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Information Technology and Quality of Care in Pediatric Hospitals

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INFORMATION TECHNOLOGY AND QUALITY OF CARE IN PEDIATRIC HOSPITALS

by

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A DISSERTATION

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ABSTRACT

The purpose of this dissertation is to examine the relationship between the adoption of information technology by pediatric hospitals and performance on several quality of care measures. This research is aimed at addressing a gap in literature by utilizing a relatively large sample size that examines health information technology adoption across institutions and utilizes validated quality indicators from Agency for Healthcare Research and Quality. The Donabedian evaluation model that encompasses "structure, process, and outcomes" provides the conceptual framework for the organization of this research, selection of variables, and analysis. Three secondary datasets were used, 2005 Information Technology Survey of the National Association of Children's Hospitals and Related Institutions (NACHRI); NACHRI hospital discharge data with pediatric quality indicators for the year 2006; and NACHRI adverse drug events dataset for the years 2006. Multiple linear regression and univariate analysis of variance was used to test the hypothesized relationships. It was found that there is not enough evidence to support the association between health information technology and specific quality of care indicators in pediatric hospitals. These results compel scholars to address the need for future research on the development of a standardized global measurement of HIT effectiveness on quality. Practitioners based upon these findings may want to take an approach that makes meaningful use of HIT applications for improvement of specific quality outcomes.

Keywords: health information technology, pediatric hospitals, quality, Donabedian model, adverse drug events, pediatric quality indicators.

DEDICATION

My family, the wind beneath my wings.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ADE	Adverse drug event
AHRQ	Agency for Healthcare Research & Quality
ANOVA	one way analysis of variance
BDSS	Bioterrorism Electronic Disease Surveillance System
CCIT	Council of Clinical Information Technology
CITC	clinical information technology capabilities
CDSS	Clinical decision support systems
CIO	Chief Information Officers
CPOE	Computerized physician order entry systems
E-Codes	external causes of injury
EHR	electronic health record
EMR	Electronic Medical Records
HIT	health information technology
ICD-9-CM	International Classification of Diseases, 9th Revision, Clinical Modification
IOM	Institute of Medicine
IS	Information systems
IT	Information Technology
LIS	Laboratory Information System
NACHRI	National Association of Children's Hospitals and Related Institutions

PACS	Picture Archiving and Communication Systems
PDI	Pediatric quality indicator
PIS	Pharmacy Information System
RIS	Radiology Information System
SPO	structure, process and outcomes

CHAPTER 1

INTRODUCTION

Recent endeavors to expand health information technology (HIT) through the American Recovery and Reinvestment Act 2009, and Medicare and Medicaid Incentive Payment Programs Notice of Proposed Rulemaking on Meaningful Use, 2010, have followed after a decade long discussion in the literature on how quality of care can be improved using HIT. The discussion was ignited in 1999, after the Institute of Medicine (IOM) published a seminal report, *To Err is Human: Building a Safer Health System*. The report highlighted the extent of errors in health care and galvanized a movement towards improving quality by demanding system-wide redesign (Institute of Medicine [IOM], 1999). The next report from the IOM , *Crossing the Quality Chasm* (2001), asserted that the development of an information technology infrastructure had enormous potential to improve the 6 attributes of quality, namely, safety, effectiveness, patient-centeredness, timeliness, efficiency, and equitability (IOM, 2001).

Researchers in response to the IOM reports have since focused on gathering empirical evidence to study the benefits gained from HIT. The potential strategic value of HIT impact has been documented by studies that have reported the effectiveness, efficiency, and use in health care, concentrating on patient safety, and satisfaction (Amarasingham, Plantinga, Diener-West, Gaskin, & Powe, 2009; Chaudhry et al., 2006; Bates et al., 1998; Bates & Gawande, 2003; Bates et al., 2001; Ash, Berg, & Coiera, 2004; Johnson, Carlson, Tucker, & Willette, 2002). This growing evidence base of advantages is slowly addressing some of the medical community's barriers in adopting HIT for improving health care quality (Bates & Gawande, 2003; Chaudhary et al., 2006). At the same time, a strong impetus comes from health care industry groups, and patient-advocacy organizations promoting the use of HIT (Conway, White & Clancy, 2009; Bates et al., 2001; IOM, 2001; Leapfrog Group, 2009; Beuscart-Ze´phir et al., 2005; King, Paice, Rangrej, Forestell, & Swartz, 2003). Support is also drawn from several previous studies on how technological innovations can be a source of strategic opportunities for organizations (Woodward, 1965; Whisler, 1970; Chandler, 1962; Porter, 1980). Studies confirm that information technology is the fastest growing innovation in both production and use for the past five decades, and the prospects for future growth are very bright (Freeman & Perez, 1988).

Despite the growing evidence and advocacy seen above, recent studies find that the adoption of HIT remains low (McCullough, 2008; Bhattacherjee, Himket, Menachemi, Kayhan, & Brooks, 2007; Poon et al., 2006; Ash & Bates, 2005). One reason for the slow adoption is the limited generalizability of evidence that links HIT to benefits (Chaudhary et al., 2006; Goldstein et al., 2009). Most of the studies on HIT have been conducted in acute care facilities, often in teaching hospitals (Cutler, Fledman, & Horowitz, 2005; Chaudhary et al., 2006; Goldzweig, Towfigh, Maglione, & Shekelle, 2009; Amarasingham et al., 2009). Additionally, the majority of work conducted (and funding available) on HIT by researchers, the federal government, and other public sector organizations has focused, almost exclusively on adults (Conway, White & Clancy, 2009; Agency for Healthcare Research & Quality [AHRQ], 2009; Robert Wood Johnson Foundation, 2009; Friedman, 2006; Kim, Lehmann, & Council of Clinical Information

Technology [CCIT], 2008). Therefore, formidable challenges prevail to completely realize the potential of HIT in the specialized children's health care settings (Miles et al., 2009; Teufel, Kazley, & Basco, 2009). Since children are not small adults but unique individuals with their own specialized needs; the work for HIT in children's health care requires special focus and individualization (National Association of Children's Hospitals and Related Institutions [NACHRI], 2007).

Additionally, unique issues that need to be addressed for the pediatric population restrict the easy implementation and adaptation of HIT from the acute care industry to the pediatric setting (Kaushal, Barker, & Bates, 2001). For example, children require individualized care as seen in the drug ordering and delivery process, where individual weight-based drug dosage calculation is essential (Kaushal et al., 2001; Teufel, Kazley, & Basco, 2009). Also, evidence continues to mount that children's health care quality is more variable and often far from optimal (Leatherman & McCarthy, 2004; Thompson, Ryan, Pinidiya, & Bost, 2003; Dougherty, Meikle, Owens, Kelley, & Moy, 2004; Simpson, Dougherty, Krause, Ku, & Perrin, 2007). The physical make-up of children and higher acuity of susceptibility is a trigger for a relatively greater risk of errors in comparison to adults (Kaushal et al., 2001; Fortescue et al., 2003; Koren, Barzilay, & Greenwald, 1986; Koren & Haslam, 1994).

