research regarding the adoption of technology by individuals uses the technology acceptance model or a variation of that model. The technology acceptance model relies on information gained regarding an individual's perceptions or attitudes of a particular innovation. Gaining information through surveys can be difficult and time consuming. Additionally the majority of studies had a relatively low response rate, raising the question of response bias. Most of the research performed focused on the adoption of innovations by hospitals or physicians' offices. Some of the newer studies focused on the acceptance of technologies by physicians.

Some of the limitations of the studies include the following. Most samples include only hospitals that are tertiary-care, teaching hospitals. These samples may not be representative of typical community hospitals or hospitals that are part of a multi-hospital system. Multi-hospital systems are becoming more common (USDOL, 2010) and the effects of system membership has only been evaluated to a limited degree. Most of the EHR systems evaluated were basic CPOE technology and not part of an integrated EHR of HIMSS Stage 5 or above.

There were few HIMSS Stage Seven EHRs in existence, and studies regarding their use had not been published.

With respect to the variables, the evaluation of the percentage of orders entered directly by the physician is a newly accepted proxy for measuring the use of EHRs by physicians. No studies performed an evaluation using the formula recommended by the AHRQ. The studies consistently showed hospital adoption of EHRs is related to the number of beds, teaching status and perceived organizational support.

The adoption of EHRs by physician groups appears to be related to the size of the group, government ownership and employment. The results for physician specialty are mixed. Some studies showed primary care physician groups are more likely than specialized physician group to implement an EHR while others showed some specialized physician groups as more likely to implement than primary care physician groups.

Individual adoption of information technology by physicians is generally negatively associated with age and positively associated with hospital-based physicians or employed physicians. Most of the studies evaluated information technology adoption such as the use of personal digital assistants, or the use of e-mail, rather than the use of an EHR. Once again, the results with respect to specialty were mixed. Studies of personal innovation showed a strong relationship between personal dispositional innovativeness and the use of the World Wide Web, mobile communications, and PDAs.

With respect to alignment, no study specifically evaluated alignment or loyalty. Studies evaluated the desire for autonomy or power, showing a negative association between information technology adoption and those desires. Only one study evaluated market saturation as a predictor of adoption, showing a positive relationship between market saturation and the use of electronic detailing. Physician-hospital alignment is a rapidly growing phenomenon and the current research with respect to EHR use is limited to expert opinion.

Multiple studies show the relationship between the perceived ease-of-use, perceived usefulness, compatibility and the use of information technology. These studies used the technology acceptance model and showed various direct and mediated relationships. The majority of these studies, however, had low response rates; none of them addressed the adoption of an EHR. No study evaluated the adoption of EH&P or EDS.

CHAPTER III

METHODOLOGY

This chapter provides a detailed view of the research methodology used in the study. The main purpose of the study is to create a parsimonious model predicting physician adoption and levels of use of the integrated electronic health record using organizational and individual level predictors. A primary goal of the study was to create a pragmatic model that offers the greatest utility for administrators who are interested in potentially implementing an EHR. The administrators want to predict the degree of acceptance their organizations may expect based on information from a successful implementation in an integrated health system. Administrative data regarding organizational variables, EHR implementation status, and individual variables such as physician specialty, age, gender, alignment and admission volume are readily available to most hospital administrators. This study develops a reasonably predictive model using administrative data alone, without the labor and time delay of surveying physicians to gain information about their perceptions.

Population

Sentara Health Care is an integrated health system in Southeastern Virginia, the 33rd largest metropolitan area in the United States, with a population of approximately 2 million people. Sentara is comprised of ten hospitals, seven nursing homes, three assisted living centers, an extended stay hospital, a 400 physician medical group, a 415,000 member health plan, a College of Health

Professions and a variety of ancillary and community-based services. Six of the ten hospitals have implemented the EHR (referred to as "eCare"). The seventh hospital implemented eCare in late 2010, after the conclusion of this study. The eighth hospital merged within the last month and was not included in this study. The medical staffs of the three most recent hospitals to activate eCare are the focus of this study. These hospitals were selected because they represent a combination of tertiary and community hospitals and the EHR implementation processes were considered stable prior to their activation. The combined medical staffs of these three hospitals consist of approximately 700 physicians.

Description of the eCare EHR

eCare is a robust clinical data repository with software that automates many of today's manual processes. It includes single-view access for integrated results retrieval, computerized order management, access to protocols, decision support tools, clinician documentation and tools for physician rounding. eCare is a customized application of Epic(tm) software that replaces information from many software applications that were previously either independent or interfaced through an interface engine. The Healthcare and Information and Management Systems Society (HIMSS) developed a staging system for categorizing EHR systems (HIMSS, 2009). The stages range from zero to seven. At Stage 0, all three ancillary systems (lab, pharmacy and radiology) are not installed. The largest share of hospitals falls into Stage 3 (38%). Stage 3 includes clinical documentation, clinical decision support, and imaging (PACS) outside of the radiology department. The eCare system in this study is a Stage 7 system,

described by HIMSS: "The hospital no longer uses paper charts to deliver and manage patient care and has a mixture of discrete data, document images, and medical images within its EHR environment. Clinical data warehouses are being used to analyze patterns of clinical data to improve quality of care and patient safety. Clinical information can be readily shared via standardized electronic transactions with all entities that are authorized to treat the patient, or a health information exchange (i.e., other non-associated hospitals, ambulatory clinics, sub-acute environments, employers, payers and patients in a data sharing environment). The hospital demonstrates summary data continuity for all hospital services (e.g. inpatient, outpatient, ED, and with any owned or managed ambulatory clinics)." Less than ten hospital systems in the United States currently have installed Stage 7 EHRs. HIMSS Stage 7 EHRs represent a huge leap in functionality, ease of use and access to data. By definition, the data is easily accessed, analyzed and used to improve healthcare systems. To emphasize the extent of the change involved in the activation of the EHR, the bulleted list below lists the software applications replaced by eCare, describing each briefly.

- Eclipsys TDS™: Hospital clinical information system used by clinical staff and physicians for orders, results and documentation.
- Eclipsys Careminder™: Nurse documentation system used in conjunction with TDS.

- Eclipsys Sunrise Clinical Manager™: Pharmacy medication order entry system used in conjunction with TDS and Pyxis (an automated, decentralized pharmacy dispensing system for use by physicians and nurses).
- TempusOne™/ Physician Web Scheduler: Ancillary services scheduling system used in the hospitals, rehab centers, Ambulatory Care Clinic, diagnostic and Advanced Imaging Centers. Physician Web Scheduler is a Web-based front end application that enables physician practices to directly schedule into Sentara facilities that use TempusOne.
- IDX™ (scheduling component only): Used in the Sentara Medical Group (SMG) physician practices. (SMG is owned by Sentara Healthcare; these physicians are employed by Sentara Healthcare.)
- Locator: Systems used in hospital health records departments for tracking the paper medical chart, recording release information and documenting deficiencies.
- Cerner FirstNet™: Emergency Department system for triage, tracking, discharge instructions and discharge prescriptions.
- Lynx™ : Emergency Physician charting templates.
- Navmanager™: Bed-capacity system used in the hospitals.

- Carevision™: Provides physician access to transcribed reports and results retrieval via the physician portal.

As stated earlier, eCare is a comprehensive EHR system. It integrates information from over 10 stand-alone or partially interfaced applications into one database.

Physician Training Program

The physician training program provided by the eCare physician implementation team is described below. Physicians have the option of completing the first two of the three classes online, however, the third class must be attended in person to assure competency evaluation. Physicians are expected to demonstrate an 80% proficiency level in order to receive their final password. The training program is standardized for all users but resource personnel are available at each location during the go-live and via a "help desk" after the first week. The education is grouped into the following modules.

Table 3: Curriculum for eCare Physician Training

Part 1: Four Hours Chart Access	Part 2: Four Hours Clinical Documentation	Part 3: Four Hours - In Person Order Management (CPOE)
Open a Patient's Chart Review a Patient's SnapShot, 24 Hr. Summary, VS, Co-Sign Orders Review Administered Meds Managing the Problem List Review New Notes Review Prior Encounters Analyze and Graph Results Review Allergies Review Past Medical, Surgical and Family History Review ED Info Computer Based Training on MDoffice	Managing the Problem List In Basket Basics Assign Attending Provider Creating Notes (H&P, Progress Notes) Co-Sign Notes Cancer Staging Review Info Prior to D/C Place D/C Orders and Prescribe Meds (Medication Reconciliation) Write a D/C Summary Computer Based Training	Ordering Basics Admission – Order to Admit and Quick Admission O/S Expected D/C date Rounding – Additional Orders MD Navigator/Order Management. Anticoagulation, Insulin & Transfusion O/S Transfer –Order Reconciliation Discharge – Order Reconciliation Additional Navigators – Procedure, Outpatient Visit & Death Outpatient workflow review

In addition to the initial training, a team of expert trainers and support personnel were readily available and stationed in the clinical areas for the first six weeks after activation. Sufficient numbers of support personnel were available to

assure physicians would have access to help with a few minutes of a request. These support personnel wore a specific uniform to make them readily identifiable (calling themselves “black shirts”) and actively offered support and assistance in addition to being available on request.

Implementation Schedule

The hospitals implemented eCare according to the following schedule. The last three hospitals are included in the study.

Table 4: Hospital Activation Schedule

Hospital (acronym)	**Size/Status**	**Go-live Date**
Sentara Leigh Hospital (SLH)	250 Bed / Teaching	2/24/08
Sentara Bayside Hospital (SBH)	158 Bed / Community	9/21/2008
Sentara Virginia Beach General Hospital (SVBGH)	274 Bed / Community	10/26/2008
Sentara Norfolk General Hospital (SNGH)	569 Bed / Teaching	3/27/2009
Sentara Williamsburg Regional Medical Center (SWRMC)	139 Bed / Community	9/12/2009
Sentara CarePlex Hospital (SCH)	205 Bed / Community	11/7/2009

Definitions of Terms and General Concepts

Dependent Variables

- Use: The primary measures of "use" are the three dependent variables - CPOE, EH&P and EDS. Use was measured by the number of tasks completed using the EHR divided by the total number of tasks completed by any method. This definition matches the formula recommended by the Agency for Healthcare Research and Quality (AHRQ).

- Adoption: This term is synonymous with "acceptance" and defined as the initial achievement of the 80% rate of use recommended by the Centers for Medicare and Medicaid Services (CMS, 2010).

- Rate of CPOE adoption: The number of months between a physician's first use of the EHR and a physician's initial achievement of an 80 percent level of CPOE use. The range of values is between one and six. If a physician adopts during the first month the value is one; the second month the score is two… the sixth month the score is six.

- Rate of EH&P adoption: The number of months between a physician's first use of the EHR and a physician's initial achievement of an 80 percent level of EH&P use. The range of values is between one and six. If a physician adopts during the first month the value is one; the second month the score is two… the sixth month the score is six.

- Rate of EDS adoption: The number of months between a physician's first use of the EHR and a physician's initial achievement of an 80 percent level of EDS use. The range of values is between one and six. If a physician adopts during the first month the value is one; the second month the score is two… the sixth month the score is six.

Hospital

- Hospital: An institution where the sick or injured are given medical or surgical care (Merriam-Webster, 2010). Hospitals are commonly categorized by the number of beds they hold, the level of service they provide and whether or not they are affiliated with a medical school (academic status). Service levels are generally divided into two groups. Secondary level "community hospitals" provide the most commonly needed services such as maternity care and refer patients to larger tertiary level hospitals as needed. Tertiary level hospitals often have trauma centers, burn units and provide complex or less common services such as open heart surgery.

Physician Group Variables

- Uses EHR in office: Physicians who had an electronic data system to store and view medical and treatment information about patients in use prior to activation of the hospital EHR. A medical office billing system does not qualify.

- Group Size: Physician groups were be categorized based on the count of physicians in a physician business group. There are five categories:

    1. one or two physicians,
    2. three to ten physicians,
    3. eleven to thirty physicians,
    4. thirty-one to 100 physicians, and
    5. greater than 100 physicians.

- Alignment Category (or Physician-Hospital Alignment Category): The degree of exclusivity, either contractual or voluntary, in the relationship between a physician and a hospital. Alignment is an ordinal variable with the following four categories:

    1. performs care at the organization but is employed by a competing organization,
    2. performs care at the organization but has no financial arrangements with the organization,
    3. performs care at the organization and maintains an exclusive contract with the organization, and
    4. employed by Sentara.

Individual Physician Variables

- Primary Hospital: The hospital within the Sentara Healthcare system where the physician first uses the EHR being activated.

- Specialty: The category of services in which the physician has privileges to practice and is board certified or board eligible. For this study, the specialties were categorized as either medical or surgical.

- Hospital-based: Hospital-based physicians primarily provide care at the hospital for patients referred to them by community-based physicians. They may have private offices for seeing patients on a limited basis. Examples include but are not limited to hospitalists, medical intensivists, radiologists, pathologists, and emergency physicians.

- Admission: A patient encounter at a hospital resulting in a billable clinical episode by the hospital and physician, either inpatient or outpatient. For example, an inpatient stay is one admission; an outpatient diagnostic or surgical procedure is one admission. Most outpatient diagnostic tests are not considered an admission since the services are not performed by a physician and a history and physical and/or discharge summary are not required. An admission is counted at the time of the patient's discharge from the hospital so the terms "admission" and "discharge" are used synonymously.

- Discharges: A measure of the number of patients admitted to the hospital but the count is taken when the patient leaves the hospital. The terms "admission" and "discharge" are used synonymously.
- Inpatient Ratio: This ratio measures the ratio of patients treated as inpatients divided by the total number of inpatients and outpatients based on eCare reports during the study period.
- Inpatient Admission: A patient encounter in which the patient is admitted under the care of a physician, for a specific problem or treatment, for at least 24 hours.
- Outpatient Admission: A patient encounter in which the patient is treated or evaluated by a physician but the patient either does not stay in the hospital over 24 hours or does not meet "inpatient criteria" as defined by the patient's insurance provider. Examples include outpatient surgery, cardiac catheterization, endoscopy and observation up to 72 hours.
- Loyalty: The percentage of all inpatient admissions at all hospitals completed at the healthcare system activating the EHR.
- Loyal 100%: This dichotomous variable groups physicians into two groups. The first group represents physicians who admit patients to hosptials in the system being studied and to competing hospitals. The

second group represents physicians who only admit patients to hospitals in the system being studied. .

Other Key Terms

The following terms are not predictor variables but require clear definitions.

- Activation: The date the hospital began using the eCare system, also known as "go-live" or the "implementation" date.
- Admitting Physician: An independent practitioner, licensed by the Board of Medicine, who directly supervises the care for a patient while the patient is in the hospital (refer to "admission" above). This research evaluates only admitting physicians and excludes physicians who do not provide services to patients who are admitted for overnight hospital stays.
- CPOE: Computerized Physician Order Entry refers to the use of EHRs by providers to input medical orders directly into the EHRs. The EHRs generally have clinical decision support systems in place to alert users of potential errors such as overdosing of medications or combinations of medications that may interact negatively.
- eCare: The EHR implemented by the healthcare system being studied.

- EHR: Electronic Health Record is an automated medical record used for review and entry of health information. There are many levels of EHRs described in the literature review. The terms EMR (electronic medical record) and EHR are used interchangeably.
- Information Technology: Electronic devices used for the analysis or conveyance of information, including computer and communication devices such as cell phones and personal digital assistants.
- Survival Analysis: A statistical method for the analysis of time until an event or time between events (Daniel, 2005).

Data Sources

Administrative data were downloaded by authorized Sentara personnel from two sources. Each source database included the physicians' Universal Provider ID Number (UPIN), name or other unique identifying number. The de-identification of information was be performed by Sentara personnel and is described in the protection of human rights section.

The first data source was maintained by the eCare administrative team. The team tracks the use levels for over 20 types of tasks performed by the provider using eCare. This database provided the data for the fields CPOE, EH&P, EDS, discharges and specialty for each physician.

The second data source was the Sentara Corporate Strategic Services Physician Database. This database of nearly 1,200 records includes most

physicians in the Sentara service area. Fields include age, group name, primary hospital and other demographic and business data. The database includes discharge data from Virginia Health Information, Incorporated, also known as VHI. VHI captures inpatient and outpatient discharge information from every public hospital in the Commonwealth of Virginia. VHI database information is converted by the Sentara corporate strategists into "inpatient ratio" and "loyalty" variables. The database is maintained quarterly by personnel at Sentara.

The data fields collected and the sources of data are provided below in Table 5.

Table 5: Data Fields and Sources

Variable	Scale	Source
Hospital	Nominal	Sentara Strategic Planning Data
Alignment	Ordinal	Sentara Strategic Planning Data
Owns physician office EHR	Dichotomous	eCare Data
Physician Group Size	Ordinal	Sentara Strategic Planning Data
Age Group	Interval	Sentara Strategic Planning Data
Gender	Dichotomous	Sentara Strategic Planning Data
Discharges	Ratio	eCare Data
Discharge Quartile	Ratio	Calculated
Specialty	Nominal	Sentara Strategic Planning Data
Hospital-based	Dichotomous	Sentara Strategic Planning Data
Inpatient Ratio	Interval	Sentara Strategic Planning Data
Inpatient Quartile	Ratio	Calculated
Loyalty	Ratio	Sentara Strategic Planning Data
Loyal 100%	Dichotomous	Calculated
CPOE Adoption Month	Interval	Calculated
EH&P Adoption Month	Interval	Calculated
EDS Adoption Month	Interval	Calculated

Protection of Human Subjects

Appropriate approval to assure the protection of human rights was obtained prior to commencing this study through Old Dominion University's College of Health Sciences Human Subjects Committee and Eastern Virginia Medical School's Institutional Review Board. Final approval was granted on November 23, 2010, protocol number 10-11-NH-0217. This is a non-experimental study involving the retrospective collection of de-identified administrative data. Patient level information was not accessed at any time. Data in this study were collected at the physician level. Sentara employees used the following process to perform a careful de-identification of the information provided. Information from the two data sources was linked into one database by Sentara employees appropriately granted access to the confidential information. After the data sources were linked, these employees removed any identifying information. The de-identified data was then provided by Sentara officials to the investigator. Analysis and reports were done at an aggregate level to assure no individual physician could be identified deductively.

Data Collection

Data collection for this study is described in this section. The sample was determined by a combination of the eCare reports listing all physicians who have provided care for patients in any Sentara facility during each monthly period and Strategy Department reports providing physician organization information. The sample was defined as all physicians who

- admitted at least 10 patients during the six months after activation of the EHR,
- admitted patients at least three of the six months, and
- did not admit patients to one of the three hospitals that activated the EHR earlier.

These inclusion and exclusion criteria assure the data analyzed includes the admitting physicians who provide the greatest proportion of care, reduce the amount of missing data in the analyses and eliminates physicians who were exposed to eCare earlier.

Physicians who cared for patients at more than one hospital were included only at the hospital where they first used the EHR. The information was gathered monthly for six months after each hospital's activation. The eCare database and the strategy department's database were linked using the physician identifiers described earlier. The resulting database captured information for 326 physicians representing 42 percent of all admitting physicians. These physicians admitted 83.6 percent of the total number of patients during the study period. The remaining physicians were excluded as described in the table below. The data from the strategy department did not include all providers resulting in the elimination of 14 physicians who performed two percent of the admissions. Fifty-five physicians were eliminated because they showed evidence of admitting to one of the hospitals that activated eCare at an earlier date. Since all of the excluded physicians also worked at The large, academic hospital, the

distributions of the variables for the excluded 55 physicians were compared to the physicians included in the study. The distributions were not significantly different with the exception of one variable: age category. The excluded group had a significantly smaller proportion of physicians in the youngest age category compared to the included group from The large, academic hospital.

Table 6: Sample Cleanup

Sample Data Reduction	Physicians	Discharges	Mean Discharges per Physician
Total Admitting Physicians	784	100,818	129
Subtract Physicians with Less than 10 Discharges	-284	-905	3.2
Subtract Physicians with Less than Three Months of Data	-105	-2,203	21
Subtract Physicians with a Lack of Matching Data in Strategy Database	-14	-2,160	154
Subtract Physicians with Prior Exposure to eCare	-55	11,224	204
Total in database	326	84,326	259

Data Analysis

Descriptive statistics and graphics were performed using SPSS™ software. Some graphics were created Microsoft Excel™. Hypotheses were tested using SPSS software. A critical value of $p<.05$ was used for the rejection

of all null hypotheses. Power was calculated for the Cox and Logistic Regression models using R2 software (Steiger & Fouladi, 1992). For example, a conservative estimate of power with a small percentage of variance explained, a sample size of 300, 20 variables, R^2 of 0.1 and alpha of 0.05, the power was calculated as 0.96. The power rises to 0.999 if the R^2 rises to 0.2. Cohen suggests effect size is medium for an R^2 between 0.3 and 0.5 and small for R^2 values between 0.1 and 0.2 (Valentine & Cooper, 2003). These calculations suggest adequate power (>0.80) for this sample size and number of variables, even for models with a limited amount of explained variation.

The month of adoption was entered manually for each physician during a visual review of each data record. Those who did not achieve an 80% level of use by the end of the six months were coded as censored. Manual entries were rechecked to assure input accuracy.

Analysis of physicians who adopted versus those who did not adopt by the end of the six months was performed for each of the three measures of use. Inferential analysis of adoption was performed using Chi-square analysis followed by predictive analysis using Logistic Regression. The rate of adoption was evaluated using survival analysis techniques including Kaplan-Meier tables, log-rank and Cox proportional hazards regression techniques. Kaplan-Meier and log-rank tests are nonparametric tests appropriate for right censored data (Tabachnick & Fidell, 1996). Censored cases are those which do not meet the criteria for the event (adoption in this case) during the period studied. Cox Regression is a semi-parametric technique that allows the evaluation of an event

over time without the requirements of normally distributed variables. Cox Regression and survival analysis techniques have the advantage of using all data including censored data. Ignoring the censored data is likely to produce severe biases (Allison, 1984). Using Cox Regression, all of the variables in the model were entered into the equation. Collinearity was evaluated and two variables had to be eliminated. Group size category and EHR in office showed high levels of multicollinearity with alignment. The strengths of the individual variables with respect to their individual odds ratios, their alpha significance and the pseudo R^2 were considered in the determination of the best models of rate of adoption. Pseudo R^2 was calculated for the Cox Regression using the formula: $R^2 = 1 - e(-G^2/n)$, where G^2 = [(-2log-likelihood for smaller model) - (-2 log-likelihood for larger model)], provided by Tabachnick and Fidell (1996, p. 538). Variables were eliminated from the equation one at a time and the model re-run to evaluate changes in the R^2, seeking the most predictive yet parsimonious models.

Hypotheses and Statistical Methods

Due to the large number of hypotheses, the hypotheses are presented in an abbreviated manner, followed by tables detailing the hypothesis number and the proposed association between the independent and dependent variables.

Research Question One: What variables predict which physicians adopt (achieve an 80% use rate) an electronic health record by six months after activation? Hypotheses were evaluated using bivariate Chi-square analysis

followed by multivariable Logistic Regression to test the predictive value of the variables adjusted for each other.

Null hypotheses: None of the variables will significantly predict adoption of CPOE, EH&P or EDS when the variables are adjusted for each other.

Alternative hypotheses: Variables in the heuristic model will significantly predict the adoption of CPOE, EH&P or EDS when adjusted for each other.

Research Question Two: What variables predict the rate of adoption (the number of months between activation and achievement of an 80% use rate) of an electronic health record by admitting physicians? Hypotheses were evaluated using bivariate Kaplan-Meier survival analysis followed by multivariable, semi-parametric Cox Regression to test the predictive value of the variables adjusted for each other.

Null hypotheses: None of the variables will significantly predict the rate of adoption of CPOE, EH&P or EDS when the variables are adjusted for each other.

Alternative hypotheses: Variables in the heuristic model will significantly predict the rate of adoption of CPOE, EH&P or EDS when adjusted for each other.

Table 7: Variables and Hypothesis Numbers

	Adoption by 6 Months			Rate of Adoption		
Variable	CPOE	EH&P	EDS	CPOE	EH&P	EDS
Hospital	1	13	25	37	49	61
Alignment	2	14	26	38	50	62
Owns physician office EHR	3	15	27	39	51	63
Group Size	4	16	28	40	52	64
Age Group	5	17	29	41	53	65
Gender	6	18	30	42	54	66
Specialty	7	19	31	43	55	67
Hospital-based	8	20	32	44	56	68
Discharge Quartile	9	21	33	45	57	69
Inpatient Quartile	10	22	34	46	58	70
Loyalty	11	23	35	47	59	71
Multivariable Hypotheses	12	24	36	48	60	72

Table 8 below, shows the hypothesized relationship of the independent and dependent variables.

Table 8: Hypothesized Relationship of Independent Variables to Adoption Outcomes

Variable	Hypothesized as More Likely to Adopt and More Likely to Adopt Faster for Each Dependent Variable
Hospital	Large, teaching
Alignment	Higher Levels
Owns physician office EHR	Owns
Group Size	Larger Groups
Age Group	Younger
Gender	Male
Specialty	Medicine Specialists
Hospital-based	Yes
Discharge Quartile	Higher
Inpatient Quartile	Higher
Loyalty	Higher

Discussion of Methodology

This study evaluated the use of the EHR by physicians using administrative data from a sample of physicians in who worked at three hospitals in a large health system. The hospitals selected for evaluation activated the care system within nine months of each other. The software, hardware and implementation and training methods were consistent and stable. The hospitals include two community hospitals and one large, academic hospital in order to provide it a better cross-section of a typical hospital system. The sample includes physicians who admit the greatest proportion of patients. The sample excludes low volume admitters and physicians who admitted during less than

three of the six months evaluated. Some physicians within the hospital setting, such as radiologists, emergency physicians and anesthesiologists, provide services to many patients but often do not act as the admitting physician of record for patients. Fifty-five physicians were eliminated from the data for one hospital due to prior exposure to eCare. An analysis was completed to assure the sample for that hospital was not biased due to that exclusion. The study evaluates two key concepts: *overall adoption and the rate of adoption for each* physician. The research questions and hypotheses guided the statistical analyses performed.

CHAPTER IV

RESULTS

There were three dependent variables representing functions in the electronic health record (EHR). Two questions were asked about each function: 1) what variables predict adoption by six months after activation and 2) what variables predict the rate of adoption. This chapter presents the results of the statistical analysis of data. First, is a general summary of the data and descriptive statistics. Second, the results for the research questions are presented in the order of the research questions and hypotheses. Third, the chapter finishes with a comparative summary and conclusions regarding hypotheses. Chapter V provides a discussion of the results.

The data analysis began with the evaluation of frequency distributions to determine if variables met the assumptions of the proposed parametric tests. Tables 9 and 10 provide the descriptive statistics for the variables. Based on the distribution of physicians for each variable, some independent variables were categorized into quartiles or dichotomies in order to reduce skewedness and eliminate outliers. Assumptions for the use of Logistic Regression and Cox Regression were met and the tests were selected as an acceptable method for evaluation of adoption and rate of adoption.

Descriptive Statistics

The number of physicians at each hospital was approximately proportional to the number of beds at each hospital. For alignment, the largest group was

independent physicians and the smallest was physicians employed by competing health systems. About 33% of physicians were employees of either the system studied or a competing system. Seventeen percent of physicians had an EMR in their office. Group size was skewed with the largest proportion of physicians belonging to groups of 100 or more. Male physicians comprised 78 percent of the overall total. Age had an approximately normal distribution among the three categories. Fifty-seven percent of physicians were medical specialists versus surgical specialists. Hospital-based physicians comprised 18% of the sample. The tables below provide descriptive statistics for the number of physicians in each category.

Table 9: Descriptive Statistics for Categorical Predictor Variables

Variable	Category	N	Percent
Hospital	Large, academic	173	53%
	Small, community	72	22%
	Mid-sized, community	81	25%
Alignment	Competing	30	9%
	Independent	154	47%
	Contracted	65	20%
	Employed	77	24%
EMR Office	No	272	83%
	Yes	54	17%
Group Size Category	<3	39	12%
	3 - 10	65	20%
	11 - 30	38	12%
	31 - 100	76	23%
	>100	108	33%
Age Category	<40	70	21%
	40-54	163	50%
	55+	93	29%
Gender	F	71	22%
	M	255	78%
Specialty	Medical	187	57%
	Surgical	138	42%
Hospital-based	No	265	81%
	Yes	60	18%
Loyal 100%	No	112	34%
	Yes	214	66%

Table 10 provides descriptive statistics for continuous predictor variables. The number of discharges was skewed with a mean of 259 and a median of 163. About one-third of the physicians in the sample provided inpatient services and no outpatient services. The average loyalty was 88% with three of every four physicians being 100% loyal, admitting only to Sentara hospitals. In order to allow Kaplan-Meier survival analysis of the number of discharges, inpatient ratio and loyalty ratio, new variables were created dividing the first two variables into

quartiles and loyalty into a dichotomous variable representing 100% loyal versus those who also service other hospitals (commonly called "splitters").

Table 10: Descriptive Statistics for Continuous Predictor Variables

Variable	N	Mean	Std. Error of Mean	Median	Mode	Std. Deviation	Skewness	Kurtosis	Range	Minimum	Maximum
Count of Discharges	326	259	15	163	10	273	1.48	2.11	1,398	10	1,408
Inpatient Percent	326	0.68	0.02	0.77	1.00	0.32	-0.67	-0.82	1.00	0.00	1.00
Loyalty Percent	326	0.88	0.01	1	1.00	0.24	-2.14	3.31	0.94	0.06	1.00

Results for Research Questions

Bivariate analyses were performed as standard preparation for multivariable analyses. For this reason, the multivariable results for each dependent variable immediately follow each the bivariate results for that variable. The Chi-square test provides omnibus results that are conclusively interpreted for dichotomous comparisons. Since there are no post hoc tests, when more than two categories are compared the differences in the results were reported descriptively. The multivariable results that follow the bivariate results for each dependent variable adjust for each of the independent variables and provide odds ratios for each category in addition to levels of alpha significance.

The results are organized in the following manner for each research question:

- CPOE: bivariate results, multivariable results;
- EH&P: bivariate results, multivariable results;
- EDS: bivariate results, multivariable results; and
- Comparison of the multivariable results for the three functions.

Research Question One

This section reviews the results of the first research question: What variables predict which physicians adopt (achieve an 80% use rate) of an electronic health record by six months after activation?

Bivariate Results of CPOE Adoption

Bivariate results using Chi-square analysis revealed differences in the proportion of adopters versus non-adopters for each dependent variable, by independent variable. Table 10 displays the summary information for the bivariate tests for CPOE. The Chi-square test provides omnibus results that are clearly interpreted for dichotomous comparisons. Since there are no post hoc tests, when more than two categories are compared the significant differences in the results are reported descriptively. The multivariable evaluation in the next section adjusts the results for CPOE by each independent variable and provides odds ratios for each category in addition to levels of alpha significance.

Five of the eleven variables had significant associations with CPOE adoption. Hospital, alignment, EHR in office, group size and hospital-based were

significant while age, gender, discharge volume, inpatient ratio and loyalty were not significant. The large, academic hospital had the lowest percentage of adopters, opposite the hypothesized relationship. Employed physicians had the highest percentage of adopters, consistent with the hypotheses. The second highest percentage was for competing physicians, contrary to hypotheses. EHR in office was hypothesized to have a positive association with adoption. The bivariate association for EHR in office was opposite what was expected for CPOE (OR = .17). Bivariate results for group size were significant but mixed. Physicians in groups with between 31 and 100 physicians had the lowest percentage adopt while the largest groups had the highest percentage adopt. Hospital-based physicians were hypothesized to have a higher percentage of adopters than those who were not hospital-based and the results supported that hypothesized association (OR = .40) .

Table 11: Bivariate Analysis of CPOE Adoption by Six Months

Variable	Category	N	Adopted	Adopted Percent	Likelihood Ratio	df	Sig.
Hospital	Large, academic	172	129	75%	21.510	2	0.000
	Small, community	72	69	96%			
	Mid-sized, community	80	72	90%			
Alignment	Competing	30	28	93%	31.988	3	0.000
	Independent	153	126	82%			
	Contracted	65	42	65%			
	Employed	76	74	97%			
EMR Office	No	270	239	89%	26.043	1	0.000
	Yes	54	31	57%			
Group Size Category	<3	39	33	85%	32.008	4	0.000
	3 - 10	64	52	81%			
	11 - 30	38	32	84%			
	31 - 100	76	50	66%			
	>100	107	103	96%			
Age Category	<40	70	62	89%	2.418	2	0.298
	40-54	161	134	83%			
	55+	93	74	80%			
Gender	F	71	55	77%	2.207	1	0.137
	M	253	215	85%			
Specialty	Medical	186	155	83%	0.00	1	0.954
	Surgical	138	115	83%			
Hospital-based	No	264	215	81%	4.124	1	0.042
	Yes	60	55	92%			
Discharge Quartile	1	83	74	89%	5.929	3	0.115
	2	79	67	85%			
	3	81	68	84%			
	4	81	61	75%			
Inpatient Quartile	1	81	71	88%	1.471	3	0.689
	2	83	64	77%			
	3	77	63	82%			
	4	83	72	87%			
Loyal 100%	No	112	89	79%	1.898	1	0.168
	Yes	212	181	85%			

Multivariable Analysis of CPOE Adoption

Logistic Regression was conducted to assess how well the eleven variables significantly predicted whether a physician adopted CPOE. The variables "group size" and "EHR in office" were eliminated from the analysis due to being highly collinear with "alignment". Logistic Regression was performed using the remaining nine predictor variables. Then, variables that were not significant were methodically eliminated (as described in Chapter III), producing the parsimonious model below. When the remaining predictor variables were considered together, they significantly predicted whether a physician adopted CPOE (χ^2 = 221.834, df = 17, N = 326, p<0.000). The Nagelkerke pseudo R^2 showed 66% of the variance was explained. Table 11 presents the results. The Logistic Regression for CPOE suggests the odds of adoption are:

- higher for the small community hospital (OR = 8.5) and the mid-sized community hospital (OR = 3.6) compared to the larger, teaching hospital,
- men compared to women (OR = 3.2),
- lower for physicians in the top quartile (over 132) of discharges compared to the first quartile (under 36) of discharges (OR = 0.34), and

- higher for physicians in the fourth quartile (over 98%) of inpatient ratio compared to the second quartile (under 46%) of inpatient ratio (OR = 3.8).

Age, hospital-based, specialty, and loyalty were not significant predictors of adoption of CPOE by six months once adjusted for other variables.

Table 12: Logistic Regression for CPOE Adoption by Six Months

Variable	Level	B	S.E.	Wald	df	Sig.	Exp(B)
Hospital	1	Reference category		15.726	2	0.000	
	2	2.143	0.663	10.443	1	0.001	8.522
	3	1.278	0.462	7.642	1	0.006	3.589
Alignment	1	Reference category		16.767	3	0.001	
	2	0.829	0.510	2.641	1	0.104	2.291
	3	0.104	0.561	0.034	1	0.853	1.110
	4	3.102	0.862	12.937	1	0.000	22.241
Gender	F	Reference category					
	M	1.156	0.389	8.822	1	0.003	3.176
Specialty	Medical	Reference category					
	Surgical	0.593	0.386	2.356	1	0.125	1.809
Discharge Quartile	1	Reference category		7.793	3	0.050	
	2	0.041	0.489	0.007	1	0.933	1.042
	3	0.014	0.502	0.001	1	0.977	1.014
	4	-1.084	0.515	4.426	1	0.035	0.338
Inpatient Quartile	1	-0.465	0.535	0.756	1	0.385	0.628
	2	-1.358	0.495	7.532	1	0.006	0.257
	3	-0.483	0.499	0.937	1	0.333	0.617
	4	Reference category		8.416	3	0.038	

Bivariate Analysis for EH&P Adoption

Bivariate results using Chi-square analysis revealed differences in the proportion of adopters versus non-adopters by variable. Table 13 displays the summary information. Seven of the eleven variables showed bivariate associations ($p<.05$) with the six-month adoption of EH&P. Hospital, alignment,

EHR in office, group size, gender and specialty had significantly associations with adoption while age, hospital-based, inpatient ratio and loyalty were not significantly associated with adoption of EH&P. Supporting the hypothesized association, results for hospital showed the large, academic hospital had the highest percentage of adopters while the lowest percentage belonged to the mid-sized community hospital. Contracted and employed physicians adopted more frequently than independent or competing physicians supporting the hypothesis that alignment is associated with adoption. EHR in office also matched the predicted association. Those with an EHR in the office prior to activation were more likely to adopt compared to those without (OR = 3.9). Group size results were significant but mixed. Physicians from groups of between 31 and 100 physicians adopted most frequently and those in the smallest groups adopted least. Females were more likely to adopt than males (OR = 1.9). Surgical specialists were more likely to adopt EH&P than medical specialists (OR = 2.0). Discharge quartile results were significant. The second quartile had the highest likelihood of adoption and the fourth quartile had the lowest likelihood of adoption. The variables were recoded into a dichotomous variable comparing physicians with discharge volume below the median to physicians with discharge volume above the median. Those below the median (70 discharges) were more likely to adopt EH&P compared to those above the median (OR = 2.0).