Research has shown that a higher incidence of patient safety events (Miller & Zhan, 2004), including adverse drug events (ADEs) (Kaushal et al., 2001; Impicciatore et al., 2001) and medication error rates occur in children (Fortescue et al., 2003; Lehmann & Kim, 2005; Kaushal, Barker & Bates, 2001; McPhillips et al., 2005). These special challenges faced by the children's health system can be partly mitigated by the use of

HIT (Van Rosse et al., 2009; Kim et al., 2008; Kaushal et al., 2001; King et al., 2003). Thus, key pediatric professional associations such as the American Academy of Pediatrics, the American Board of Pediatrics, the Child Health Corporation of America, and the NACHRI, call for more research in child health settings to identify how information technology is associated with quality care in our most vulnerable population (NACHRI, 2007).

Background

Quality of care has been defined as the degree to which health services for individuals and populations can increase the likelihood of desired health outcomes consistent with current professional knowledge (Lohr, 1990; IOM, 2009). The AHRQ National Resource Center for Health IT has advocated innovations such as HIT applications as a mandatory tool to achieve this quality of care (AHRQ, 2009). They have released a series of reports that define and highlight lessons and best practices learned about various HIT applications (AHRQ, 2009). These applications include electronic medical records (EMR), computerized provider order entry systems (CPOE), and clinical decision support systems (CDSS), along with other functions which are collectively known as clinical or "health" information technologies (Amarsingham et al., 2009; AHRQ, 2009). Numerous studies evaluated the impact of stand-alone applications on quality of care. For example, some studies looked at CPOE systems and reported reduction in medication errors and/or an increase in adherence to guidelines (Bates et al., 1998; Evans et al., 1998; Leape et al., 1991; Teich et al., 2000). Other studies observed that EMRs can provide a positive financial return on investment (Wang et al., 2003;

Johnston, Pan, Walker, Bates, & Middleton, 2003). Additionally, while many studies on CDSS have demonstrated at least modest benefits (Rothschild et al., 2007; Smith et al., 2006), few have demonstrated marked benefits (Galanter, Polikaitis, & DiDomenico, 2004) from this technology. Unfortunately these and similar HIT studies offer empirical support limited mostly to large, acute health care organizations (Chaudhary et al., 2006), referred to in the literature as “health IT leaders” (Goldzweig et al., 2009, p.282). These organizations have spent years implementing the systems (Chaudhary et al., 2006) and have more advanced financial and human resource capabilities than other organizations thus facilitating their propensity to adopt HIT (Sobol, Humphrey, & Jones, 1992; Warner, Menachemi, & Brooks, 2005; Burke, Wang, Wan, & Diana, 2002). These organizations essentially support the prospector strategy having access to the larger market, characterized by their repeated efforts to innovate and bring changes (Miles & Snow, 1978).

As a result, concerns about the conclusions drawn from these findings and its utility to all health care institutions have been raised (Goldzweig et al., 2009; Chaudhary et al., 2006; Asaro, Sheldahl, & Char, 2006; Cutler, Feldman & Horowitz, 2005). More specifically, the results are not applicable to specialized areas of health care such as children’s health care settings (Kaushal et al., 2001; Menachemi, Ettel, Brooks, & Simpson, 2006). Congruent with the defender strategy (Miles & Snow, 1978) these hospitals often have a restricted market, and stress production efficiency.

To a certain extent it is possible to generalize some of the HIT studies conducted in the adult settings as some of the elements of HIT used in health care for adults can be tailored towards children (Conway, White, & Clancy, 2009). But for the most part, the studies from acute health care settings cannot be completely extrapolated to pediatric hospitals because as discussed earlier children differ from adults in their health care needs and in the way they use care (Palmer, & Miller, 2001). Even common pediatric diseases do not occur with frequencies comparable to those of common adult conditions (Mangione-Smith, & McGlynn, 1998). They also face a higher risk in special domains such as, continuous intravenous infusions and chemotherapy which may have higher immediate and/or cumulative toxicities than other drug types (Kim et al., 2006; Kim et al., 2008; Johnson, 2004). The variations in the normal ranges of body weights, sizes, and physiologic responses, length of stay and care require adaptations of clinical, technical, and information workflows to provide pediatric specific quality of care (Kim et al., 2008). It is therefore obvious that pediatric hospital HIT have different requirements than HIT systems found in serving primarily adults. At the same time it is important to note that the benefits to children from HIT are more important than adults in general (Kaushal et al., 2001) as children are more vulnerable, have higher susceptibility, and utilize more health care services (Chevarley, Owens, Zodet, Simpson, & McCormick, 2006).

Despite the special needs of children, scientific evidence supporting the effectiveness of HIT in children's health care settings is limited. Research is necessary to understand the system capabilities of HIT in pediatrics to facilitate growth, flexibility, and sustainability in the quality of health care provided (MacTaggart & Bagley, 2009). Researchers who have conducted literature reviews on the few available pediatric studies have observed benefits of HIT interventions in improving patient safety and reducing medication errors in children's health care (Yu, Salas, Kim, & Menachemi, 2009; Van Rosse et al., 2009; Johnson, 2001; Kaushal et al., 2001). Most of these reviewed empirical pediatric HIT studies, similar to acute care hospitals discussed earlier, have looked at individual applications. Examples include, studies on EMRs in pediatric settings which have analyzed the barriers, effect on preventive services, and mortality (Adams, Mann, & Bauchner, 2003; Bordley, Margolis, Stuart, Lannon, & Keyes, 2001; Gaglani, Riggs, Kamenicky, & Glezen, 2001; Kemper, Uren, & Clark, 2006). Some have observed the role of CPOE in medication errors, and mortality (Potts, Barr, Gregory, Wright, & Patel, 2004; Han et al., 2005).

Overall, the majority of studies on children's HIT have a higher percentage of reporting specific benefits such as effect on medication errors and administration errors (Kaushal et al., 2001; Johnson, & Davidson, 2004). A few studies have also reported results contradicting each other (Han et al., 2005; Del Beccaro, Jeffries, Eisenberg, & Harry, 2006; Walsh et al., 2006; McPhillips et al., 2005).