Table 13: Bivariate Analysis of EH&P Adoption by Six Months

Variable	Category	N	Adopted	Adopted Percent	Likelihood Ratio	df	Sig.
Hospital	Large, academic	173	127	73%	19.984	2	0.000
	Small, community	68	44	61%			
	Mid-sized, community	74	36	44%			
Alignment	Competing	25	15	50%	31.963	3	0.000
	Independent	149	82	53%			
	Contracted	65	58	89%			
	Employed	76	52	68%			
EHR Office	No	261	161	59%	14.748	1	0.000
	Yes	54	46	85%			
Group Size Category	<3	38	18	46%	18.719	4	0.001
	3 - 10	62	36	55%			
	11 - 30	38	23	61%			
	31 - 100	75	62	82%			
	>100	102	68	63%			
Age Category	<40	67	42	60%	3.046	2	0.218
	40-54	159	111	68%			
	55+	89	54	58%			
Gender	F	68	53	75%	5.075	1	0.024
	M	247	154	60%			
Specialty	Medical	186	108	58%	5.58	1	0.018
	Surgical	140	99	71%			
Hospital-based	No	256	172	65%	0.834	1	0.361
	Yes	59	35	58%			
Discharge Quartile	1	76	58	69%	8.846	3	0.031
	2	78	58	73%			
	3	81	47	57%			
	4	80	44	54%			
Inpatient Quartile	1	77	55	68%	7.157	3	0.067
	2	83	46	54%			
	3	74	56	73%			
	4	81	50	60%			
Loyal 100%	No	105	67	60%	0.989	1	0.320
	Yes	210	140	65%			

Multivariable Results for EH&P Adoption

Logistic Regression was conducted to assess whether the eleven predictor variables significantly predicted whether a physician adopted CPOE. When predictor variables with alpha levels of less than 0.20 are considered together in a parsimonious model, they significantly predict whether a physician adopted CPOE (χ^2 = 90.782, *df* = 10, N = 326, p<0.000). The Nagelkerke pseudo R^2 for the model is 0.34. Table 14 presents the variables in the equation, which suggest the odds of adoption are:

- higher for the large, academic hospital compared to mid-sized, community hospital (OR = 2.4),
- higher for contracted physicians compared to competing physicians (OR = 17.3) and higher for employed physicians compared to competing physicians (OR = 5.9), and
- higher for physicians with discharges below the median (under 70 discharges) compared to physicians with discharges at or above the median (ORs = 2.45 & 4.2).

Age, gender, specialty, inpatient percent, and loyalty were not significant predictors of adoption of EH&P by six months.

Table 14: Logistic Regression of EH&P Adoption by Six Months

Variable	Category	B	S.E.	Wald	df	Sig.	Exp(B)
Hospital	Large, academic	Reference category		8.432	2	0.015	
	Small, community	-0.316	0.314	1.008	1	0.315	0.729
	Mid-sized, community	-0.863	0.298	8.411	1	0.004	0.422
Alignment	Competing	Reference category		37.984	3	0.000	
	Independent	0.593	0.337	3.100	1	0.078	1.810
	Contracted	2.849	0.524	29.566	1	0.000	17.276
	Employed	1.779	0.437	16.608	1	0.000	5.924
Age Category	<40	Reference category		4.038	2	0.133	
	40-54	0.531	0.295	3.230	1	0.072	1.701
	55+	0.074	0.335	0.049	1	0.825	1.077
Discharge Quartile	1	Reference category		16.358	3	0.001	
	2	-0.023	0.373	0.004	1	0.950	0.977
	3	-0.898	0.373	5.788	1	0.016	0.408
	4	-1.425	0.407	12.278	1	0.000	0.240

Bivariate Results for EDS Adoption

Bivariate results using Chi-square analysis revealed significant differences in the proportion of adopters versus non-adopters of EDS by independent variable. Table 15 displays the summary information. Six of the eleven predictor variables had significant bivariate associations ($p<.05$) with EDS adoption. Hospital, alignment, EHR in office, group size, specialty and hospital-based had significant associations with EDS adoption. Age, gender, discharge volume, inpatient ratio and loyalty were not significantly associated with a higher likelihood of adoption of EH&P. Supporting the hypothesized association, the large academic hospital had the highest likelihood of adopting. Results for alignment supported predicted associations as aligned physicians had a higher likelihood of adopting. Contracted physicians had a higher likelihood of adopting followed by employed physicians. The lowest likelihood of adopting belonged to

competing physicians. Physicians with EHR in office prior to activation had a higher likelihood of adopting than those without (OR = 1.37). Group size was significantly associated but the results did not support the proposed association that larger groups would adopt at a higher rate. Physicians from groups of between 11 and 100 physicians had the highest likelihood of adopting. The percentage of adopters (82% – 86%) was higher compared to those with less than ten or over 100 physicians (56% - 66%). Contrary to the hypothesized associations, medical specialists had a lower likelihood of adopting than surgical specialists (OR = .73) and hospital-based physicians had a lower likelihood of adopting than non-hospital-based physicians (OR = .80).

Table 15: Bivariate Analysis of EDS Adoption by Six Months

Variable	Category	N	Events	Adopted Percent	Likelihood Ratio	df	Sig.
Hospital	Large, academic	166	130	78%	16.844	2	0.000
	Small, community	70	48	68%			
	Mid-sized, community	67	34	51%			
Alignment	Competing	25	10	40%	31.161	3	0.000
	Independent	147	94	64%			
	Contracted	56	52	93%			
	Employed	75	56	75%			
EMR Office	No	251	165	65%	15.028	1	0.000
	Yes	52	47	90%			
Group Size Category	<3	38	24	63%	16.731	4	0.002
	3 - 10	61	35	56%			
	11 - 30	29	25	86%			
	31 - 100	74	61	82%			
	>100	101	67	66%			
Age Category	<40	62	46	73%	1.692	2	0.429
	40-54	154	110	71%			
	55+	87	56	64%			
Gender	F	68	52	76%	1.949	1	0.163
	M	235	160	68%			
Specialty	Medical	170	102	60%	17.96	1	0.000
	Surgical	134	110	82%			
Hospital-based	No	251	182	72%	4.115	1	0.043
	Yes	52	30	58%			
Discharge Quartile	1	70	44	62%	2.873	3	0.412
	2	76	54	71%			
	3	79	56	71%			
	4	78	58	74%			
Inpatient Quartile	1	69	46	67%	1.471	3	0.689
	2	83	58	70%			
	3	72	54	75%			
	4	79	54	68%			
Loyal 100%	No	102	75	73%	0.707	1	0.400
	Yes	201	137	68%			

Multivariable Results for EDS Adoption

Logistic Regression was conducted to assess whether the eleven predictor variables significantly predicted whether a physician adopted EDS. When influential predictor variables are considered together, they significantly predict whether a physician adopted EDs (χ^2 = 109.429, *df* = 11, N = 304, p<0.000). The Nagelkerke R^2 was 0.40. Table 16 presents the odds ratios for the parsimonious model, which suggest the odds of adoption are:

- higher for the large, academic hospital compared to mid-sized, community hospital (OR = 2.7),
- higher for independent physicians (OR = 2.4), contracted physicians (OR = 15.9) and employed physicians (OR = 6.1) compared to competing physicians, and
- higher for surgical specialists compared to medical specialists (OR = 2.5).

Age, gender, specialty, hospital-based, discharge quartile, inpatient quartile and loyalty were not significant predictors of adoption of EDS by six months.

Table 16: Logistic Regression EDS Adoption by Six Months

Variable	Category	B	S.E.	Wald	df	Sig.	Exp(B)
Hospital	Large, academic	Reference category		9.024	2	0.011	
	Small, community	-0.146	0.324	0.204	1	0.652	0.864
	Mid-sized, community	-0.985	0.334	8.711	1	0.003	0.374
Alignment	Competing	Reference category		27.130	3	0.000	
	Independent	0.861	0.331	6.749	1	0.009	2.364
	Contracted	2.768	0.618	20.033	1	0.000	15.925
	Employed	1.807	0.452	15.978	1	0.000	6.092
Gender	F	Reference category					
	M	-0.384	0.325	1.397	1	0.237	0.681
Specialty	Medical	Reference category					
	Surgical	0.899	0.313	8.253	1	0.004	2.458
Hospital-based	No	Reference category					
	Yes	-0.786	0.429	3.352	1	0.067	0.456

Comparison of CPOE, EH&P and EDS Multivariable Adoption Results

The multivariable association of the predictor variables to adoption within six months is described in this section. A simplified table displaying the alpha values ("Sig.") and the odds ratios ("Exp. B") comparing categories to the reference category for each variable is presented in Table 17. The mid-sized and small community hospitals had higher CPOE adoption compared to the large, academic hospital (ORs = 3.59 & 8.52). The mid-sized community hospital had lower adoption of EH&P and EDS compared to the large academic hospital. Employed physicians were more likely to adopt CPOE (OR = 22.4), EH&P (OR = 5.92) and EDS (OR = 6.09). Contract physicians were not significantly more likely to adopt CPOE but had the highest likelihood of adopting EHP and EDS compared to the competing physicians (ORs = 17.28 & 15.93). Male gender was significant for CPOE adoption (OR = 3.18) and was not significant for other

functions. Surgical specialists were more likely to adopt EDS (OR = 2.46) compared to medical specialists but specialty was not a significant predictor of adoption of the other functions. Physicians with discharge volumes in the fourth quartile (over 132 discharges) were less likely to adopt CPOE than those with discharge volumes in the first quartile (under 36 discharges) (OR = 0.34). Physicians with discharge volumes in the third and fourth quartile (above 70 discharges) were less likely to adopt EH&P than those with discharge volumes in the first quartile (OR = 0.41 & 0.24). Discharge volume was not a significant predictor of EDS adoption. Physicians with an inpatient ratio in quartile two (between 46% and 76%) were significantly less likely to adopt CPOE compared to physicians with inpatient ratios in the fourth quartile (over 98%) (OR = 0.26). Inpatient ratio was not significantly predictive in the other quartiles or for the functions of EH&P or EDS.

Bivariate analysis was performed in order to explore possible multivariable associations with the dependent variables. Two variables that were included in the bivariate analysis were eliminated from the multivariable analysis. The variables alignment, EHR in office and group size were highly collinear. In Chi-square analysis, group size was significantly associated with adoption of all three factors. The sizes of the groups that were associated with adoption did not follow any logical progression and differed from function to function. EHR in office prior to the activation of the hospital EHR was negatively associated with CPOE adoption and positively associated with EH&P and EDS adoption. When the variables were used in the multivariable analysis, alignment remained significant.

EHR in office was significant only for EH&P adoption but the direction of the relationship was the opposite of what was found in the bivariate analysis. Group size was not significant once adjusted for other variables. Of the three collinear variables, alignment was selected for use in the multivariable analysis. Loyalty was not significantly associated with adoption in bivariate or multivariable analysis.

Table 17: Summary of Multivariable Results for EHR Adoption

		CPOE		EH&P		EDS	
		Pseudo R^2 = 0.66		Pseudo R^2 = 0.34		Pseudo R^2 = 0.40	
Variable	**Category**	**Sig.**	**Exp(B)**	**Sig.**	**Exp(B)**	**Sig.**	**Exp(B)**
Hospital	Large, academic	0.000	RC	0.015	RC	0.011	RC
	Small, community	0.001	8.52	0.315	0.73	0.652	0.86
	Mid-sized, community	0.006	3.59	0.004	0.42	0.003	0.37
Alignment	Competing	0.001	RC	0.000	RC	0.000	RC
	Independent	0.104	2.29	0.078	1.81	0.009	2.36
	Contracted	0.853	1.11	0.000	17.28	0.000	15.93
	Employed	0.000	22.24	0.000	5.92	0.000	6.09
Gender	F		RC				
	M	0.003	3.18				
Specialty	Medical						RC
	Surgical					0.004	2.46
Discharge Quartile	1	0.050	RC	0.001	RC		
	2	0.933	1.04	0.950	0.98		
	3	0.977	1.01	0.016	0.41		
	4	0.035	0.34	0.000	0.24		
Inpatient Quartile	1	0.385	0.63				
	2	0.006	0.26				
	3	0.333	0.62				
	4	0.038	RC				

Notes: RC = reference category; blank = not significant

Research Question Two

This section displays the results for research question number two: what variables predict the rate of adoption (the number of months between activation and achievement of an 80% use rate) of an electronic health record by admitting physicians? Kaplan-Meier survival analysis was used to evaluate bivariate effects on estimated mean and median adoption times of CPOE, EH&P and EDS. Kaplan-Meier survival analysis is a descriptive procedure for evaluation of the time until an event occurs for use when time is the only predictor variable. The bivariate results of this test can represent misleading averages that obscure important differences formed by the covariates. In survival analysis, the term "covariate" is commonly used for all independent variables. To minimize confusion, this study consistently uses the term "variable", "predictor variable" or "independent variable" instead of the term "covariate". The Kaplan-Meier bivariate analysis was used to explore associations prior to multivariable analysis. Multivariable analysis of the rate of adoption for CPOE, EH&P and EDS follows the bivariate analysis for each dependent variable.

Bivariate Results for CPOE Rate of Adoption

Faster adoption was associated with the two community hospitals, the lowest and highest alignment levels (competing and employed), not having an office based EHR, being from a very large or very small group of physicians, being hospital-based, and being 100% loyal to the hospital system. Gender, age, specialty, discharge volume and inpatient ratio were not significantly associated

with the rate of adoption. Table 17 details the bivariate results for CPOE rate of adoption.

Table 18: Kaplan-Meier Analysis of Rate of Adoption of CPOE

Variable	Category	Mean Est. Adoption Time	95% CI Lower	95% CI Upper	Median Est. Adoption Time	Sig.
Hospital	Large, academic	3.03	2.70	3.36	2	0.000
	Small, community	2.22	1.89	2.55	2	
	Mid-sized, community	2.03	1.67	2.38	1	
Alignment	Competing	1.97	1.45	2.49	1	0.000
	Independent	2.8	2.48	3.13	2	
	Contracted	3.18	2.62	3.74	2	
	Employed	1.96	1.65	2.27	1	
EMR Office	No	2.41	2.19	2.63	2	0.000
	Yes	3.58	2.97	4.19	4	
Group Size Category	<3	2.29	1.76	2.82	2	0.000
	3 - 10	2.7	2.18	3.23	2	
	11 - 30	3.08	2.36	3.80	2	
	31 - 100	3.34	2.84	3.84	3	
	>100	1.95	1.69	2.22	1	
Age Category	<40	2.31	1.86	2.77	1	0.323
	40-54	2.64	2.33	2.94	2	
	55+	2.73	2.32	3.14	2	
Gender	F	2.71	2.23	3.18	2	0.353
	M	2.56	2.32	2.80	2	
Specialty	Medical	2.61	2.32	2.90	2	0.875
	Surgical	2.57	2.25	2.90	2	
Hospital-based	No	2.74	2.50	2.99	2	0.004
	Yes	1.94	1.55	2.33	1	
Discharge Quartile	1	2.2	1.83	2.58	1	0.124
	2	2.53	2.09	2.96	2	
	3	2.86	2.40	3.32	2	
	4	2.79	2.34	3.24	2	
Inpatient Quartile	1	2.21	1.83	2.59	1	0.058
	2	3.12	2.64	3.60	2	
	3	2.55	2.11	3.00	2	
	4	2.47	2.08	2.87	2	
Loyal 100%	No	3.04	2.64	3.44	2	0.014
	Yes	2.35	2.10	2.60	1	

Multivariable Analysis of CPOE Rate of Adoption

Cox Regression survival analysis was performed to assess if the variables, adjusted for each other, were predictive of the rate of adoption for CPOE. Hospital, alignment, age, gender, specialty, hospital-based, discharge volume, inpatient percent and loyalty were included. The variables "group size" and "EHR Office" were highly collinear with "alignment" and eliminated from the evaluation. Three hundred twenty four cases were included in the analysis; 54 or 16.6% of the physicians were censored because they had not reached the 80% level of use defined as the threshold for adoption.

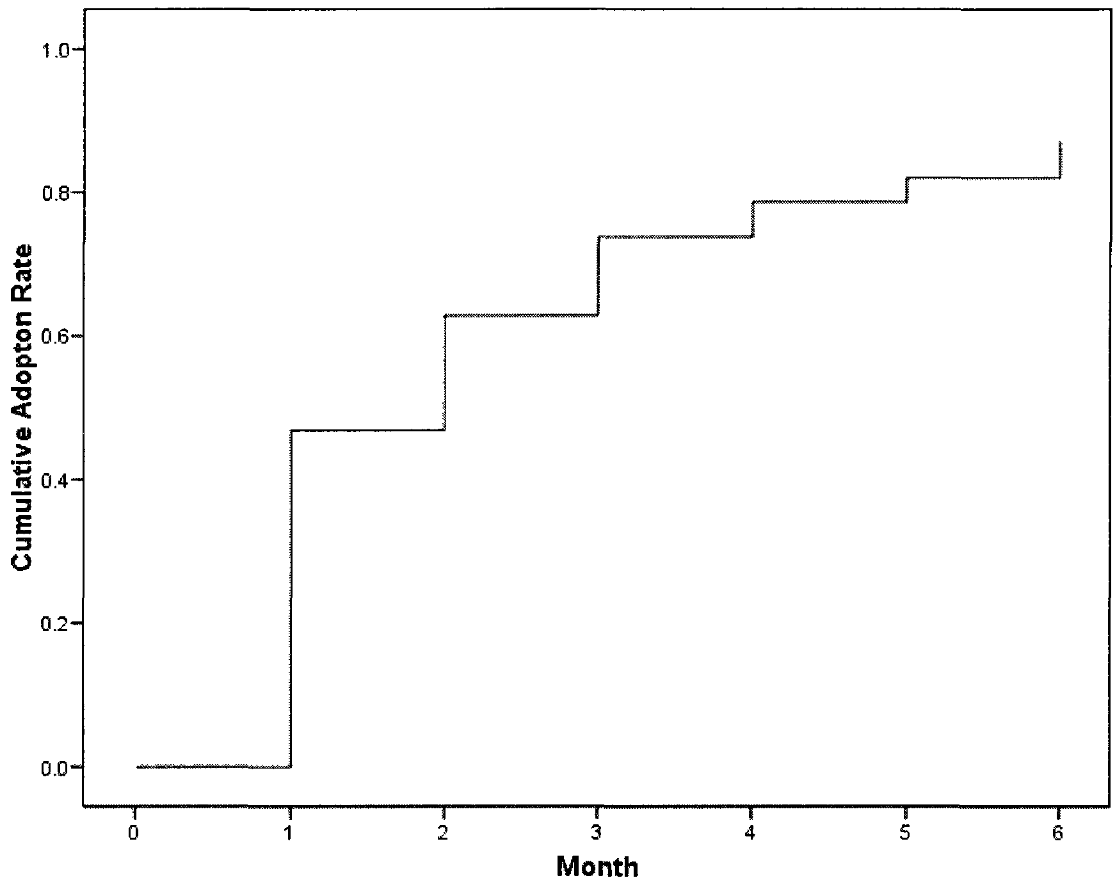
The overall model was significant (χ^2 = 34.972, p=0.006) with a pseudo R^2 of 0.10 using Steiger and Fouladi's R2 software (1992). After adjustment for other independent variables, the bivariate associations were no longer significant. None of the variables in the model had a statistically significant effect on the hazard of CPOE adoption at alpha < 0.05. While the overall model was significant, none of the independent variables significant predicted the rate of adoption and the amount of variance explained was small. The null multivariate rate of adoption hypothesis for CPOE was not rejected.

Table 19: Cox Regression for CPOE

Variable	Level	B	SE	Wald	df	Sig.	Exp(B)
Hospital	1	Reference category		3.475	2	0.176	
	2	0.076	0.179	0.183	1	0.669	1.079
	3	0.303	0.167	3.284	1	0.070	1.354
Alignment	1	Reference category		6.849	3	0.077	
	2	-0.215	0.241	0.795	1	0.373	0.806
	3	-0.545	0.299	3.316	1	0.069	0.580
	4	0.003	0.263	0.000	1	0.992	1.003
Age Category	<40	Reference category		1.976	2	0.372	
	40-54	-0.175	0.161	1.179	1	0.277	0.839
	55+	-0.247	0.180	1.894	1	0.169	0.781
Gender	F	Reference category					
	M	0.196	0.161	1.491	1	0.222	1.217
Specialty	Medical	Reference category					
	Surgical	0.160	0.151	1.116	1	0.291	1.173
Hospital-based	No	Reference category					
	Yes	0.352	0.213	2.722	1	0.099	1.421
Discharge Quartile	1	Reference category		6.063	3	0.109	
	2	0.018	0.185	0.009	1	0.922	1.018
	3	-0.185	0.186	0.994	1	0.319	0.831
	4	-0.422	0.199	4.479	1	0.034	0.656
Inpatient Quartile	1	Reference category		5.258	3	0.154	
	2	-0.354	0.181	3.822	1	0.051	0.702
	3	-0.016	0.186	0.008	1	0.931	0.984
	4	0.029	0.217	0.018	1	0.893	1.030
Loyal 100%	No	Reference category					
	Yes	0.117	0.148	0.622	1	0.430	1.124

Figure 2 shows the cumulative adoption of CPOE at the mean of the covariates. This curve depicts the cumulative percentage of CPOE adopters over the six months studied, adjusted for the effects of the variables in the equation. Approximately 50% of physicians adopted CPOE within the first month and about 80% adopted by the end of the sixth month. The rate of adoption steadily decreased each month. The x-axis measures the number of months after activation of the EHR. The y-axis measures the cumulative ratio of physicians who adopted.

Figure 2: Adoption Curve for CPOE at the Mean of Covariates



Bivariate Results for EH&P Rate of Adoption

Bivariate results using Kaplan-Meier analysis estimated mean and median adoption times showed the following variables were significantly associated with faster adoption of EH&P: the large, academic hospital, higher levels of alignment, EHR in office, group size between 31 and 100 physicians, female gender, surgical specialty, second quartile discharge volume and third inpatient ratio quartile. Age, being hospital-based and loyalty were not significantly associated with the rate of adoption. Table 20 details the results.

Table 20: Kaplan-Meier Analysis of Rate of Adoption of EH&P

Variable	Category	Mean Est. Adoption Time	95% CI Lower	95% CI Upper	Median Est. Adoption Time	Sig.
Hospital	Large, academic	3.13	2.81	3.45	2	0.000
	Small, community	3.75	3.25	4.25	4	
	Mid-sized, community	4.12	3.62	4.62	.	
Alignment	Competing	4.03	3.24	4.83	6	0.000
	Independent	4.06	3.72	4.41	6	
	Contracted	2.17	1.75	2.59	1	
	Employed	3.35	2.87	3.84	2	
EMR Office	No	3.72	3.46	3.99	4	0.000
	Yes	2.46	1.94	2.99	1	
Group Size Category	<3	4.28	3.57	5.00	.	0.000
	3 - 10	4.03	3.51	4.56	5	
	11 - 30	3.58	2.87	4.29	3	
	31 - 100	2.62	2.15	3.08	2	
	>100	3.54	3.13	3.95	3	
Age Category	<40	3.57	3.04	4.10	3	0.221
	40-54	3.33	3.00	3.67	3	
	55+	3.8	3.34	4.25	4	
Gender	F	3.24	2.72	3.75	2	0.042
	M	3.59	3.32	3.86	3	
Specialty	Medical	3.75	3.42	4.07	4	0.016
	Surgical	3.21	2.85	3.56	2	
Hospital-based	No	3.49	3.22	3.75	3	0.45
	Yes	3.63	3.05	4.21	3	
Discharge Quartile	1	3.51	3.06	3.96	3	0.046
	2	2.95	2.49	3.41	2	
	3	3.93	3.44	4.42	5	
	4	3.65	3.15	4.16	3	
Inpatient Quartile	1	3.33	2.85	3.81	2	0.036
	2	4.02	3.57	4.48	5	
	3	3.06	2.57	3.56	2	
	4	3.59	3.10	4.08	3	
Loyal 100%	No	3.66	3.24	4.08	3	0.361
	Yes	3.44	3.15	3.73	3	

Multivariable Analysis of EH&P Rate of Adoption

Cox Regression survival analysis was performed to assess if the variables, adjusted for each other, were predictive of the rate of adoption. Hospital, alignment, age, gender, specialty, hospital-based, discharge volume, inpatient percent and loyalty were included. The variables “group size” and “EHR in office” were highly collinear with “alignment” and eliminated from the evaluation. Three hundred twenty six cases were included in the analysis; 119 or 36.5% were censored because they had not reached the 80% level of use defined as the threshold for adoption. The overall model was significant (χ^2 = 48.5, p=0.000) with a pseudo R^2 of 0.14.

Three of the variables in the model had a statistically significant effect on the likelihood of faster adoption of EH&P at alpha < 0.05. Adjusted for other variables, adoption was faster among physicians from the large, academic hospital compared to physicians from the mid-sized, community hospital (OR = 1.74). Employed and contracted physicians were more likely to adopt faster compared to physicians who were employed by competing health systems (ORs = 1.86 & 2.65). Physicians from the lowest quartile of discharge volume were more likely to adopt faster compared to physicians from the highest two quartiles (ORs = 1.64 & 1.74). Gender, specialty and inpatient ratio were no longer significantly associated with the rate of adoption of EH&P once adjusted for other variables. Loyalty was not significantly associated with the rate of adoption of EH&P in bivariate or multivariable evaluations.

Table 21: Cox Regression for EH&P Rate of Adoption

Variable	Category	B	SE	Wald	df	Sig.	Exp(B)
Hospital	Large, academic	Reference category		7.383	2	0.025	
	Small, community	-0.235	0.197	1.428	1	0.232	
	Mid-sized, community	-0.551	0.204	7.313	1	0.007	0.576
Alignment	Competing	Reference category		29.824	3	0.000	
	Independent	0.038	0.307	0.016	1	0.900	1.039
	Contracted	0.974	0.334	8.518	1	0.004	2.649
	Employed	0.621	0.318	3.801	1	0.050	1.860
Discharge Quartile	1	Reference category		12.019	3	0.007	
	2	-0.009	0.192	0.002	1	0.964	0.991
	3	-0.493	0.206	5.746	1	0.017	0.611
	4	-0.551	0.216	6.491	1	0.011	0.576

Figure 3 shows the cumulative adoption of EH&P at the mean of the variables. Approximately 30% of physicians adopted EH&P within the first month and about 75% adopted by the end of the sixth month. The rate of adoption increased quickly in the second month then steadily decreased each month. Figures 4 through 6 show the cumulative adoption curve for the statistically significant variables.

Figure 3: Adoption Curve for EH&P at the Mean of Covariates

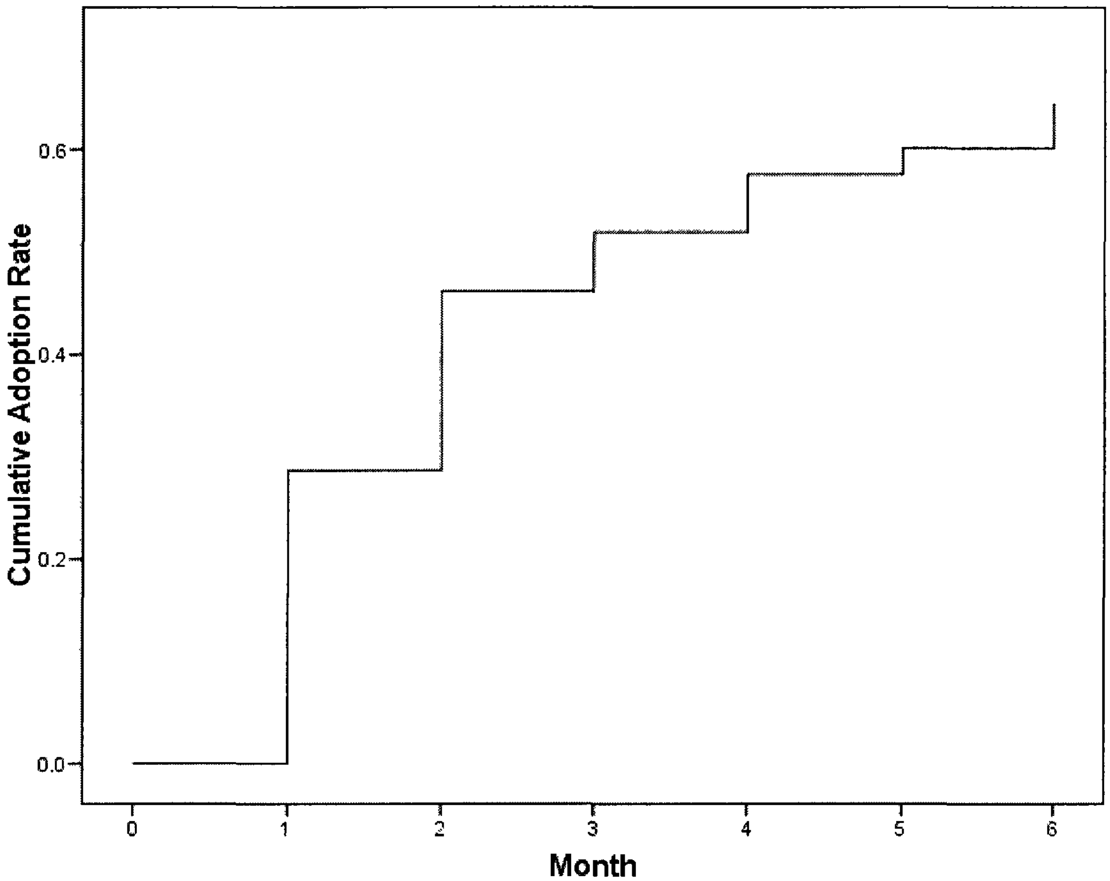
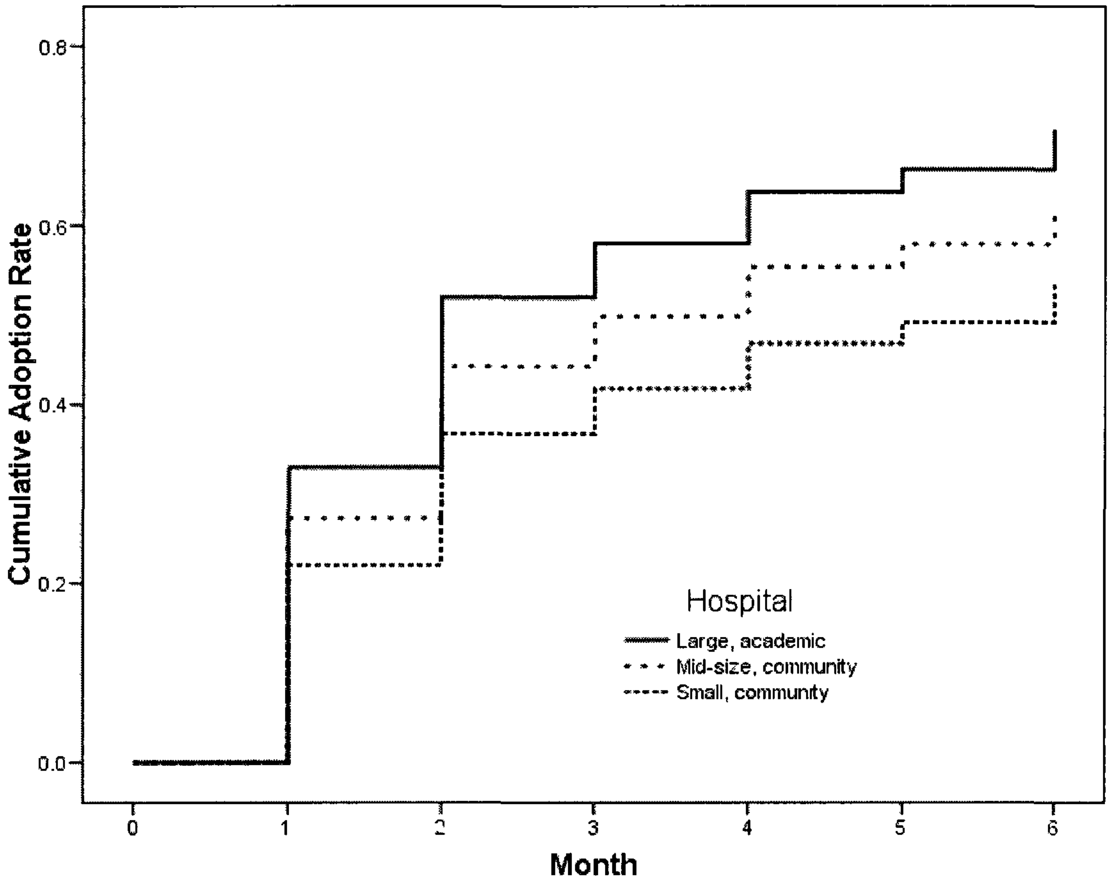
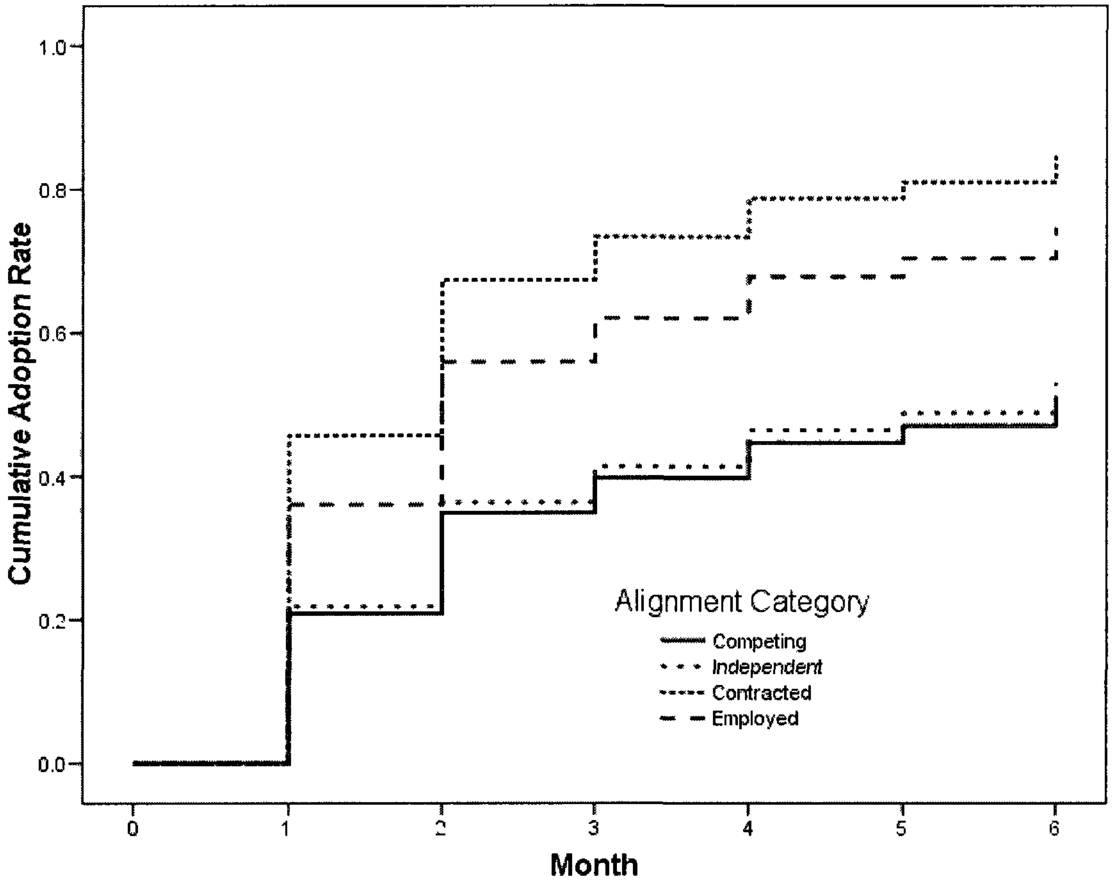


Figure 4: Adoption Curve for EH&P by Hospital



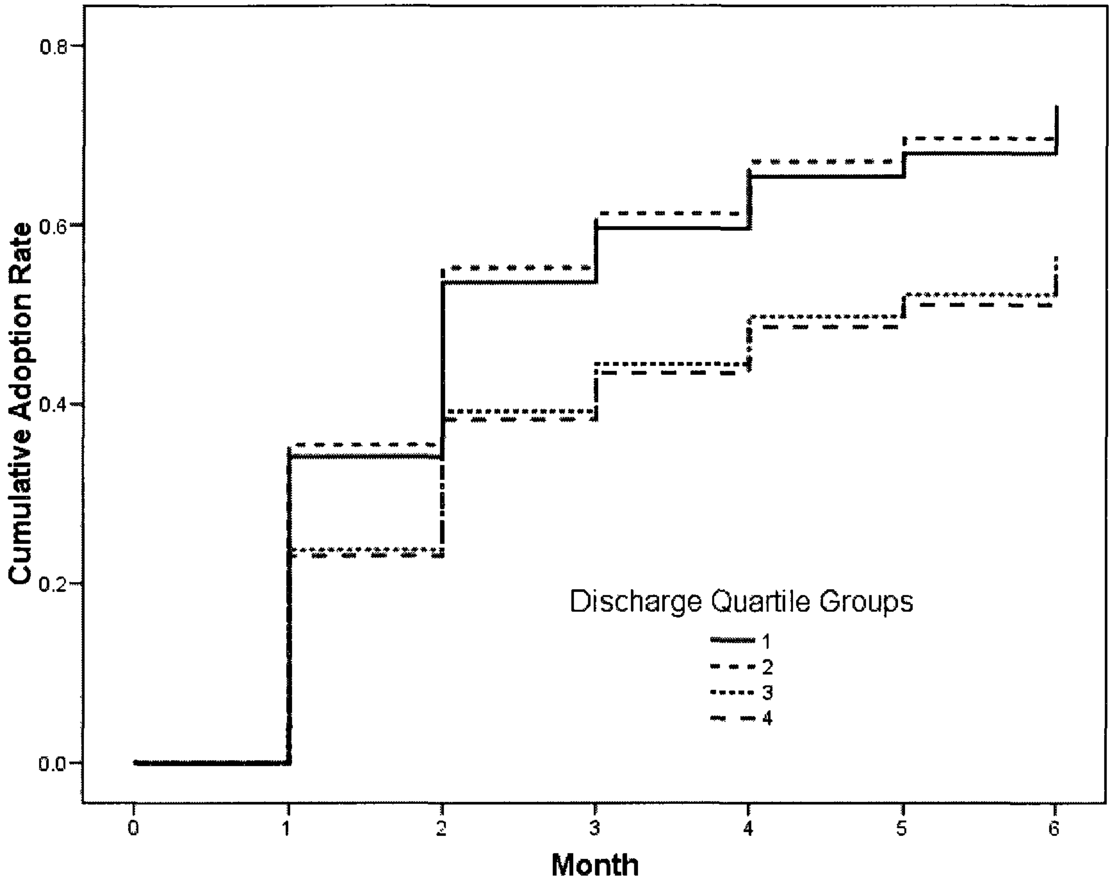
The large, academic hospital showed rapid adoption during the first two months. All showed steady growth rates throughout the six months with similar slopes after the first two months.