Unfortunately similar to studies from acute care settings, existing pediatric HIT studies have limited generalizability, as most studies are restricted to single-site evaluations (Adams et al., 2003; Del Becarro et al., 2006; Han et al., 2005). Additionally, they are often academic hospitals (Upperman et al., 2005a; Walsh et al., 2006; Kim et al., 2006) that have developed their systems internally and incrementally, sometimes over decades (Amarsingham et al., 2009). The result is scarcity and infancy of evidence essential in adopting new and often expensive (Miller et al., 2005), and complex HIT systems (Kemper et al., 2006). More so important in this context, as HIT in children's hospitals need more specialization and individualization (MacTaggart & Bagley, 2009), and unfortunately many of the available products are unable to meet the needs of children's health care, due to lack of key pediatric functionalities (such as weight-based dosing) (Shiffman, Spooner, Kwiatkowski, & Brennan, 2001). Therefore, we identify a gap in the pediatric literature as a result of the incremental, inconclusive and non-generalizable published evidence.

Strategic Implication of Health Information Technology

Since its inception scholars have accepted that information technology plays a significant role within organizations (Porter & Millar, 1985; McFarlan, McKenny, & Pyburn, 1983; Henderson & Venkataraman, 1999). Information technology can support or even shape business strategy (Croteau & Bergeron, 2001). Furthermore, utilization of information technology can become strategic when used in innovative ways (Wiseman, 1988). Product and process innovations (Van de Ven, 1986), and innovative behavior is a strategic activity by which organizations gain and lose competitive advantage (von Hippel, 1988). Early 1990s implementation of information technology was one of the top 10 concerns of senior IT executives (Janz, Brancheau, & Wetherbe, 1996). Since late 1990s a similar concern has been observed in the health care industry (Bates & Gawande, 2003).

Unfortunately, a lack of strategic management research focus is observed in pediatric HIT studies. This focus is essential as appropriate strategic use of HIT would assist organizations as they “gain competitive advantage, reduce competitive disadvantage, or meet other strategic enterprise objectives” (Bergeron & Raymond 1995, p. 82). It has been established in research that the analyzer strategically approaches new developments cautiously with an emphasis on well laid out plans (Miles & Snow, 1978). This is often seen in organizations such as pediatric hospitals resulting in effective use of

HIT which in turn leads to higher performance (Croteau & Bergeron, 2001; Shortell, Gillies, Anderson, Morgan-Erickson, & Mitchell, 1996).

Additionally, all the studies conducted on pediatric HIT have not adopted any theoretical approach or conceptual model during the investigations. This lack is despite evidence of the beneficial role of theories in information technology (Baskerville, & Pries-Heje, 2001; Bharadwaj, 2001; Taylor, & Todd, 1995; Yusuf, Kujlis, Papazafeiropoulou, & Stergioulas, 2008) and HIT research (Burke, & Menachemi, 2004; Ash, 1997; England, Stewart, & Walker, 2000). At the same time even though organizational study journals have published a number of papers that directly explore the consequences of adopting and using information technologies (Constant, Sproull, & Kiesler, 1996; DeSanctis & Poole, 1994; Mitchell & Zmud, 1999; Orlikowski & Yates, 1994), none focus on HIT in pediatric settings.

To assist in the quest for quality care, a study across institutions is necessary in that it will support and compliment previous studies that have looked at various individual HIT implementations and outcomes in a single organization. The logical next step is to also base this study on a strong conceptual framework to address the lack of theory-driven evaluations in the pediatric HIT literature. This kind of research will lead us to make informed decisions that will assist in improving the quality of care for children at the level of both individuals and populations.

Statement of the Purpose

Overall information technology affects competition by creating competitive advantage which leverages performance (Porter & Millar, 1985; Bakos & Treacy, 1986;

Cash & Konsynski, 1985; Johnston & Carrico, 1988; McFarlan, 1984). Health care executives may observe this through lowered costs, enhanced differentiation and improved performance (Shortell & Kaluzny, 2005). This ability to use innovation (HIT in this research) as competitive weapon should give the organizations incentive to develop competencies to perform better than their competitors (Cohen & Levinthal, 1990). It is logical therefore to observe a strong, relationship between the competitive advantages created by HIT innovation through the quality outcome measures. Thus the research questions are as follows:

1. Do pediatric hospitals with relatively greater HIT capabilities perform better on a set of validated, widely-recognized, quality of care indicators?
2. Do pediatric hospitals with specialized HIT capabilities designed to improve the medication ordering and dispensing processes experience fewer adverse drug events?

Some of the benefits from this research in children's health care are:

- Analysis of the relationship between HIT and quality, in the pediatric setting, across multiple institutions thus providing greater generalizability than previous studies in this setting.
- Utilization of a conceptually specified framework to better understand the competitive advantage of HIT adoption through quality outcomes in the pediatric setting.
- Key decision makers will gain a better understanding of the relationship between pediatric HIT and specific quality outcomes. Considering the high costs of HIT

and the potential strategic, operational and financial consequences, this study across multiple institutions will be invaluable.

- Health care executives can identify and rank information technology based upon the competitive advantage it creates.
- Health care executives could consider making an action plan to capitalize on the outcomes from the use of innovation HIT. For example, making organizational changes that would reflect the role of HIT inside and outside the company.
- Provide policymakers insights into the effectiveness and utility of pediatric HIT on quality outcomes, at a multiple institutional level. Policy makers can make use of this information for further funding research and development of pediatric HIT.

Overview of the Chapters

This dissertation will proceed as follows. Chapter two will provide a (1) literature review of the pediatric health care HIT literature and (2) a basis for the theoretical foundation of this dissertation. Specifically, the theoretical foundation will draw upon the work of Donabedian who examined structures, processes, and outcomes of health care institutions. The review and application of this work will yield the specification of several testable hypotheses. Next, chapter three will describe the methodology of the proposed study, including the design, data, and analytical approach. Chapter four will present results of the analysis. Chapter five will provide a discussion of the findings, the implications and limitations of the study, recommendations for future research and conclusions of the study.

CHAPTER 2

REVIEW OF LITERATURE

The purpose of this chapter is two-fold. First the five stages of the diffusion of innovation theory (Rogers, 1962) will be used to review the available literature on the impact of HIT in the pediatric hospital setting. This is followed by a discussion about the gaps in the literature setting a stage for this dissertation project. Next, literature foundational to the theoretical framework is reviewed. This section discusses past research in the healthcare industry that has utilized structure, process and outcomes (SPO) as their framework based on the Donabedian Model (Donabedian, 1966). This assists in the development of a conceptual framework utilizing this model. Hypotheses are developed based upon the literature review and the model. This framework will guide the research on relationship between HIT in pediatric hospitals and specific quality outcomes.