Figure 5: Adoption Curve for EH&P by Alignment



Contracted physicians start out with over 45% adopting in the first month closely followed by employed physicians. The curves for competing and independent physicians were nearly identical and lagged behind physicians with higher alignment. All three show rapid adoption in the second month and a steady decrease in the following months.

Figure 6: Adoption Curve for EH&P by Discharge Quartile



The adoption curves for the lower two quartiles are nearly identical, showing rapid growth in the first two months and steadily diminishing growth each month. By the end of the six months, 70% of physicians achieved the goal of 80% use of EH&P. The curves for the top two quartiles were also nearly identical to each other and run approximately parallel to, but lower than, the curves for the lower two quartiles.

Bivariate Results for EDS Rate of Adoption

Bivariate results of Kaplan-Meier survival analysis showed the following variables were significantly ($p<.05$) associated with faster EDS adoption: physicians at the large, academic hospital and the small community hospital, contracted or employed, physicians with and EHR in the office, group size between 30 and 100 physicians, and surgical specialty. Age, gender, hospital-based, discharge volume, inpatient ratio and loyalty were not significantly associated with the rate of adoption. Table 22 details the results.

Table 22: Kaplan-Meier Analysis of Rate of Adoption of EDS

Variable	Category	Mean Est. Adoption Time (months)	95% CI Lower	95% CI Upper	Median Est. Adoption Time	Sig.
Hospital	Large, academic	3.29	2.98	3.60	2	0.000
	Small, community	3.35	2.87	3.83	2	
	Mid-sized, community	4.37	3.89	4.85	6	
Alignment	Competing	4.44	3.66	5.22	4	0.000
	Independent	3.93	3.60	4.26	4	
	Contracted	2.25	1.86	2.64	2	
	Employed	3.44	2.98	3.90	3	
EMR Office	No	3.78	3.52	4.03	4	0.000
	Yes	2.4	1.97	2.84	2	
Group Size Category	<3	3.97	3.31	4.63	5	0.000
	3 - 10	4.23	3.71	4.74	5	
	11 - 30	3.28	2.59	3.96	3	
	31 - 100	2.68	2.26	3.09	2	
	>100	3.67	3.27	4.08	3	
Age Category	<40	3.29	2.77	3.80	2	0.215
	40-54	3.42	3.10	3.75	3	
	55+	3.94	3.52	4.37	4	
Gender	F	3.18	2.70	3.65	2	0.097
	M	3.65	3.38	3.91	3	
Specialty	Medical	3.9	3.59	4.22	4	0.000
	Surgical	3.09	2.76	3.22	2	
Hospital-based	No	3.48	3.23	3.73	3	0.085
	Yes	3.85	3.26	4.44	4	
Discharge Quartile	1	3.59	3.07	4.11	3	0.566
	2	3.68	3.23	4.14	3	
	3	3.68	3.24	4.12	4	
	4	3.22	2.77	3.66	2	
Inpatient Quartile	1	3.77	3.30	4.24	4	0.284
	2	3.76	3.32	4.20	4	
	3	2.99	2.53	3.45	2	
	4	3.63	3.15	4.10	3	
Loyal 100%	No	3.39	2.99	3.78	3	0.298
	Yes	3.62	3.34	3.91	3	

Multivariable Analysis of EDS Rate of Adoption

Cox Regression survival analysis was performed to assess if the variables, adjusted for each other, were predictive of the rate of adoption of EDS. Hospital, alignment, age, gender, specialty, hospital-based, discharge volume, inpatient percent and loyalty were included. The variables “group size” and “EHR in Office” were highly collinear with “alignment” and were eliminated from the evaluation. Three hundred four cases were included in the analysis; 92 or 28.2% were censored because they had not reached the 80% level of use defined as the threshold for adoption. The overall model was significant (χ^2 = 64.232, p=0.000) with a pseudo R^2 of 0.187.

Four of the variables in the model had a statistically significant effect on the likelihood of faster adoption of EDS at alpha < 0.05. Adjusted for other variables, adoption was faster among physicians with: the large, academic hospital compared to the mid-sized, community hospital (OR = 1.49), physicians who were independent, contracted or employed compared to competing (ORs = 1.93, 4.34 & 2.93), surgical specialists compared to medical specialists (OR = 1.47), and those who admitted to multiple facilities compared to 100% loyal physicians (OR = 1.39).

Table 23: Cox Regression for EDS

Variable	Level	B	SE	Wald	df	Sig.	Exp(B)
Hospital	1	Reference category		6.859	2	0.032	
	2	0.189	0.193	0.955	1	0.328	1.208
	3	-0.402	0.211	3.640	1	0.056	0.669
Alignment	1	Reference category		22.439	3	0.000	
	2	0.661	0.351	3.540	1	0.060	1.937
	3	1.469	0.391	14.100	1	0.000	4.346
	4	1.073	0.367	8.573	1	0.003	2.925
Age Category	<40	Reference category		3.886	2	0.143	
	40-54	-0.137	0.181	0.569	1	0.451	0.872
	55+	-0.389	0.207	3.545	1	0.060	0.678
Gender	F	Reference category					
	M	-0.175	0.168	1.093	1	0.296	0.839
Specialty	Medical	Reference category					
	Surgical	0.387	0.163	5.664	1	0.017	1.473
Hospital-based	No	Reference category					
	Yes	-0.280	0.252	1.232	1	0.267	0.756
Loyal 100%	No	Reference category					
	Yes	-0.333	0.154	4.653	1	0.031	0.717

Figure 7 shows the cumulative adoption of EDS at the mean of the covariates. Approximately 20% of physicians adopted EDS within the first month and about 70% adopted by the end of the sixth month. The rate of adoption steadily decreased each month. Figures 8 - 11 show the adoption curves for the statistically significant variables.

Figure 7: Adoption Curve for EDS at the Mean of Covariates

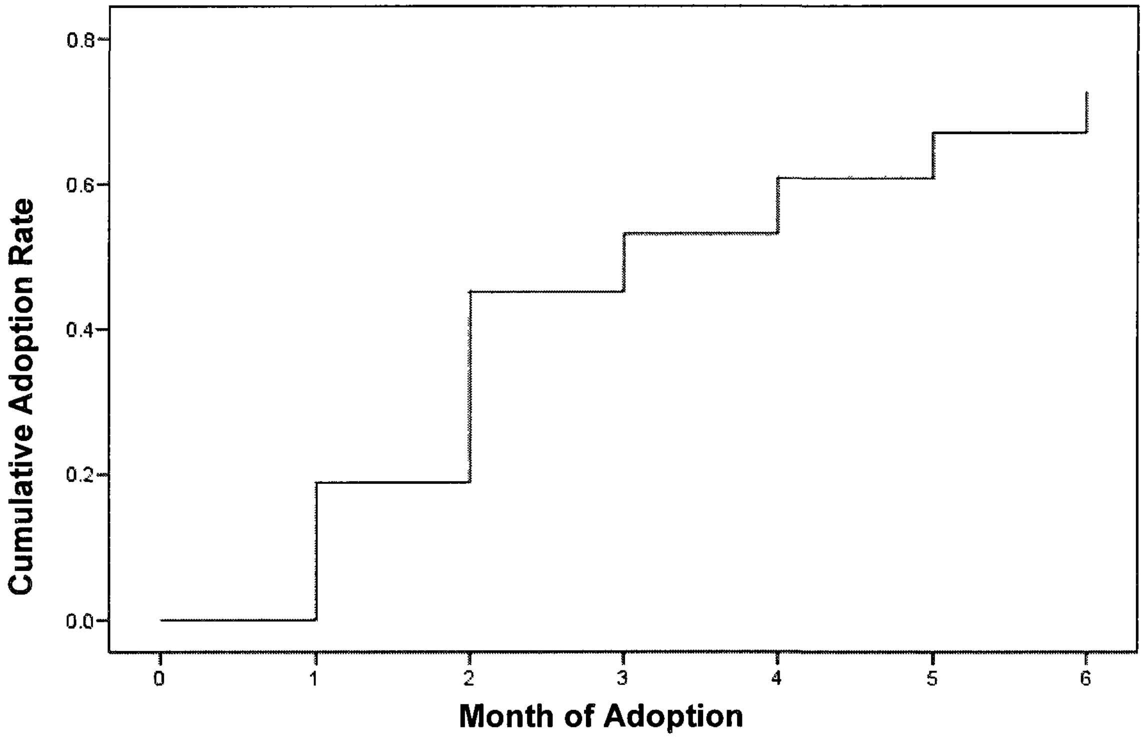
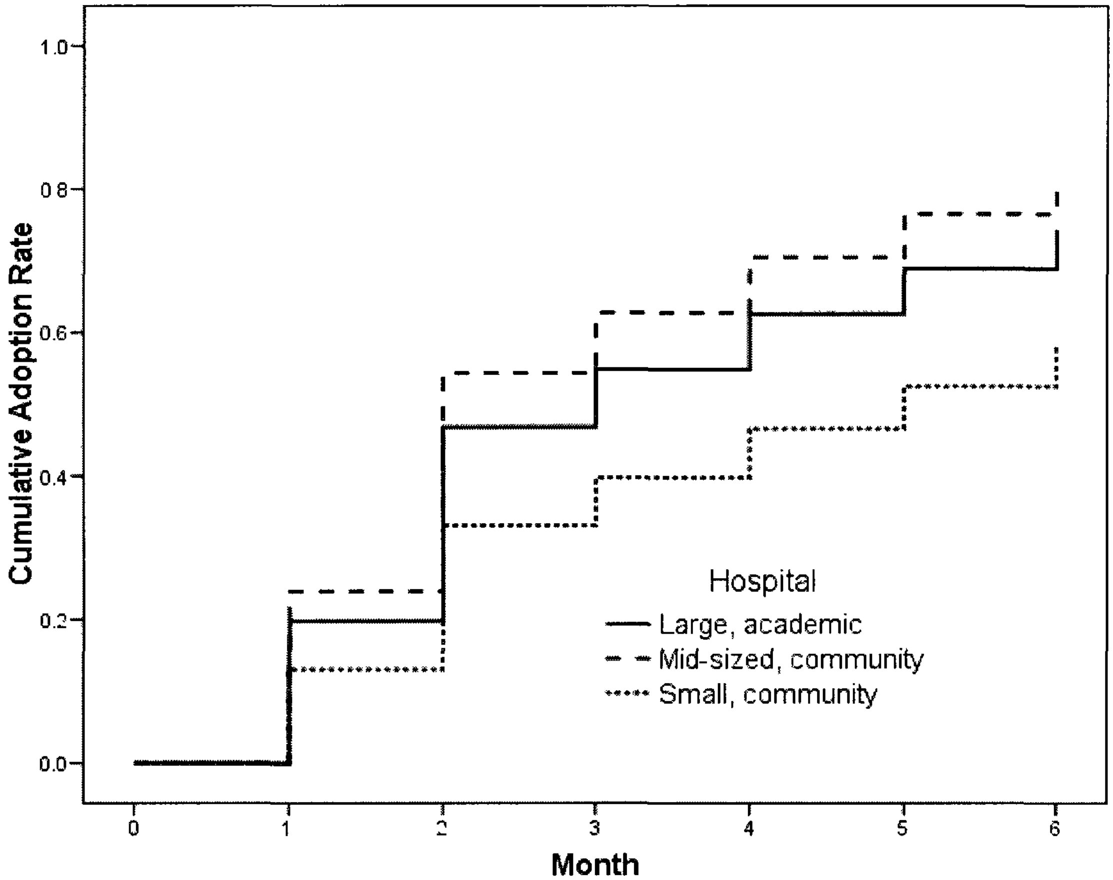
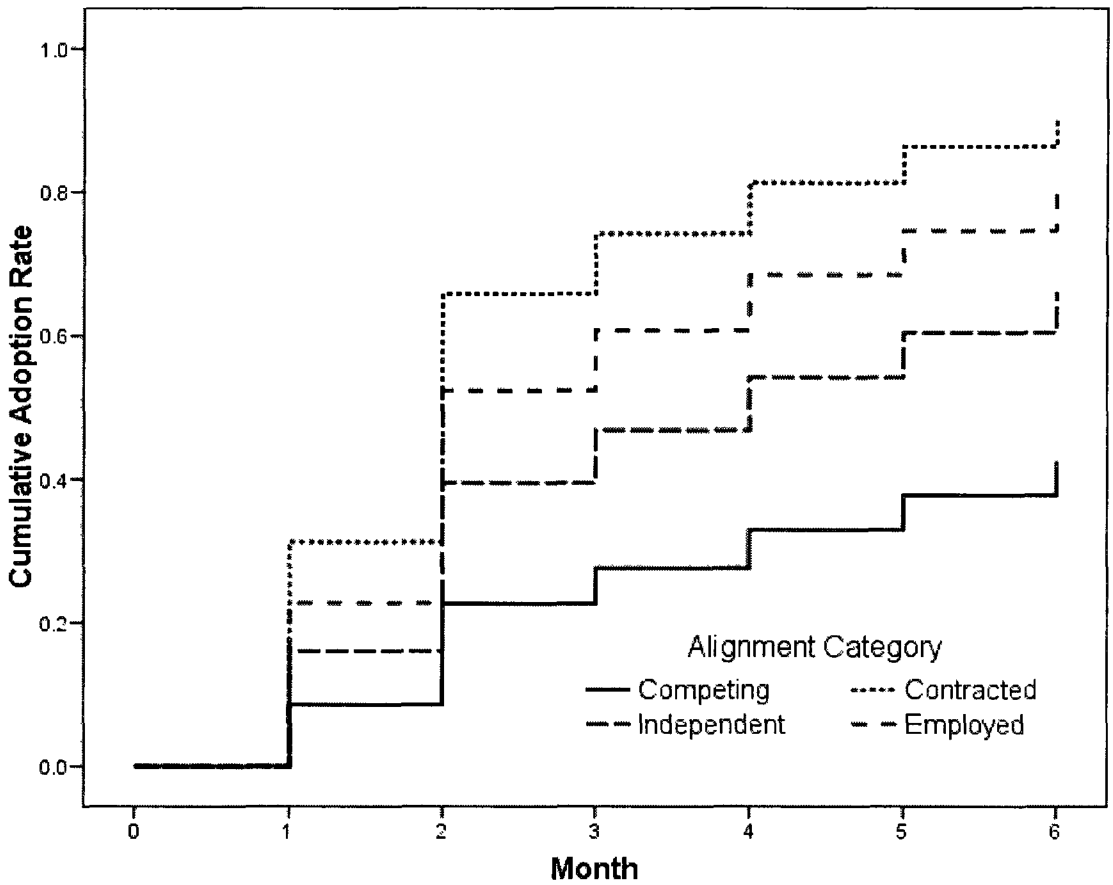


Figure 8: Adoption Curve for EDS by Hospital



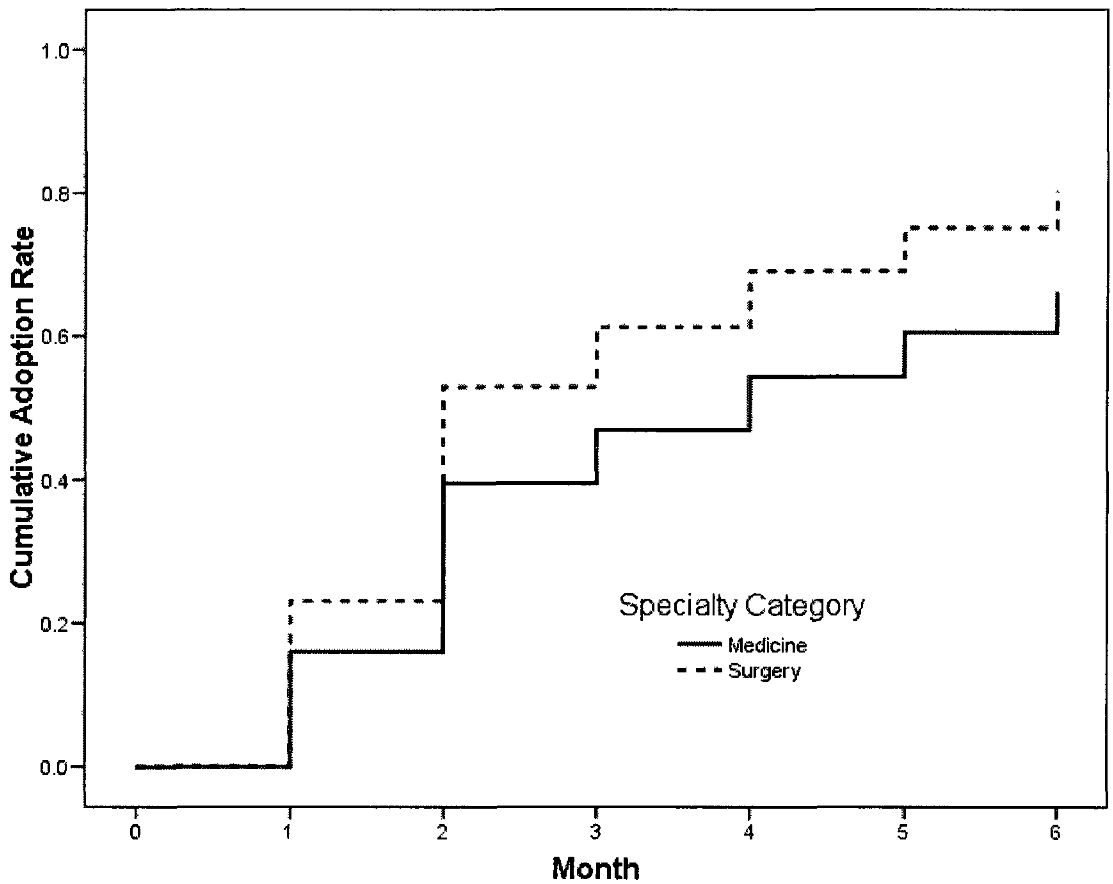
The curve for the mid-sized community hospital was consistently lower than the curves for the other two hospitals. The adoption rate decreased after the second month but appears to be steady afterward. The large, academic hospital and the small, community hospital had their greatest increase in the adoption during the second month. Both curves show steady decreases in the number of new adopters each month after the second month.

Figure 9: Adoption Curve for EDS by Alignment Category



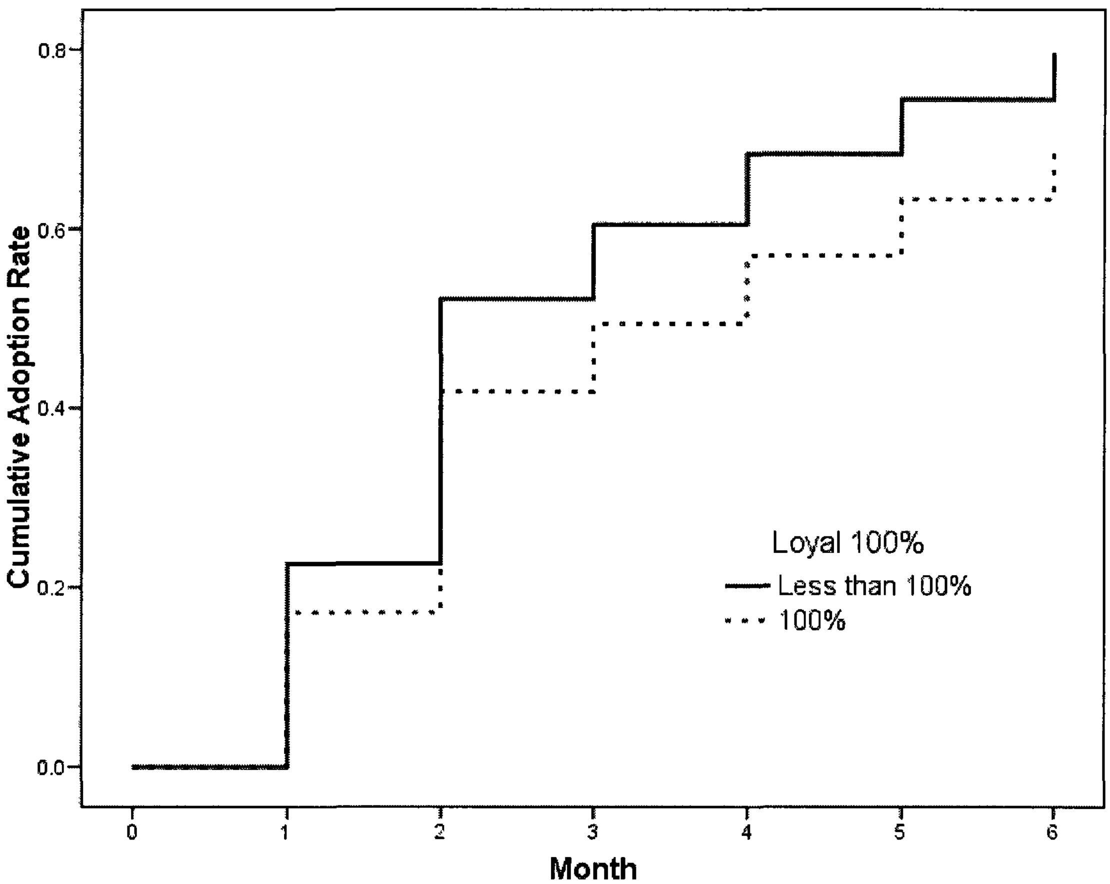
The curves for contract, employed and independent physicians run parallel to each other and have steeper slopes compared to the curve for the competing physicians. About 90% of contract physicians adopted within six months. About 40% of competing physicians adopted during the six months.

Figure 10: Adoption Curve for EDS by Specialty Category



Surgical specialists outpaced the medical specialist from the beginning with most of the adoption occurring during the first two months. The lines have similar slopes after the second month. Cumulative adoption was about 64% for surgical specialists and about 80% for medical specialists.

Figure 11: Adoption Curve for EDS by Loyalty



Both categories of physicians adopted rapidly during the first two months. After two months, the splitters reached 55% and the 100% loyal physicians reached 45%. The slopes of the curves were parallel and steadily decreased thereafter.

Table 24: Summary of Cox Regression of Rate of Adoption

		CPOE		EH&P		EDS	
		Pseudo R^2 = 0.10		Pseudo R^2 = 0.14		Pseudo R^2 = 0.19	
Variable	**Category**	**Sig.**	**Exp(B)**	**Sig.**	**Exp(B)**	**Sig.**	**Exp(B)**
Hospital	Large, academic			0.025	RC	0.032	RC
	Small, community			0.232		0.328	1.21
	Mid-sized, community			0.007	0.58	0.056	0.67
Alignment	Competing			0.000	RC	0.000	RC
	Independent			0.900	1.04	0.060	1.94
	Contracted			0.004	2.65	0.000	4.35
	Employed			0.050	1.86	0.003	2.93
Specialty	Medical						RC
	Surgical					0.017	1.47
Discharge Quartile	1			0.007	RC		
	2			0.964	0.99		
	3			0.017	0.61		
	4			0.011	0.58		
Loyal 100%	No						RC
	Yes					0.031	0.72

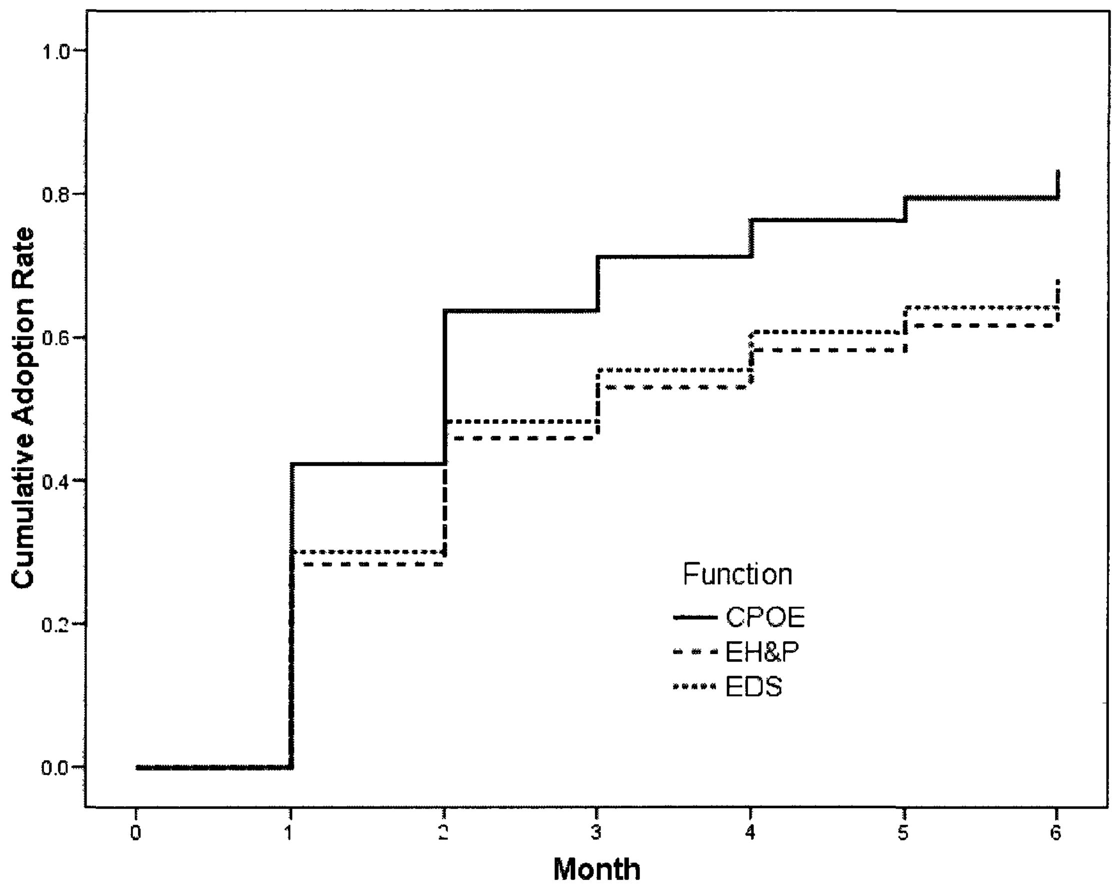
Notes: RC = reference category; blank = not significant

Table 24 provides a side-by-side comparison of the significant multivariable results for each dependent variable. No variables significantly predicted the likelihood of faster adoption of CPOE. The amount of variance explained by the variables was higher for EDS than EH&P. Hospital and alignment variables were predictive of faster adoption of EH&P and EDS by physicians at the large, academic hospital. Specialty and loyalty were only predictive of the rate of EDS adoption. Discharge volume was only predictive of EH&P.

Overall Comparison of CPOE, EH&P and EDS

Statistical methods for determining the significance of the difference in the rate of adoption of the three applications were not available so the evaluation was performed descriptively using a graph of the adoption curve for the three measures of use. Figure 13 displays the adoption curves for the three measures of use at the mean of covariates. At the end of the first month, approximately 50%, 30% and 20% of physicians adopted CPOE, EH&P and EDS, respectively. After the first month, the rate of adoption for EDS surpassed that of EH&P. By the end of the six months approximately 80%, 59% and 67% of physicians had adopted CPOE, EH&P and EDS, respectively.

Figure 12: Overall Comparison of Survival Curves



Summary of Hypothesis Tests

This summary draws specific conclusions based on accepting or rejecting individual null hypotheses. In some cases, the alternative hypothesis was not correct but the null was rejected because the test was significant at an alpha level less than 0.05. The associations of each variable and the overall results are discussed in Chapter V including potential spurious conclusions and results that were unexpected. Tables 25 and 26 summarize the hypothesized

relationships, significant results and the direction of the associations. Each null hypothesis is listed below with a conclusion based on the results.

Bivariate Hø 1: There will be no significant association between hospital where a physician practices and physician adoption of CPOE. The large, academic hospital was less likely to adopt than the two community hospitals. The results were not in the hypothesized direction. The null hypothesis was rejected.

Bivariate Hø 2: There will be no significant association between alignment and physician adoption of CPOE. Physicians employed by competing health systems and physicians employed by the health system that activated the EHR were more likely to adopt than independent or contracted physicians. The null hypothesis was rejected.

Bivariate Hø 3: There will be no significant association between having an EHR in the office prior to activation and physician adoption of CPOE. Physicians with an EHR in the office prior to activation of the hospital EHR were less likely to adopt. The results were not in the hypothesized direction. The null hypothesis was rejected.

Bivariate Hø 4: There will be no significant association between group size and physician adoption of CPOE. Physicians from different sized groups had significantly different likelihoods of adopting. Physicians in groups of over 100 physicians were more likely to adopt compared to physicians from groups of 31 to 100 physicians. The results were not in the hypothesized direction. The null hypothesis was rejected.

Bivariate Hø 5: There will be no significant association between age and physician adoption of CPOE. There were no significant differences in CPOE adoption by age group. The null hypothesis was not rejected.

Bivariate Hø 6: There will be a significant association between gender and physician adoption of CPOE. There were no significant differences in CPOE adoption by gender. The null hypothesis was not rejected.

Bivariate Hø 7: There will be no significant association between specialty and physician adoption of CPOE. There were no significant differences in CPOE adoption by specialty. The null hypothesis was not rejected.

Bivariate Hø 8: There will be no significant association between being a hospital-based physician and physician adoption of CPOE. Hospital based physicians were more likely to adopt CPOE. The null hypothesis was rejected.

Bivariate Hø 9: There will be no significant association between discharge volume and physician adoption of CPOE. There were no significant differences in CPOE adoption by discharge volume. The null hypothesis was not rejected.

Bivariate Hø 10: There will be no significant association between inpatient ratio and physician adoption of CPOE. There were no significant differences in CPOE adoption by inpatient ratio. The null hypothesis was not rejected.

Bivariate Hø 11: There will be no significant association between loyalty and physician adoption of CPOE. There were no significant differences in CPOE adoption by loyalty. The null hypothesis was not rejected.

Multivariable Hø 12: None of the variables will significantly predict the rate of adoption of CPOE when the variables are adjusted for each other. Community hospital, alignment through employment, male gender, discharge volume less than 132 and high inpatient ratio significantly predicted a higher likelihood of CPOE adoption. The null hypothesis was rejected.

Bivariate Hø 13: There will be no significant association between hospital where a physician practices and physician adoption of EH&P. Physicians from the larger, academic hospital were more likely to adopt EH&P than physicians from the two community hospitals. The null hypothesis was rejected.

Bivariate Hø 14: There will be no significant association between alignment and physician adoption of EH&P. Physicians who were financially aligned were more likely to adopt EH&P than independent or competing physicians. The null hypothesis was rejected.

Bivariate Hø 15: There will be no significant association between having an EHR in the office prior to activation and physician adoption of EH&P. Physicians with an EHR in the office prior to activation of the hospital EHR were more likely to adopt compared to those without an EHR in the office. The null hypothesis was rejected.

Bivariate Hø 16: There will be no significant association between group size and physician adoption of EH&P. Physicians from groups of 31 to 100 physicians were more likely to adopt compared to physicians from groups of three or less.

The results were not in the hypothesized direction. The null hypothesis was rejected.

Bivariate Hø 17: There will be no significant association between age and physician adoption of EH&P. There were no significant differences in adoption by age category. The null hypothesis was not rejected.

Bivariate Hø 18: There will be no significant association between gender and physician adoption of EH&P. There were no significant differences in adoption by gender. The null hypothesis was rejected.

Bivariate Hø 19: There will be no significant association between specialty and physician adoption of EH&P. Surgical specialists were more likely to adopt compared to medical specialists. The null hypothesis was rejected.

Bivariate Hø 20: There will be no significant association between being a hospital-based physician and physician adoption of EH&P. There were no significant differences in adoption by hospital-based status. The null hypothesis was not rejected.

Bivariate Hø 21: There will be no significant association between discharge volume and physician adoption of EH&P. Physicians with more than 132 discharges were less likely to adopt compared to physicians who had between 36 and 70 discharges. The results did not match the hypothesized direction. The null hypothesis was rejected.

Bivariate Hø 22: There will be no significant association between inpatient ratio and physician adoption of EH&P. There were no significant differences in adoption by inpatient ratio. The null hypothesis was not rejected.

Bivariate Hø 23: There will be no significant association between loyalty and physician adoption of EH&P. There were no significant differences in adoption by inpatient ratio. The null hypothesis was not rejected.

Multivariable Hø 24: None of the variables will significantly predict the rate of adoption of EH&P when the variables are adjusted for each other. Adjusted for other variables, admitting to the large, academic hospital, financial alignment, and discharge volume below the median predicted a higher likelihood of physician adoption of EH&P. The null hypothesis was rejected.

Bivariate Hø 25: There will be no significant association between hospital where a physician practices and physician adoption of EDS. Physicians at the large, academic hospital were more likely to adopt compared to physicians from the mid-sized, community hospital. The null hypothesis was rejected.

Bivariate Hø 26: There will be no significant association between alignment and physician adoption of EDS. Physicians with financial alignment were more likely to adopt than physicians employed by competing systems. The null hypothesis was rejected.

Bivariate Hø 27: There will be no significant association between having an EHR in the office prior to activation and physician adoption of EDS. Physicians with an EHR in the office prior to activation of the hospital EHR were more likely to

adopt than physicians who did not have an EHR in the office. The null hypothesis was rejected.

Bivariate Hø 28: There will be no significant association between group size and physician adoption of EDS. Physicians from groups with 11 to 100 physicians were more likely to adopt compared to physicians from larger or smaller groups. The results did not match the hypothesized direction. The null hypothesis was rejected.

Bivariate Hø 29: There will be no significant association between age and physician adoption of EDS. There were no significant differences in EDS adoption by age category. The null hypothesis was not rejected.

Bivariate Hø 30: There will be a significant association between gender and physician adoption of EDS. The null hypothesis was not rejected.

Bivariate Hø 31: There will be no significant association between specialty and physician adoption of EDS. Surgical specialists were more likely to adopt compared to medical specialists. The null hypothesis was rejected.

Bivariate Hø 32: There will be no significant association between being a hospital-based physician and physician adoption of EDS. Physicians who were hospital-based were less likely to adopt than physicians who were not hospital-based. The results did not match the hypothesized direction. The null hypothesis was rejected.

Bivariate Hø 33: There will be no significant association between discharge volume and physician adoption of EDS. There were no significant differences in adoption by discharge category. The null hypothesis was not rejected.

Bivariate Hø 34: There will be no significant association between inpatient ratio and physician adoption of EDS. There were no significant differences in adoption by inpatient ratio. The null hypothesis was not rejected.

Bivariate Hø 35: There will be no significant association between loyalty and physician adoption of EDS. There were no significant differences in adoption by loyalty. The null hypothesis was not rejected.

Multivariable Hø 36: None of the variables will significantly predict the rate of adoption of EDS when the variables are adjusted for each other. Admitting to the large, academic hospital, not being employed by a competing health system and surgical specialty predicted a higher likelihood of adopting EDS. The null hypothesis was rejected.

Bivariate Hø 37: There will be no significant association between hospital where a physician practices and the rate of adoption of CPOE. Physicians from the two community hospitals adopted faster compared to physicians from the large, academic hospital. The results did not match the hypothesized direction. The null hypothesis was rejected.

Bivariate Hø 38: There will be no significant association between alignment and the rate of adoption of CPOE. Physicians employed by a competing health

system or the system activating the EHR adopted faster than physicians who were independent or contracted. The null hypothesis was rejected.

Bivariate Hø 39: There will be no significant association between having an EHR in the office prior to activation and the rate of adoption of CPOE. Physicians with an EHR in the office prior to hospital activation of an EHR adopted slower than physicians who did not have an office EHR. The results did not match the hypothesized direction. The null hypothesis was rejected.

Bivariate Hø 40: There will be no significant association between group size and the rate of adoption of CPOE. Physicians from groups with over 100 physicians adopted faster compared to physicians from groups with between 11 and 100 physicians. The results did not match the hypothesized direction. The null hypothesis was rejected.

Bivariate Hø 41: There will be no significant association between age and the rate of adoption of CPOE. There were no significant differences in adoption by age category. The null hypothesis was not rejected.

Bivariate Hø 42: There will be a significant association between gender and the rate of adoption of CPOE. There were no significant differences in adoption by gender. The null hypothesis was not rejected.

Bivariate Hø 43: There will be no significant association between specialty and the rate of adoption of CPOE. There were no significant differences in adoption by specialty. The null hypothesis was not rejected.

Bivariate Hø 44: There will be no significant association between being a hospital-based physician and the rate of adoption of CPOE. Hospital-based physicians adopted faster than physicians who were not hospital-based. The null hypothesis was rejected.

Bivariate Hø 45: There will be no significant association between discharge volume and the rate of adoption of CPOE. There were no significant differences in adoption by discharge volume. The null hypothesis was not rejected.

Bivariate Hø 46: There will be no significant association between inpatient ratio and the rate of adoption of CPOE. There were no significant differences in adoption by inpatient ratio. The null hypothesis was not rejected.

Bivariate Hø 47: There will be no significant association between loyalty and the rate of adoption of CPOE. Physicians who were 100% loyal adopted faster than physicians who also admitted to a competing hospital. The null hypothesis was rejected.

Multivariable Hø 48: None of the variables will significantly predict the rate of adoption of CPOE when the variables are adjusted for each other. The null hypothesis was not rejected.

Bivariate Hø 49: There will be no significant association between hospital where a physician practices and the rate of adoption of EH&P. Physicians who admitted to the large, academic hospital adopted faster compared to physicians from the mid-sized, community hospital. The null hypothesis was rejected.