Diffusion of Health Information Technology

Diffusion of innovation theory (Rogers, 1962) has been widely used for conducting empirical studies on information technology adoption and diffusion (Sharpe, 2003; Ash et al., 2001; Zhu & Kraemer, 2005; Geroski, 2000). The theory has provided researchers with useful perspectives on the most persistently challenging topics in the information technology field, such as, how to improve technology assessment, adoption and implementation (Finchman, 1992; Mustonen-Ollila & Lyytinen, 2004; Ash et al., 2001; Swanson, 1994). As a result it has also been utilized in several HIT studies (Rogers, 2003; Burke & Menachemi, 2004; Ash, 1997; Ash, Lyman, Carpenter & Fournier, 2001), such as, Bower (2005), and England, Stewart, and Walker (2000) which emphasized the role of diffusion theory in the adoption of EHR.

The diffusion theory treats information technology as an ‘innovation’ (Riemer-Reiss, 1999). Innovation being defined as, “an idea, practice, or objective perceived as new by an individual, a group, or an organization” (Rogers, 2003, p.5). Innovation, as Damanpour (1987) suggests, can also be an idea that gets implemented and preserves or improves organizational performance. Greenhalgh and co-authors (2004), conducted an extensive literature review of studies using diffusion theory, and defined innovation in health service delivery as a “novel set of behaviors, routines, and ways of working that are directed at improving health outcomes, administrative efficiency, cost effectiveness, or users' experience and that are implemented by planned and coordinated actions ” (p.582).

Rogers (2003) proposed that there are five main attributes of innovative technologies which influence their adoption rate. These are relative advantage, compatibility, complexity, trialability, and observability. These attributes makes it easier to communicate an innovative idea to the members of a social system through various channels (Rogers, 2003). Additionally, other characteristics that influence diffusion and transfer are: types of adopters, the social network to which these adopters belong, environmental characteristics, the process by which the innovation is communicated, and the characteristics of those who are promoting the innovation (Rogers, 2003). Rogers (2003) explains that this is a part of the innovation-decision process. For example, in this research project an organization such as a pediatric hospital passes from the stage of gaining primary knowledge of the innovation, in this case HIT, to the stage of forming an attitude about HIT. They then make a decision to adopt or reject the implementation of this new idea, and finally confirm the decision. It is thus a passage consisting of five stages: knowledge, persuasion, decision, implementation, and confirmation (Rogers, 2003). Most of the research in the hospital environment has observed similar stages at the organizational levels (Shortell & Zajac, 1990).

Rogers (2003) explained that the five stages are "useful as a means of simplifying a complex reality" (p. 195). Therefore for the purposes of this research, the stages will be utilized as a basis for understanding the pediatric HIT literature. These stages also provide a framework to classify the literature into various categories, such as the type of study (empirical or non-empirical research). Non-empirical publications have been further sub-categorized as commentary or editorial (non-empirical paper which provides a critical analysis and an overview about a topic by an expert in the field), and review (non-empirical paper unless a meta-analysis, providing an analysis on published literature about a specific topic). Additionally, for the purposes of this review, empirical papers are categorized based upon the number of institutions at which the research was conducted (single or multiple institutions). This division has been made after careful analysis of the paper based upon criteria explained in each stage. An important point to be noted is that the process of diffusion rarely spreads out in a smooth and predictable fashion (Attewell, 1992; Fichman & Kemerer, 1999; Swanson & Ramiller, 1997). Although the studies have been categorized into different stages as accurately as possible, there is a chance that some may or can overlap into different stages.

Knowledge Stage

According to diffusion theory, knowledge stage occurs when the decision maker is exposed to an innovation's existence and gains some understanding of how it functions (Rogers, 2003). In this stage, decision makers usually play a passive role (not actively seeking information) or an active role (initiating the knowledge process themselves) (Rogers, 2003). When an active role is being played, the individuals are selective about the information they seek and develop an interest only when a 'need' is felt for the innovation. Need is primarily a state of dissatisfaction and frustration and can be addressed through information-seeking to reduce the uncertainty (Rogers, 2003). Thus, in this stage the decision maker is seeking answers to: how does the innovation work? And why does it work?

Therefore articles providing knowledge, awareness and commentaries on pediatric hospital HIT can be included in this stage. Due to the limited published literature in this stage apart from hospitals some important ambulatory setting studies have also been considered. All these articles have looked for answers to questions such as: "What is HIT?" "How does it work?" Thus the studies included in this stage address the following features (Rogers, 2003, p. 199): recall of information, comprehension of messages, knowledge or skill for effective adoption of the innovation.

In the following sub-section a brief discussion is provided about HIT studies that can be categorized into the knowledge stage.

HIT Studies in the Knowledge Stage

Almost a decade after the identification of the need for adoption of HIT a gradual infiltration of HIT from acute care hospitals has been seen in pediatric hospitals (Kaushal, Barker & Bates, 2001; Adams et al., 2003). According to the knowledge stage this is due to three main reasons. The first reason is the result of 'awareness-knowledge' (Rogers, 2003, p. 173) about HIT from successes seen in the acute care settings (Bates & Gawande, 2003). Second reason is the need for adoption of HIT created by dissatisfaction and frustration seen in the quality outcomes in pediatric hospitals (Kaushal, 2001). Third, the research community and policy makers have acted as change agents creating this need for adoption of HIT by 'pointing out the existence of desirable new ideas' (Rogers, 2003, p. 172) and its benefits (Koren, 2002; Fortescue et al., 2003; D'Alessandro & Dosa, 2001).

An early article by D'Alessandro and Dosa (2001) argued about the benefits of child and family empowerment with information technology. They suggested the use of electronic pediatric personal medical records, customized health information systems, interactive physician offices with electronic mail (e-mail), and telemedicine capabilities to communicate with the patient and generate more knowledge and awareness. At the same time Johnson (2001) discussed the barriers which impede the adoption of pediatric HIT. Based upon a literature review he concluded that the most significant barrier is that pediatricians may lack the knowledge or training to use HIT effectively. These were instances of a conscious effort towards raising the awareness of benefits of HIT in pediatrics.

In this stage we can also find studies discussing the early adopters' trials and strategies. An appropriate case study representing this stage is the Peverini and co-authors (2000) discussion of the design, development, and implementation of a decision support system for prescribing neonatal parenteral nutrition solutions. They concluded these systems would be commonly seen in the future. Waitman and team (2003) had a similar paper about design, implementation, and use of a new order entry system module for neonatal intensive care. In 2002, Ramnarayan and Britto wrote a paper that summarized the past, present, and future of CDSS, with special emphasis on their role in pediatrics. It predicted that CDSS will be used in the future extensively and will work *with* the physicians rather than *instead of* the physicians.