Bivariate Hø 50: There will be no significant association between alignment and the rate of adoption of EH&P. Contracted physicians adopted faster than employed, independent and competing physicians. The null hypothesis was rejected.

Bivariate Hø 51: There will be no significant association between having an EHR in the office prior to activation and the rate of adoption of EH&P. Physicians with an EHR in the office prior to hospital activation of an EHR adopted faster than physicians who did not have an office EHR. The null hypothesis was rejected.

Bivariate Hø 52: There will be no significant association between group size and the rate of adoption of EH&P. Physicians from groups with between 31 and 100 physicians adopted faster than physicians from groups with less than 31 or over 100 physicians. The results did not match the hypothesized direction. The null hypothesis was rejected.

Bivariate Hø 53: There will be no significant association between age and the rate of adoption of EH&P. There were no significant differences in adoption by age category. The null hypothesis was not rejected.

Bivariate Hø 54: There will be a significant association between gender and the rate of adoption of EH&P. Female physicians adopted faster compared to male physicians. The null hypothesis was rejected.

Bivariate Hø 55: There will be no significant association between specialty and the rate of adoption of EH&P. Surgical specialists adopted faster compared to medical specialists. The null hypothesis was rejected.

Bivariate Hø 56: There will be no significant association between being a hospital-based physician and the rate of adoption of EH&P. There were no significant differences in adoption by hospital-based physician status. The null hypothesis was not rejected.

Bivariate Hø 57: There will be no significant association between discharge volume and the rate of adoption of EH&P. Physicians in the second quartile adopted faster compared to physicians with over 70 or less than 36 discharges. The null hypothesis was rejected.

Bivariate Hø 58: There will be no significant association between inpatient ratio and the rate of adoption of EH&P. Physicians in the third quartile (76% to 98% inpatient ratio) adopted faster compared to physicians in the second quartile. The null hypothesis was rejected.

Bivariate Hø 59: There will be no significant association between loyalty and the rate of adoption of EH&P. There were no significant differences in adoption by loyalty. The null hypothesis was not rejected.

Multivariable Hø 60: None of the variables will significantly predict the rate of adoption of EH&P when the variables are adjusted for each other. Admitting to the large, academic hospital, being an independent, contracted or employed physician, and admitting fewer than 36 patients predicted faster physician adoption of EH&P. The null hypothesis was rejected.

Bivariate Hø 61: There will be no significant association between hospital where a physician practices and the rate of adoption of EDS. Physicians from the large,

academic hospital and the small, community hospital adopted faster compared to physicians from the mid-sized, community hospital. The null hypothesis was rejected.

Bivariate Hø 62: There will be no significant association between alignment and the rate of adoption of EDS. Contracted physicians admitted faster than physicians who were employed, independent or from competing health systems. The null hypothesis was rejected.

Bivariate Hø 63: There will be no significant association between having an EHR in the office prior to activation and the rate of adoption of EDS. Physicians with an EHR in the office prior to hospital activation of an EHR adopted faster than physicians who did not have an office EHR. The null hypothesis was rejected.

Bivariate Hø 64: There will be no significant association between group size and the rate of adoption of EDS. Physicians from groups with between 31 and 100 physicians adopted faster than physicians from groups with less than 31 or over 100 physicians. The results did not match the hypothesized direction. The null hypothesis was rejected.

Bivariate Hø 65: There will be no significant association between age and the rate of adoption of EDS. There were no significant differences in adoption by age category. The null hypothesis was not rejected.

Bivariate Hø 66: There will be a significant association between gender and the rate of adoption of EDS. There were no significant differences in adoption by gender. The null hypothesis was not rejected.

Bivariate Hø 67: There will be no significant association between specialty and the rate of adoption of EDS. Surgical specialists adopted faster than medical specialists did. The null hypothesis was rejected.

Bivariate Hø 68: There will be no significant association between being a hospital-based physician and the rate of adoption of EDS. There were no significant differences in adoption by hospital-based status. The null hypothesis was not rejected.

Bivariate Hø 69: There will be no significant association between discharge volume and the rate of adoption of EDS. There were no significant differences in adoption by discharge volume. The null hypothesis was not rejected.

Bivariate Hø 70: There will be no significant association between inpatient ratio and the rate of adoption of EDS. There were no significant differences in adoption by inpatient ratio. The null hypothesis was not rejected.

Bivariate Hø 71: There will be no significant association between loyalty and the rate of adoption of EDS. There were no significant differences in adoption by loyalty. The null hypothesis was not rejected.

Multivariable Hø 72: None of the variables will significantly predict the rate of adoption of EDS when the variables are adjusted for each other. Admitting to the large, academic hospital or the small, community hospital, being an independent, contracted or employed physician, being a surgical specialist and being less than 100% loyal predicted faster physician adoption of EDS. The null hypothesis was rejected.

Table 25: Predicted (P) and Reversed (R) Adoption Results

			CPOE		EH&P		EDS	
Variable	Category	Hypothesized Associations with Increased Adoption	χ^2	L.R.	χ^2	L.R.	χ^2	L.R.
Hospital	Large, academic Small, community Mid-sized, community	Large, academic	R	R	P	P	P	P
Alignment	Competing Independent Contracted Employed	Contracted or Employed	M	P	P	P	P	P
EMR Office	No Yes	Yes	R	Exc	P	Exc	P	Exc
Group Size Category	<3 3 - 10 11 - 30 31 - 100 >100	Larger	M	Exc	P	Exc	M	Exc
Age Category	<40 40-54 55+	Youngest						
Gender	F M	No association		Male	Fe-male			
Specialty	Medical Surgical	Medical			R		R	R
Hospital-based	No Yes	Hospital-based	P				R	R
Discharge Quartile	1 2 3 4	Higher volume		R	M	R		
Inpatient Quartile	1 2 3 4	Higher ratio		P				
Loyal 100%	No Yes	Loyal 100%						

$\chi2$ = Chi-square bivariate analysis; L.R. = Logistic Regression; Exc = excluded; P = Significant and Predicted; R = Significant and Reversed; M = Significant and Mixed; Blank = not significant

Table 26: Predicted (P) and Reversed (R) Rate of Adoption Results

			CPOE		EH&P		EDS	
Variable	Category	Hypothesized Associations with Faster Adoption	K.M.	Cox	K.M.	Cox	K.M.	Cox
Hospital	Large, academic Small, community Mid-sized, community	Larger, academic	R		P	P	P	P
Alignment	Competing Independent Contracted Employed	Contracted or Employed	M		P	P	P	P
EMR Office	No Yes	Yes	R	Exc	P	Exc	P	Exc
Group Size Category	<3 3 - 10 11 - 30 31 - 100 >100	Larger	M	Exc	P	Exc	M	Exc
Age Category	<40 40-54 55+	Youngest						
Gender	F M	No association			Female			
Specialty	Medical Surgical	Medical			R		R	R
Hospital-based	No Yes	Hospital-based	P					
Discharge Quartile	1 2 3 4	Higher volume			R			
Inpatient Quartile	1 2 3 4	Higher ratio			M			
Loyal 100%	No Yes	Loyal 100%	P					R

K.M. = Kaplan-Meier survival analysis; Cox = Cox Regression; Exc = excluded; P = Significant and Predicted; R = Significant and Reversed; M = Significant and Mixed; Blank = not significant

CHAPTER V

DISCUSSION AND CONCLUSION

Stimulated by the need for quality, efficiency and safety improvements, as well as government incentives, activations of complex Electronic Health Records (EHR) by hospitals continue to rise. Physician adoption is pivotal to the success of the EHRs. This study evaluated the six-month adoption and rate of adoption by admitting physicians at three hospitals in Southeastern Virginia. Data for the use of computerized physician order entry (CPOE), electronic history and physical (EH&P) and electronic discharge summary (EDS) functions were collected for six months following the activation at each hospital. Achievement of a use rate of 80 percent was considered successful adoption of a function. A heuristic combination of Diffusion of Innovations Theory (DI) and Resource Dependence Theory (RDT) was developed and tested. The selected constructs chosen from these two theories provide the needed theoretical background to support the hypotheses. Additionally, the heuristic combination enabled evaluation of the model using administrative data.

The propositions from DI theory used in this study focus on characteristics of the innovator and where the innovation was adopted. DI suggests physicians from larger hospitals and physician groups and younger physicians are more likely to adopt an innovation. DI posits that more innovative physicians and those who have the opportunity to trial a system will be more likely to adopt. This study hypothesized physicians from a large, academic hospital, larger physician groups

or who had an office EHR prior to the activation of the EHR may be more disposed to innovation or have had the opportunity to trial a similar innovation, thereby making them more likely to adopt.

Propositions from RDT focus on the level of dependence between the hospital and the physician. RDT suggests employed or contracted physicians who have higher levels of financial alignment with the hospital will be more likely to adopt due to higher levels of external control and dependence for resources (patients) than physicians who are independent or employed by competing hospitals. This study hypothesized that higher levels of alignment would be associated with higher likelihood of adoption and faster adoption. RDT also proposes that adoption is more likely if the resource is important or efficient. To test this, it was hypothesized that the importance of the EHR was higher for medical specialists, hospital-based physicians, or physicians who had higher patient volume or a higher inpatient ratio, making them more likely to adopt the EHR. Physician loyalty was also evaluated as a potential measure of voluntary alignment, willingness or efficiency of the relationship. This chapter presents a discussion of the physician adoption and rate of adoption findings tying results to the underlying theories that informed the research.

First, the overall results are summarized and interpreted. Second, the results for each independent variable are interpreted and discussed. Possible reasons for differences in the results compared to the hypothesized results are presented. Implications, limitations, suggestions for future research, and conclusions follow the discussion of the statistical analysis.

Summary and Interpretation of Analysis Results

Diffusion of Innovations theory proposes the normal adoption of an innovation has an "S" shaped curve. The adoption is slow at first as innovators adopt then increases rapidly until it reaches a "tipping point". Once the tipping point is reached the adoption rate decreases in a curve that is symmetric to the curve prior to the tipping point. The "S" curve is appropriate for voluntary adoption of innovations. Since the adoption of the EHR was essentially "mandatory" due to the virtual elimination of paper medical records, the adoption curve for this study was expected to appear like the second half of the DI adoption curve (rapid adoption at first with a progressive decline over time). The adoption curves for all three functions evaluated were approximately the shape and magnitude that was expected. The cumulative adoption curves showed steep growth in the first months followed by a steady decline in new adopters. The variables in the model significantly predicted adoption of the three EHR functions evaluated. The variables and theory surrounding the results are discussed in detail below. There were also apparent differences in the adoption of the three functions that will be discussed below.

Differences in Adoption and Rate of Adoption of CPOE, EH&P and EDS

The differences in adoption of the three functions of the EHR might be explained by DI or RDT. CPOE was clearly adopted by more physicians than EH&P and EDS. The rate of adoption appears to be faster, and the cumulative adoption level higher, for CPOE than EH&P and EDS. CPOE was adopted

rapidly the first month after activation of the EHR. During the second month the number of new adopters of EH&P surpassed that of CPOE, suggesting the delay in adoption may have been the result of physicians setting priorities as to what functions they chose to adopt first. In general, the adoption and rate of adoption results for the EDS and EH&P functions are similar to each other but different and sometimes opposite those of CPOE. The mandatory nature of the use of CPOE may help explain why it was adopted at a higher level and faster. Paper physician orders were not readily available to physicians. Hospital management and normative pressures to adopt CPOE were high. In contrast, services for dictation and transcription of EH&P and EDS remained readily available to physicians. The adoption was encouraged but not required. Physicians who chose to adopt EH&P or EDS did so without management coercion. Normative forces proposed by DI or the higher efficiency of EHR use proposed by RDT may have a more prominent role in physician adoption of EH&P and EDS.

CPOE is an "action function" in which a physician tells another member of the health care team to perform a task. In contrast, EH&P and EDS are "retrospective, documentation functions" a physician performs to assure services that were provided and conditions that were treated are documented and available for review by other members of the healthcare team. After activation of the EHR, the rate of CPOE use was calculated and reported frequently at each hospital. The leaders at the hospitals were expected to help their physicians achieve an overall average rate of at least 80 percent for all orders entered. (The rate reported to leadership included outpatient orders such as those from the

Emergency Department and procedural areas. This study evaluated a subset of all orders including orders entered by admitting physicians.) The level of attention of leaders and educators and managing to the 80% CPOE expectation, in addition to the lack of availability of paper order forms, may help explain why CPOE was adopted faster and with a higher cumulative level of adoption than other functions.

Discussion of the Results for Predictor Variables

The next section provides a discussion of the theory and propositions while evaluating the results for each predictor variable.

Hospital

Diffusion of Innovations theory proposes that physicians at larger facilities are more likely to be early adopters. Additionally, DI posits academic facilities are more likely to be early adopters of innovations. Large, academic facilities often have greater access to capital and tend to attract people interested in learning or innovation (Russell & Spooner, 2004; S. R. Simon, et al., 2007). The results for hospital were significant for each dependent variable but the direction of the association for CPOE was contrary to the hypothesis. Physicians at the large, academic facility were less likely to adopt CPOE compared to physicians at the smaller community hospitals. The association of hospital to physician adoption of EH&P and EDS supported the hypothesized direction. Why were there differences in the direction of association? Only three hospitals were included in this study, limiting the conclusions that may be drawn about hospital

as a predictor variable. "Hospital" could represent many environmental variables such as academic status, number of beds, presence of tertiary services, market effects such as competition or payer mix, patient demographics, social norms, attitudes or leadership. DI theory proposes that social norms affect adoption but these norms were not measured in this study. Possible reasons for the significant differences between hospitals are provided below but due to the small number of hospitals, for this study "hospital" is primarily used for adjusting the results of other variables. A detailed analysis of the differences between hospitals is beyond the scope of this study.

The large, academic facility, was hypothesized to adopt all three measures at higher levels and faster than the two smaller hospitals. Bivariate results found lower levels of adoption and slower rate of adoption of CPOE in the large, academic hospital. The association between hospital and CPOE remained significant when adjusted for other variables. The hospital differences in rate of adoption of CPOE were no longer significant once adjusted for the other variables. Contrary to the CPOE results, the physicians at the large, academic hospital were more likely to adopt EH&P and EDS than the mid-sized community hospital. The EH&P and EDS physician adoption rates were also more likely to be faster at the large, academic hospital compared to the mid-sized community hospital. The results suggest there may be a difference between the way physicians adopt the "action" function of CPOE compared to the "documentation" functions of EH&P and EDS.

The differences in adoption and rate of adoption between hospitals may be due to many variables that were not measured. The social norms of the hospital with respect to what physicians prefer to read may affect the use of the documentation functions. An unpublished qualitative study performed concurrently with this study found physicians in the fellowship training programs at the large teaching hospital were significantly more satisfied than the attending physicians with the admission and discharge processes using eCare (Arora, Britt, & Schwentker, 2011). DI theory suggests the learning environment at the academic hospital may create a social norm that increases the likelihood of adoption. Leadership may have focused less time and energy on the evaluation and management of the performance of documentation functions at the mid-sized, community hospital three than the large, academic hospital. It is notable that the large, academic hospital is the lowest and slowest adopter of CPOE but the highest and fastest adopter of the other two functions. One may be tempted to conclude the use of the documentation functions could be higher due to the presence of young fellows and residents at the large academic facility, however, age was not a significant predictor of any of the outcomes evaluated for the three functions.

The large, academic hospital activated the EHR six months before hospital two and eight months before hospital three. Something may have occurred between the activations that affected the differences. Formal reporting of the performance of physicians and their individual rates of CPOE use may have improved over time. Better, more frequent reporting of these metrics may

have enabled the implementation team to focus efforts. If reports improved, they may have caused an increase in the Hawthorne effect at the hospitals that adopted later, resulting in greater efforts to meet the goal of 80% use. The differences are worthy of further evaluation. A qualitative evaluation of differences in perceptions of the impact of the hospital leadership, details of management methods and the perceived value, ease of use and usefulness of the various functions at the different hospitals may prove useful.

In summary, the adoption of EH&P and EDS was voluntary and DI constructs regarding size, academic setting and social norms may explain the higher rates of adoption of EH&P and EDS at the large, academic hospital. Compared the EH&P and EDS, CPOE was relatively mandatory and the development of increased external control/management may explain the higher adoption of CPOE at the two community hospitals that activated after the large, academic hospital. The results should be evaluated with consideration given to the fact that only three hospitals were included in the study.

Alignment

Resource dependence theory proposes that a high degree of dependence of one organization for resources provided by a second organization results in a higher degree of compliance by the organization that is dependent. In the case of employment or contractual relationships between hospitals and physicians, the physician depends on the hospital for patients or even a paycheck. It was hypothesized that higher levels of physician-hospital alignment would result in

significantly higher odds of adoption or faster adoption. Multivariable results showed alignment, by either employment or contract, with the health system installing the EHR was significantly associated with higher odds of adoption of CPOE, EH&P and EDS compared to competing physicians. The results supported the hypothesized association. Contracted physicians had much higher odds of adopting EH&P and EDS compared to physicians employed by competing health systems. It is difficult to determine if physicians who are employed are more dependent on the hospital than physicians who are contracted for services. The categories within the alignment variable were thought to be in a logical order resulting in alignment being an ordinal variable. The results suggest it may be appropriate to treat alignment as a nominal variable. The higher likelihood of adoption of the documentation functions (EH&P and EDS) may be influenced by the sub-specialties of physicians who are contracted with the hospital compared to employed physicians. This study only evaluated medical versus surgical specialties so it was not possible to evaluate if sub-specialty confounded the alignment results. Further evaluation of the differences in adoption between employed and contract physicians could be beneficial in determining the differential value of employing versus contracting physicians. The RDT proposition that high dependence for resources appears to be supported.

Office EHR

DI theory proposes that physicians who are more innovative or have the opportunity to trial an innovation are more likely to be early adopters. This

variable was hypothesized to be positively related to all three measures of all three functions. Bivariate results show the presence of an electronic health record in the office prior to activation of the EHR was significantly associated with CPOE, EH&P and EDS adoption and rate of adoption. Office EHR is negatively associated with the adoption and rate of adoption of CPOE. It is positively associated with the adoption and rate of adoption of EH&P and EDS functions. The negative association with CPOE does not support DI theory and may suggest a lack of compatibility with systems used in the office. None of the office systems interfaced with the eCare system. One might expect that familiarity with the overall CPOE process due to prior use in the office would ease the adoption of eCare but these physicians were less likely to adopt CPOE. Conversely, these physicians were more likely to adopt EH&P and EDS. Their office EHR systems included history and physical functions. While the systems were not interfaced, the physicians may have been able to “cut and paste” recent documentation into the eCare system easing the electronic documentation process and increasing the likelihood of adoption.

The variable could not be included in the multivariable Cox and Logistic Regression evaluations due to high multicollinearity with alignment. The multicollinearity of the variable was identified using collinearity diagnostics and validated using stepwise Cox Regression. The direction of the association between EHR in office and the dependent variables at each step matched the direction of the Kaplan-Meier analysis until alignment was entered into the equation in a subsequent block. Once alignment was included, the variable

developed an odds ratio that was the opposite direction or was no longer significant.

The presence of an EHR in the office prior to activation was also intended to be a proxy for "personal innovativeness", a predictor variable from DI proposed to be directly associated with early adoption. More than half of the physicians who used an office EHR prior to activation were employed by a single large group. The group is the faculty of the local medical school. The office EHR was implemented several years earlier. Consequently, the variable was not a good measure of personal innovativeness. Additionally, the hospital system was actively preparing to install office-based systems in several practices during the study period. These activations may have reduced the reliability of the data collected for this variable. The loss of this variable from the model is unfortunate but the utility of information provided by the alignment variable is higher.

Group Size

DI proposes that individuals from larger organizations are more likely to be early adopters. Contrary to DI, RDT proposes organizations that are members of larger systems may be less likely to meet demands posed by other organizations. Physicians function as independent organizations, billing for services provided to patients. According to the RDT proposition, physicians who belong to larger groups may be less likely to adopt the mandated EHR compared to physicians from smaller groups. Based on DI and the results from prior research, larger physician groups were hypothesized to have higher odds of

adoption and faster adoption for all three dependent variables. Group size yielded mixed results in bivariate analyses and was excluded from the Cox Regression and Logistic Regression due to multi-collinear associations with the alignment variable. The largest groups of physicians are the physicians employed by hospitals. Although the results in some cases were significant, the results showed no order or logical relationship between group size and any of the outcomes. The mixed results do not support either of the opposite propositions provided by DI and RDT.

Age

In several studies of adoption and diffusion of innovations, young age is associated with higher levels of adoption and faster adoption (N. Menachemi & R. G. Brooks, 2006; Steven R. Simon, et al., 2008). DI theory proposes characteristics of the innovator are predictive of innovation. According to DI, early adoption is associated with youth. In this study, youth was hypothesized as predictive of adoption and faster adoption. Multivariate results showed no significant association between any age category and the adoption or rate of adoption of CPOE, EH&P or EDS. Age was divided into three categories (<40, 40-54 and 55+). The lack of differences between the oldest and the youngest and the lack of differences in any category are surprising, especially since younger physicians are generally believed to have more exposure to many different forms of information technology than the older physicians do. The lack of differences by age may suggest the EHR is easy to use for all ages.

Gender

Gender was hypothesized to have no association with any of the outcomes. Neither DI nor RDT propose significant differences in adoption by gender. The literature was inconsistent in its conclusions regarding the association of gender and the adoption of innovations (Kralewski, et al., 2008; Lindenauer, et al., 2006). Bivariate results showed female physicians were more likely to adopt EH&P and adopt it faster compared to male physicians. The differences in adoption of EH&P by gender were no longer statistically significant when adjusted for the other variables. Multivariate results showed gender was significantly associated with CPOE adoption but not rate of adoption. Adjusted for other variables, male physicians were three times more likely to adopt CPOE compared to female physicians. With the exception of adoption of CPOE, concluding there is a gender difference may be considered spurious. These results do not support or refute the propositions of DI or RDT and no other theories were found that might help explain this result.

Specialty

RDT proposes higher efficiency in the relationship between two organizations may result in higher adoption. Because medical specialists provide highly complex care to a wide variety of patients compared to surgical specialists, medical specialists were hypothesized to use and adopt the functions of the EHR at higher levels and faster than surgical specialists. Specialty was not significantly associated with CPOE adoption or rate of adoption. Bivariate results

showed surgical specialists were more likely to adopted EH&P and adopt it faster compared to medical specialists. These differences were no longer significant when adjusted for the other variables. In bivariate and multivariable results, EDS was more likely to be adopted and adopted earlier by surgical specialists compared to medical specialists.

The higher and faster adoption of EDS by surgical specialists might be explained by differences in the routines of medical and surgical specialists. Surgeons are required to document postoperative notes on all procedures. The EDS function in the electronic health record is similar to the function used for documenting postoperative notes. If the surgeon adopts one, he may adopt the other. Additionally, surgeons are very methodical and perform similar procedures many times. It may be easier for surgeons to develop a routine script for their discharge summaries than it is for medical specialists since the process of care for a medical patient is more variable than the care of a surgical patient. This would also help to explain the difference between EDS adoption by surgeons and adoption of the other functions. CPOE and EH&P may be less routine since each patient requires different orders for treatment and has a different history and physical assessment. In retrospect, the EHR is probably more efficient for surgical specialists than medical specialists to use. If that is true, the results support the proposition of RDT.

Hospital-Based Physicians

RDT proposes the importance and efficiency of a resource affects the likelihood of adoption. Hospital-based physicians work almost exclusively in the hospital environment. The EHR is the main method for communicating care that needs to be, or has been, provided and should be an important and efficient tool. Being a hospital-based physician was hypothesized as being positively associated with adoption and faster adoption. Bivariate results showed being a hospital-based physician was associated with higher and faster CPOE adoption compared to physicians who were not hospital-based. These differences were no longer significant when adjusted for other variables. There were no associations between hospital-based and the adoption or rate of adoption of EH&P. Hospital-based physicians were about two times less likely to adopt the use of EDS by the end of the six-month period than physicians who were not hospital-based. Further analysis may require qualitative assessment. It could be that hospital-based physicians do not perceive the electronic discharge summaries to be useful or easy to use. Since the option to dictate notes is still readily available, they may prefer to dictate rather than use the template and type. The results for this variable did not support the propositions of RDT.

Discharge Volume

RDT suggests higher levels of importance or efficiency may increase the probability of adoption. Additionally, if a physician discharges a large volume of patients, he is more dependent on that hospital as a place to work and the

resources it provides. Resource dependence theory proposes the higher volume physicians may be more dependent on the hospital as a place to work and therefore more likely to adopt the EHR. Similar to hospital-based physicians, physicians with a large number of patients may find the EHR important and efficient. The adoption and rate of adoption of the three functions were hypothesized to be directly associated with the number of discharges a physician performed. Physicians in the highest quartile for discharges were unexpectedly less likely to adopt CPOE and EH&P and more likely to adopt CPOE and EH&P slower than physicians in the lowest quartile. Discharge volume was not significantly associated with EDS adoption or rate of adoption.

The results support the RDT propositions when viewed from an inter-organizational perspective. It is possible these physicians are not adopting as a demonstration of power. The physicians who admit the highest volume of patients are dependent on the hospital as a place to work but the hospital is also highly dependent on these physicians for patients to use hospital services. Because these physicians provide a large number of admissions to the hospital, they may not be as likely to meet the hospital's demands and the hospital leaders may be reticent to coerce them to adopt the EHR for fear of losing patient volume. The inter-organizational relationships proposed by RDT fit these results. Drawing from constructs in DI theory, the Technology Acceptance Model posits that if the EHR is useful, easy to use and compatible with a physician's routines, it will be adopted (Adams, Nelson, & Todd, 1992; Al-Azmi, Al-Enezi, & Chowdhury, 2009; Al-Gahtani & King, 1999). It is possible the physicians with a

large number of discharges find the functions to be cumbersome rather than enabling. Another intuitive explanation may be, regardless of their perceived ease of use, usefulness and compatibility, the highest volume physicians may not have taken take time away from patient care to learn the EHR systems.

Inpatient Ratio

RDT proposes the importance and efficiency of a resource affects the likelihood of adoption. The EHR is expected to improve the process of care by eliminating redundant steps and improving communication between members of the care team. Inpatient care is generally considered more complex than outpatient care. It was hypothesized that physicians who perform a higher proportion of their hospital services for inpatients than outpatients would be more likely to use and adopt all functions. The direction of the hypothesis is based on the proposition in RDT that the more important the resource is, the more likely the physician will be to adopt. Inpatient care can only be provided in a hospital and the number of inpatient facilities is limited. Outpatient services may be provided in a much larger number of locations.

Adjusted for other variables, inpatient ratio was significant in the Logistic Regression model predicting the adoption of CPOE. The highest level of inpatient ratio was four times as likely to adopt CPOE by the end of six months. Inpatient ratio was not significantly associated with the adoption or rate of adoption of EH&P or EDS. The results for CPOE support the hypothesized relationship and the RDT propositions but overall, the results are mixed. CPOE

allows the use of order sets and can be a much more efficient method for entering orders. EH&P and EDS are documentation functions that some physicians may still consider cumbersome compared to dictation of notes.

Loyalty

Higher efficiency and importance of the hospital resources are proposed by RDT to be associated with higher likelihood of adoption. Physicians choose where they admit patients and may move from one hospital to another in the same geographic area without great burden. Physicians choose to be loyal to a particular hospital because it is an efficient place to work and it provides the important resources needed (Teska & Wolosin, 2006). Those resources could be hospital infrastructure and systems or they may be referrals of patients from other physicians such as from the Emergency Department. The association between loyalty and the adoption or use of the information technology was not evaluated in any studies in the extant literature. Loyalty was included in the model as a measure of voluntary alignment. In many hospital systems, few physicians are employed or exclusively contracted to provide services. Administrators of hospitals may intuitively believe that physicians who are loyal will be agreeable and adopt the EHR if installed in their hospital.

In this study, loyalty was not significantly predictive of any of the outcomes except six-month adoption of EDS. The association of loyalty and EDS was the opposite of what was predicted. Chi square evaluation showed a significant association between loyalty and alignment. Loyalty levels increased directly with

each increasing level of alignment. The study shows that loyalty and alignment do not have the same effect on EHR adoption. Loyalty may not be a good proxy for efficiency or importance of the resource. In the current environment in which physicians are rapidly aligning financially with health systems, loyalty may be an outdated concept.

Implications of the Findings

The combination of the DI and RDT dimensions used in the heuristic model provide a pragmatic model for the prediction of EHR adoption. The organizational variables and the relationship between the physician and the hospital were more important to the predictive value of the model than individual physician variables representing the innovativeness of the physician or the importance or efficiency of the hospital. The hospital environment was significantly associated with adoption of all three EHR functions. The direction of that association varied and may suggest leadership, change management methods, social norms at each facility or other environmental factors affect adoption differently for different functions in the EHR software. The lack of association between loyalty and adoption suggests non-financial relationships or physician habits are not reliable predictors of adoption of the EHR.

The model may be used by legislators and hospital leaders to improve the adoption and rate of adoption of the EHR. Proposed implications and findings are provided in the following section.

Policy Implications

The adoption of CPOE at a level of 80 percent was suggested by experts as the hurdle for the receipt of incentive payments from the government. The final HITECH Act reduced the level to 50 percent. Although this health system is not typical, this study shows the 80 percent rate is achievable in this environment and provides information about the association of physician alignment and other variables. No incentives are in place for the use the documentation functions of the EHR and physician adoption of those functions lags behind CPOE. Since alignment was significantly associated with adoption, it may be valuable for the government to continue plans to integrate the payment for services for physician and hospital services, thereby encouraging physician-hospital alignment and consequently EHR adoption.

Administrative Implications

Hospital administrators may use the results of this study to perform an assessment of the likelihood of adoption by the medical staff at individual hospitals. Understanding the variables that are associated with success or failure will enable them to devise strategies to improve the odds of high use and adoption. The effect of the hospital environment was significant but unclear so administrators may benefit from focusing on addressing the other variables. Understanding the association of financial alignment may encourage administrators to further their efforts to hire or contract with physicians. Actions may also include increasing attention to physicians predicted to be slow adopters

to increase the odds that they buy-in to the system. Hospital administrators traditionally have relied on good relationships and physician loyalty as a predictor of future behavior. Loyalty, however, was not a predictor of adoption or the rate of adoption of EDS.

Methodology Implications

The method is pragmatic for use at any hospital but lacks the measurement of hospital differences and the perceptions and attitudes of physicians. Adding the measurement of the perceived ease of use, compatibility and usefulness would most likely increase the strength of the predictions but complicate the process of data collection. The number of hospitals is limited and many environmental variables were not measured and included in the study. The use of Cox Regression and Logistic Regression were effective methods for statistical evaluation of adoption within a defined period, and rate of adoption. The number of new adopters in the fifth and six months continued to diminish but was higher than expected. Increasing the number of months of data collection would improve the power of the Cox Regression. The use of the pseudo R^2 calculation and interpretation as the percentage of variance explained is controversial, limiting the value of the calculation (Garson, 2010). The variables EHR in office and group size were both significant in bivariate analysis but could not be included in the multivariable analysis. In this study, the EHR in office and group size variables were discarded because of multicollinearity. Evaluation of the variable alignment was considered to have higher utility at this time. In future

studies, it may be more desirable to discard alignment in favor of including one of the other two variables, depending on the focus of the studies.

Theoretical Implications

Use of dimensions from DI and RDT proved to be a good method for evaluating physician adoption rate of adoption of the EHR. Dimensions from DI regarding the environment where the adoption occurs (hospital, group size, EHR in office) were predictive but the directions of the associations were not consistent from one dependent variable to another. Dimensions of the hospital environment are missing from the model tested in this study. Previous studies found size (number of beds) and academic status to be predictive of hospital adoption of EHRs but generalizing the results to physician adoption of a hospital EHR should not be done. Individual hospital factors that were not measured such as change management techniques used by the hospital leaders, social norms that developed after the activation of the EHR and infrastructure differences like availability of computer terminals may need to be added to the model to understand why the direction of association between hospital and each dependent variable was different. The type of the financial relationship between the hospital and the physicians appears to be moderately predictive of EHR adoption and mildly predictive of the rate of adoption. Alignment, especially via contract, strongly predicts adoption of EH&P and EDS. The personal physician variables such as age, gender and specialization generally were not significant once adjusted for other variables. Relative to other variables, loyalty was not predictive. Addition of perception variables from DI or the technology adoption

model would probably improve the model but may be impractical due to the need to gain information through surveys. Research of the adoption of innovations focuses on people who seek out innovations and choose voluntarily to begin using them.

Overall, the results supported the use of the selected dimensions from DI and RDT. Organizational and inter-organizational propositions were generally supported while propositions regarding individual physician factors, with the exception of specialty, had little or mixed support. Inter-organizational theories such as RDT may be useful for future studies of adoption of electronic health records by physicians.

Limitations of the Study

Limitations of this study are both theoretical and methodological. In order to be as pragmatic as possible, the model was limited to information that could be collected without a survey. Lack of information regarding the perceptions of physicians may limit the ability of the model to predict the outcomes. The study is a case study of a sample within a hospital system that is one of the most highly integrated systems in the country. The EHR is rated HIMSS Stage 7, the highest level available. The environment and EHR installed are not representative of the typical hospital system. This study only focuses on adoption and does not evaluate whether adoption resulted in any improvements in patient care or patient outcomes.

Suggestions for Future Study

The model could be tested using a larger number of hospitals and physicians and in a wider variety of hospitals with different geographical, political, leadership and reimbursement levels. The study time could be extended to reduce the number of censored cases. Different levels for what is considered adoption could be evaluated. Evaluation of achievement of 50 percent use could be beneficial for those seeking government incentives through the HITECH Act. The focus could also be expanded to include all physicians rather than limiting to admitting physicians.

Addition of environmental variables describing each hospital would greatly refine the results. Further breakdown of variables may help to answer some questions using quantitative methods such as:

- Why do employed physicians adopt CPOE at a level much higher compared to contracted physicians?
- Why do contracted physicians adopt EH&P and EDS at a rate much higher than employed physicians?
- Do the fellows and residents use the EHR more or adopt the EHR faster?

Limited scale, quantitative evaluations of the patient care and process efficiency outcomes associated with the implementation of the EHR have been performed by employees of the health system. A comprehensive, independent

assessment by an impartial researcher may increase the understanding of the financial and clinical value of the system.

Qualitative assessment should be considered to evaluate the following questions. The use of physician focus groups to identify important themes for more detailed interviews may be beneficial. Development of a structured interview to be completed with a random sample of physicians would enable organized collection of information. Performance of individual interviews may result in the greatest amount of information and a higher response rate than surveys.

- Why was there a difference between the use and adoption of CPOE and EH&P and EDS?
- Why do physicians with the highest number of discharges use the EHR the least?
- Why do surgeons use the EDS functions more compared to medical specialists?
- Why is loyalty not a predictor of adoption and rate of adoption?

Conclusions

This evaluation undertook two separate approaches to evaluating the use and adoption of EHR using three functions of the EHR as dependent variables. The literature and public policy currently addresses the use of only one of the

three functions: CPOE. The value of the EH&P and EDS functions requires further study.

This study shows that organizational dimensions of DI theory and resource importance and efficiency dimensions of RDT are predictive of EHR adoption and rate of adoption. Hospital, physician-hospital alignment, physician volume and inpatient ratio variables can predict the adoption of specific functions of an EHR. The adoption of electronic health records might relate to leadership influence, change management methods and alignment techniques among other hospital environmental variables. Individual characteristics of the adopter expected to be predictive of adoption failed to do so. Demographic variables such as gender and age had little or no significant effect. Loyalty was minimally associated with one of the six multivariate hypotheses.

There are differences in the adoption and rate of adoption for the “action” function of CPOE compared to the “retrospective, documentation functions” of EH&P and EDS. The variables that strongly predict adoption and rate of adoption of the action versus documentation functions are the same but the direction of the associations are different. Future research to explain these differences is recommended.

This study evaluated the installation of a fully integrated EHR at a health system that was highly integrated and had high levels of physician-hospital alignment. The level of physician-hospital alignment and complexity of the EHR provided a unique opportunity to evaluate the effects of alignment on the

adoption of the EHR and create a predictive model for future use. Physician-hospital alignment had a consistent positive effect on physician adoption of the three EHR functions studied. The concept of loyalty, long held by hospital administrators as a measure of the strength of the relationship between the hospital and the physician, and a good predictor of future physician cooperation, appears to have been upstaged by financial alignment. Knowing the results of this study may help administrators improve EHR installations.

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VITA

John Sharon Hudson, RN, MSN, PhD
E-mail: jshudson1@aol.com

John Hudson is a healthcare leader, analyst and educator with over 20 years experience in the implementation and optimization of health services. He maintains a record of operational successes and internal promotions. He is experience in directing change in multiple locations and in a variety of healthcare settings. Most recently, John develped expertise in health information technology implementation and optimization.

Employment:
SENTARA HEALTH SYSTEM
Director Surgical Services, Orthopaedic Hospital Administrator, Senior Strategist, Director of Imaging and Breast Services

MEDICAL UNIVERSITY OF SOUTH CAROLINA
Administrator – Children's Heart Program of S.C.

TIDEWATER PHYSICIANS MULTISPECIALTY GROUP, P.C.
Assistant Administrator

MARY IMMACULATE HOSPITAL, INC. (Bon Secours Health System)
Vice President

THE DETROIT MEDICAL CENTER
Manager of Nursing Consulting

THE CLEVELAND CLINIC
Registered Nurse, Cardiovascular Intensive Care Unit

Education:
Ph.D. Health Services Research
Cognate Area: Leadership
OLD DOMINION UNIVERSITY; Norfolk, Virginia
Phi Kappa Phi Honor Society

M.S.N. Gerontological Nursing and Administration
CASE WESTERN RESERVE UNIVERSITY; Cleveland, Ohio

B.S.N. Nursing
MICHIGAN STATE UNIVERSITY; East Lansing, Michigan