McAlearney and co-authors (2006) evaluated the use of three evidence-based computerized order sets (asthma, post-appendectomy care, and community-acquired pneumonia). They concluded that hospitals implementing computerized order sets must consider the different factors that may influence the use of each order set rather than rely on a one-size-fits-all implementation strategy. Level of physician involvement in order set development and consensus around order set content may be particularly important factors influencing order set utilization.

Additionally, there are a few articles which have provided a report on the special requirements of EHRs in pediatric settings (Spooner & CCIT, 2007; Kim et al., 2007). Spooner and CCIT (2007) discussed the addition of certain applications to pediatric HIT for immunization management, growth tracking, medication dosing, and special privacy enhancements. Building on this article, Spooner and Classen (2009) discussed the evolving technical infrastructure essential for integrating systems and coordinating data standards, as well as the numerous organizations working on expanding these standards.

Kim and co-authors (2007) described the problems encountered during a three week period following the deployment of a modified commercial CPOE system on three floors of an academic pediatric center. They identified the following problems: center-specific implementation problems (45%), transfer-hand off collaboration problems (14%), missing product functionalities (11%), inadequate training (11%), hardware problems (5%), password problems (4%) and human error (2%). Wang, et al. (2003) observed medication errors and ADEs which were intercepted by a system of pediatric clinical pharmacists and determined whether the addition of a CPOE would improve medication safety. They observed that a CPOE could capture additional potentially harmful prescribing and transcription errors (54%–73%) but not administration errors (0% versus 6%).

Studies by Fortescue et al. (2003) while studying medication errors and ADEs, found that CPOE with CDSS is an effective strategy for preventing medication errors. They estimated that CPOE with basic CDSS could prevent 66% of errors, whereas more advanced decision support could prevent 73%. A similar study evaluated introduction of a CPOE system, a review process to remove hazardous drugs from wards, and new training of residents at a large tertiary pediatric hospital (Koren, 2002). Utilizing incident report data, this study estimated that combined interventions decreased medication incidents (defined as errors that actually reach the patient) by half. In this stage, supportive articles can be included that discuss strategies for child safety in hospitals through the implementation of CPOE with decision support and other tools (Sullivan & Buchino, 2004; Kaushal, Jaggi, Walsh, Fortescue, & Bates, 2003).

Persuasion Stage

Persuasion stage ideally occurs when an individual or system of individuals forms a favorable or unfavorable attitude towards the innovation (Rogers, 2003). It means that an organization may be amenable to innovate in general, but not ready or willing to assimilate a particular innovation (Greenhalgh et al., 2003). This stage is more affective and therefore some of the attributes of the innovation become more important (Rogers, 2003). As a result, the rate of adoption of innovation is based upon the following factors (Greenhalgh, et al. 2004) : *relative advantage* where innovations have a "clear, unambiguous advantage in either effectiveness or cost-effectiveness" (p. 594); *compatibility* with the "intended adopter's values, norms , and perceived needs " (p. 596); *complexity* should not be present; *reinvention* wherein the "adopters can adapt, refine, or otherwise modify the innovation to suit their needs" (p. 596); unclear boundaries of use act as a barrier for adoption (Rogers, 2003).

Additionally, quite a few of the innovations in this stage are 'preventive innovations' (Rogers, 2003, p. 176). It means the innovation is adopted in order to avoid the occurrence of an unwanted event. Essentially the aim of this stage is to reduce the future uncertainty and find answers to questions such as: "What are the advantages and disadvantages of HIT?" These answers are usually sought through the experiences of others or scientific evidence (Rogers, 2003). Examples of these forms of studies for pediatric hospital HIT are provided in the following sub-section. These studies are a 'cue-to-action' (Rogers, 2003, p. 176) for the adoption of HIT, and include at least some of the following features (Rogers, 2003, p. 199): liking the innovation, discussion of the new behavior with others, acceptance of the message about the innovation, formation of a positive image of the message about the innovation, and support for the innovation behavior from the system.

HIT in the Persuasion Stage

Some papers have been written reviewing the HIT literature to spread "affectiveness (or feeling)" (Rogers, 2003, p.175) about HIT. Kaushal, Barker and Bates (2001) conducted a review of the current HIT literature evaluating the role of HIT in decreasing pediatric medication errors in both inpatient and outpatient settings. They concluded that this literature is significantly less robust than the adult setting literature and more research is essential. They also described the benefits of various HIT applications for reducing medication error rates which are higher in children due to the need for weight-based dosing. A later article by Johnson and Davison (2004) supported this discussion by providing an overview on the general utilities of different HIT applications. A commentary by MacTaggart and Bagley (2009) seems appropriate in this stage as it discusses the role that State and Federal governments will play in the promotion of EHR and other HIT systems. The authors argue that government funding will act as a strategy to incentivize the adoption of HIT in children's hospitals. In the same issue of *Pediatrics*, Miles and co-authors (2009) offer support by discussing the work other communities such as Alliance for Pediatric Quality are performing to promote HIT. Kim and co-authors (2008) additionally focused on the pediatric aspects of inpatient HIT. They argued that pediatric HIT should be considered in terms of technical, organizational and cultural aspects.

We observe some single institutional studies in this stage that were conducted as a "cue-to-action." For example, Killelea and others (2007) researched the physician acceptance of dosing and frequency decision support elements in pediatric CPOE at an academic medical center. They concluded that commercial vendors of dosing knowledge bases need to deliver effective products concentrating on the needs of the pediatric settings. They argued that this would build effective systems which will be easily accepted by physicians. Thompson and colleagues (2004) measured the effect of CPOE on timeliness of urgent laboratory and imaging tests. The time from ordering to obtaining laboratory specimens decreased from 77 to 21.5 minutes; ordering laboratory results decreased from 148 to 74 minutes, ordering completed images decreased from 96.5 to 29.5 minutes.

Decision Stage

The decision stage happens when the organization takes on activities with the innovation that leads to a choice to adopt or reject it (Rogers, 2003). The decision maker in this stage decides that minimal use of the innovation is warranted. This leads towards a choice of either accepting or rejecting the decision and acting as a probationary period to vicariously experience the usefulness. This stage in pediatric hospital literature is thus represented by small case-studies or trials discussing HIT. Rogers (2003) also discusses the use of 'trials by others' in this stage (p.177). However as pediatric HIT has special requirements, the utilization of the results of studies on HIT from other hospitals such as acute care is limited (Kaushal et al., 2003). The studies thus included in this stage have the following features (Rogers, 2003, p. 199): intention to seek additional information about the innovation, and intention of trying the innovation.

HIT in the Decision Stage

All studies belonging to this stage in the pediatric literature discuss the decision to adopt HIT after a trial period. For example, Vaidya and co-authors (2006) in a paper presented at a conference discussed the benefits of customizing CPOE for ordering continuous drug infusion in pediatric patients. They observed the benefits in this trial through the significant reduction in numbers of errors and time spent in ordering with introduction of CPOE. The same team of authors (Sowan et al., 2006) utilizing the same dataset also studied the ability of nurses to detect medication administration errors with a customized CPOE. Interestingly, they observed that nurses saved time in the ordering process but the ability to detect administration errors did not increase. However, the nurses assisted in the decision to implement the CPOE by voting a preference for CPOE over handwritten orders. Fiks and co-authors (2007) utilized an EHR to assess whether clinical alerts for routine pediatric vaccinations within an EHR would reduce missed opportunities for vaccination and improve immunization rates for young children. The results were positive and they concluded that EHRs should be more commonly used to enhance immunization rates.

Upperman and co-authors' (2005b) paper documented the introduction of CPOE-centered changes in an academic tertiary care center and simultaneously reviewed the CPOE-focused literature. They discussed that CPOE implementation process is more than a technological change; it involves an organizational cultural transformation such as creating a realistic, positive, work environment, hospital wide participation and integration. McPhillips et al. (2005) in a review of outpatient pediatric pharmacy administrative data, found no difference in rates of potential overdosing or underdosing errors between clinics that used basic CPOE and those that did not use CPOE. While Shulman and co-authors (2005), found a significant reduction in medical errors with CPOE when non-intercepted and intercepted errors were combined. They compared the impact of CPOE without decision support with hand-written prescribing on the frequency, type and outcome of medication errors in the intensive care unit. The following year, Walsh et al. (2006) in a retrospective study for CPOE implementation found that serious pediatric computer-related errors were uncommon (3.6 errors per 1000 patient-days), but computer systems do introduce some new pediatric medication errors not typically seen in a paper ordering system.

Mullet and colleagues (2001) evaluated a stand-alone anti-infective computerized decision support tool adapted from an existing adult version. The results showed a decline in the rate of pharmacy interventions for erroneous drug doses by 59%, rate of days with sub-therapeutic anti-infectives by 36%, number of excessive doses by 28%, and costs per patient decreased by 9%. Rates of ADEs remained unchanged.

Lehmann and colleagues (2002) implemented an online total parenteral nutrition order entry system (TPNCalculator) using Internet technologies. They observed a reduction in the following: calculation errors (100%), osmolality issues (87%) and other knowledge problems (84%). Users were enthusiastic, supportive and compared it favorably to the prior paper based system. A similar study was conducted in 1997 by Porcelli and Block (1997). They assessed if computer software assisted ordering improves the system of designing parenteral nutrition by increasing the amount of calcium (Ca) and potassium (P) ordered, without Ca : P precipitation. The results were positive indicating that computer assistance shows its benefits.

Implementation Stage

Implementation has been defined by Meyers, Sivakumar, and Nakata (1999) as "the early usage activities that often follow the adoption decision" (p. 295). Implementation depends on the progress made in the initial adoption decision and the early stages of assimilation (Rogers, 2003). The key components of system readiness for an innovation are highly relevant to the early stages of implementation (Greenhalgh et al., 2003). In addition, the stage is associated with successful “routinization” (Greenhalgh et al., 2003), acquisition of additional information about the innovation, and continued use of the innovation (Rogers, 2003). The organization at this stage has already encountered numerous shocks, setbacks, and unanticipated events because of its experience with the previous stages (Van de Ven, 1986).

All the studies representing this stage are the ones that have gone beyond the thinking process and are setting the innovation into practice (Rogers, 2003). We may therefore observe some uncertainty and unwarranted results in the stage, for example some studies conducted at single institutions such as pediatric setting have shown mixed results with respect to mortality (Del Beccaro et al., 2006; Han et al., 2005). Hence, the role of the researchers here is to provide more information to the following questions (Rogers, 2003): “What are the better ways of using HIT?“ “What are the operational problems that can be encountered with pediatric HIT, and how can they be solved? “ Answers to these questions are a way to institutionalize HIT and therefore the papers included in this stage have the following features (Rogers, 2003, p. 199): acquisition of additional information about the innovation, use of the innovation on a regular basis, and continued use of the innovation.

Overall the evidence regarding the implementation of innovations has been sparse possibly due to its complexity in general from the other stages (Rogers, 2003; Greenhalgh et al., 2003). We will confirm if the same scenario exists for the HIT studies based upon the discussion in the following sub-section.

HIT in the Implementation Stage

Since the innovation is implemented in this stage, problems on exactly how to use the innovation crop up (Rogers, 2003). The Han et al. (2005) study is a good example of this issue. Their study which was conducted at a tertiary care children's hospital, questioned the patient-safety benefits of CPOE implementation with regard to mortality in the critical care setting. It was a retrospective study in which the mortality rate for inter-facility transfers into an ICU was compared before and after implementation of a CPOE system. Statistical analysis revealed that mortality rates significantly increased from 2.80% (30 deaths of 1394 patient transfers during 13 months) before CPOE implementation to 6.57% (36 deaths of 548 transfers during 5 months) after CPOE implementation. The authors suggested that an increase in mortality after implementation of CPOE may have been the result of several factors including process changes associated with HIT implementation. This article was followed by a study conducted by Del Becarro, et al. (2006) which observed contrasting results. They found that the implementation of CPOE in the PICU was not associated with an increase in mortality. The authors suggested that "careful design, build, implementation, and support can mitigate the risk of implementing new technology even in an ICU setting" (p. 290). But again Walsh and co-authors (2006) in a retrospective study of CPOE implementation found that serious pediatric computer-related errors are uncommon (3.6 errors per 1000 patient-days), but computer systems introduce some new pediatric medication errors not typically seen in a paper ordering system.

Additional studies with similar research designs had contradictory results regarding the impact of CPOE. For example, King and co-authors (2003) reported significant reductions in medical errors after CPOE implementation. The error rate in the ward using CPOE was significantly lower than that in the control ward. However, they did not observe a significant difference in ADEs. Potts and colleagues (2004) observed that the use of CPOE by physicians in a pediatric critical care unit was associated with a significant (40.9% reduction) elimination of medication prescribing errors and a significant but less dramatic effect on potential ADEs. While Upperman et al. (2005a) during a 9-month study period reported the potential of CPOE systems to significantly reduce ADEs in the pediatric inpatient setting. In addition, they observed that CPOE provides an automated system for monitoring and improving health care quality.

A randomized control trial conducted by Walsh and colleagues (2008) found 7% decrease in level of the rates of nonintercepted serious medication errors, but no change in rate of injuries as a result of error after CPOE implementation. Kim et al. (2006) found that after CPOE implementation, daily chemotherapy orders had reduced improper dosing, incorrect dosing calculations, missing cumulative dose calculations, and incomplete nursing checklists. No difference was found in the likelihood of improper dosing on treatment plans and a higher likelihood of not matching medication orders to treatment plans. A recent study by Taylor et al. (2008) observed that implementation of a CPOE in a NICU was associated with a significant decrease in the rate of medication administration variances. However, even with the use of CPOE, variances were observed for 11% of all medication administrations, which suggests that more research is necessary.

Recently twelve studies which looked at the impact of CPOE implementation were reviewed by Van Rosse and authors (2009). The authors studied the effects of CPOE on medication prescription errors, ADEs, and mortality in inpatient pediatric care and neonatal, pediatric or adult intensive care settings. Based upon the 12 studies, all observational, they found that there was significant decreased risk of medication prescription errors with the use of CPOE. However, they noted there was no significant reduction in ADEs or mortality rates.

One EHR study by Adam and colleagues (2003) can be included in this stage. They conducted a study in a pediatric primary care center evaluating the quality of pediatric primary care and preventive services, before and after the introduction of EHR. They observed an overall improvement in the quality of care such as computer-based clinicians were significantly more likely to address a variety of routine health care maintenance topics including: diet, sleep, at least one psychosocial issue, infant sleep position, breastfeeding, and child safety. Another study observed the effect on ADEs, medication prescription errors, and rule violations before CPOE implementation; after CPOE implementation; after CDSS implementation; and after a change in prescription authorization (Kadmon et al., 2009). They observed that CPOE implementation decreased prescription errors only to a small extent. However, addition of a CDSS reduced prescription error rates and, potential ADEs significantly.

Confirmation Stage

In this stage the organizations look for support to maintain the innovation-decision already made, or reverse the decision and reject it (Rogers, 2003). At this point, the decision-makers are avoiding conflict or attempting to reduce it if it does occur. Essentially, verifying the enhancement of or from the innovation (Rogers, 2003). So it is essential that the innovation must yield some relative advantage to attain success and therefore most of the studies in this stage will be supportive studies. Thus in the sub-section, studies that analyze HIT from hospitals that have already advanced beyond the trial phase have been included. These organizations are now adding new accessories to the pre-existing HIT applications (Giannone, 2005), confirming the role of other agents in the progress of adoption (Menachemi, Brooks, Schwalenstocker, & Simpson, 2009), conducting retrospective studies to confirm the advantages (Cordero, Kuehn, Kumar, & Mekhjian, 2004; Holdsworth et al., 2007; Rosenbloom et al., 2006), and simultaneously understanding the technology cluster (Fairbrother & Simpson, 2009). The studies cited in this stage will include the following features (Rogers, 2003, p. 199): recognition of the benefits of using the innovation, integration of the innovation into one's ongoing routine, and promotion of the innovation to others.

HIT in the Confirmation Stage

In this stage we have a list of studies that have analyzed the impact of HIT adoption on various factors such as medication errors, ADEs, and quality. Beginning with Cordero and colleagues (2004) who studied the implementation of CPOE in a NICU in which the adult departments already had a CPOE. They assessed the efficacy of CPOE in reducing medication errors by focusing on two specific medication administration issues, namely, the time from ordering to administration of caffeine loading doses and the accuracy of gentamicin dosing. They found significant reduction in medication turn-around times and medication errors for the selected drugs (caffeine and gentamicin), and a decrease in ancillary service (radiology) response time. They concluded that a few adjustments to the adult settings' CPOE can have a significant impact on pediatrics. The same endeavor was illustrated by Giannone (2005) in the development of a CPOE embedded solution for weight-based neonatal drug infusion in a university hospital. Sard, et al. (2008) also conducted a study about enhancing the utility of CPOE by the addition of quicklist. They observed significant reduction in error rates. The error rate was 1.9 errors per 100 orders when the quicklist was used, compared with 18.3 errors per 100 orders when the list was not used. Errors of wrong formulation, allergy, drug-drug interaction, and rule violations were eliminated. Holdsworth et al. (2007) determined the impact of CPOE with substantial decision support, on the incidence and types of ADEs in hospitalized children. They observed the number of preventable ADEs (46 versus 26) and potential ADEs (94 versus 35) was reduced. A prospective cohort study was conducted by Kirk and co-authors (2005) which assessed the rate of medication errors in predominantly ambulatory settings in a hospital. The results showed that the computer calculated dose error rate was 12.6% compared with the traditional prescription error rate of 28.2%. Rosenbloom et al. (2006) in their study observed that EHR systems and integrated growth charts can manipulate data, perform calculations, and adapt to user preferences and patient characteristics. Keene et al. (2007) tested mortality rate after the initiation of CPOE in a pediatric population that was directly admitted to the neonatal and pediatric intensive care. Post-CPOE initiation status remained unassociated with mortality after adjusting for all covariates.

A few studies included in this stage provide an overview of the adoption of HIT. For example, Teufel and authors (2009) recently published a paper about the rate of adoption of CPOE in hospitals that care for children. They observed that in 2003, 6% of the hospitals that care for children reported using CPOE. Early adoption of CPOE was associated with children's hospitals, private hospitals, urban-teaching hospitals, and hospitals outside of the western region. A more recent descriptive analysis by Menachemi and colleagues (2009) examined the adoption of HIT in children's hospitals and documented barriers and priorities in the HIT adoption. Among 109 responding hospitals (55%), the common HIT applications include clinical scheduling (86.2%), transcription (85.3%), and pharmacy (81.9%) and laboratory (80.7%) information. Interestingly EHR (48.6%), CPOE (40.4%), and CDSS (35.8%) were not so widespread. They noted that the most common barriers to HIT adoption were vendors' inability to deliver products or services to satisfaction (85.4%), lack of staffing resources (82.3%), and difficulty in achieving end-user acceptance (80.2%). Separately, Menachemi and another team of co-authors (2007) studied 98 acute care hospitals in Florida. They observed that hospitals caring for higher pediatric volume were more likely to adopt HIT.

A study by Vardia and co-authors (2006) reported no errors after CPOE + CDSS were implemented (100% error reduction for 46,970 orders). Time to completion of drug forms dropped significantly from 14 mins 42 s to 2 min 14 s. Costakos (2006) based upon a CDSS enhancement project at Mayo Health systems reviewed other studies and discussed development and deployment of the addition of total parenteral nutrition software on existing EHR.

Gerstle and co-authors (2007) wrote a technical report about ambulatory settings which discussed the benefits of adding electronic prescribing to EHRs. Based upon a comprehensive literature review they concluded that CPOE and e-prescribing systems together are able to reduce medical errors and improve outcomes. King et al (2007) conducted a study at a Canadian children's hospital wherein a clinical evidence module (CEM) for bronchiolitis management was integrated into the hospital CPOE. It resulted in a significant decrease in antibiotic use and an end to multiple bronchodilator use. The majority of physician trainees found the CEM to be a useful educational tool.

A recent study by Longhurst and co-authors (2010) observed that implementation of a locally modified, and commercially sold CPOE system was associated with a statistically significant reduction in the hospital-wide mortality rate at a quaternary care academic children's hospital. The mean monthly mortality in this case reduced by 20%.

Also included in this stage are publications demonstrating the role of change agents. For example, one of the publications discussed the role of government and public sector in the promotion of HIT in children's settings (Conway, White, & Clancy, 2009). Fairbrother and Simpson's (2009) editorial provides an overview on the use of HIT to improve child health. Brian (2007) reviewed the role of the EHR in automating adverse event detection in the study of medication errors, nosocomial infection, and in the perioperative setting. They concluded that EHR can play an important role in reducing errors and provide data for improvement. Vaidya (2006) wrote an editorial discussing about studies looking at computerized calculator for continuous medication infusions.

Mack, Wheeler, and Embi (2009) recently reviewed the CDSS literature focusing on its benefits in the PICU. They discussed the types and features of various CDSS tools and the supporting evidence. Factors such as liability, human factors engineering, alert fatigue, and audit trails were also covered.

Conclusion of literature review

Table 1 provides a summary of the extensive review of the literature related to HIT in the pediatric hospital settings, which was conducted using the diffusion theory. Additionally, another table summarizing findings of all the studies has also been included. Most of the publications research the role of HIT in the improvement of quality, concentrating more on medical errors and ADEs. They emphasize the importance of appropriate implementation of HIT in pediatric hospitals. However, to date, most studies are limited to single institution HIT evaluations, most often academic hospitals that have more resources and more experience (Amarasingham et al., 2009; Chaudhary et al., 2003). Additionally, most studies were based on a before/after design; limiting the generalizability of these studies to other types of institutions that care for children (Van Rosse, 2009). Also, most studies do not have the power to detect differences in ADEs and have evaluated a small number of "homegrown" systems (Kaushal, Shojania, & Bates, 2003, p. 1413) identifying issues associated with adoption. Research therefore should be conducted on a wider scale which should evaluate more applications, components of applications and various other factors (Kaushal et al., 2003; Van Rosse et al., 2009; Amarsingham et al., 2009). Ideally, a study across institutions will provide robust evidence for the effect of HIT on specific quality outcomes (Van Rosse et al., 2009). This research endeavors to address these concerns and gaps that have been identified in the literature.

The next section of this chapter develops a conceptual framework from the Donabedian model. The section will first provide an overview about the Donabedian model and then discuss the suitability of the theoretical perspective to the question on the relationship between HIT in pediatric hospitals and quality outcomes. Next will be the development of a conceptual model and the derivation of testable hypotheses that incorporate the HIT applications and their relationship to quality.

Theoretical Framework

The Donabedian model has been recognized by many in the field of health care as a useful and sensible way to analyze medical care and its organizations (Hiss, 1998; Revere, Black, & Huq, 2004; Battle & Lilford, 2003). The initial uses of Donabedian model in hospitals was in administrative applications focused on cost savings through automation and increased productivity, starting with payroll and patient accounting systems (Hiss, 1998). Recent research utilizing the model has looked at ADEs (El-Jardali & Lagace', 2005; Cho, 2001), restructuring (Jawad & Sofie, 2001), quality improvement processes (Rever, Black, & Huq, 2004), and other patient safety efforts (Carayon et al., 2006; Mitchell & Sloper, 2001).

Donabedian's model essentially analyzes quality through three factors: structure, process, and outcome (SPO) (Donabedian, 1980; Donabedian, 1966). Structure refers to prerequisites, such as hospital buildings, staff and equipment. Process describes the activities conducted within the structure. Outcome refers to results of the processes.

Structures are usually thought to affect processes, which in turn produce desirable or undesirable outcomes (Mitchell, Ferketich, & Jennings, 1998). The theoretically strongest Donabedian model papers (Kunkel, Rosenqvist, & Westerling, 2007; Hiss, 1988; Pronovost et al., 2006) crucial for building a predictive theory are outside HIT. However, the key papers using the model lead us to believe that the general model is applicable to HIT and quality outcomes specifically. A study of the relationships between structure, process, and outcome could provide information that would benefit hospital decision-makers, clinicians and other professionals, as well as health policy makers. The following sub-sections provide a detailed look at SPO.

Structure

According to Donabedian (2005) structure is “the settings in which a process and outcome take place and the instrumentalities of which it is the product” (p.695). It is thus the relatively stable characteristic of the organizational setting. Structural measures indicate the extent to which healthcare organizations have the ability to provide adequate levels of care (Williams & Torrens, 1993). Thus this term normally pertains to the attributes of the health care setting such as the adequacy of facilities and equipment; qualifications of medical staff and their organization; administrative structure and operations of programs and institutions providing care, number, distribution, physical facilities, equipment, and other physical resources and qualification of professional personnel, number and size of equipment, and ways in which delivery of health services is organized (Donabedian, 1966, 1988). Structural characteristics are therefore measurable and objective factors of a hospital (Donabedian, 2005). Information about structures is fairly concrete and accessible information.

Process

Process is not only a lever to achieve results, but is also a tool to understand whether “good" medical care has been applied (Donabedian, 2005). Process factors relate to how things work and are actioned within an organization (Upenieks & Abelew, 2006). It is a collective term for all activities ongoing and continuously redefined (Sidani, Doran, & Mitchell, 2004; Tiedeman & Lackinland, 2004), and readily attributable to the provider of care (Goddard et al., 2002). Process factors are responsible for producing desired outcomes and include accessibility, continuity and delivery of care. Subsequently, processes study the effectiveness of the organization.

However, it has been observed that in comparison with the outcome measures process measures have not been used prevalently (Crombie & Davies, 1998). This is because they are not as clinically relevant as the outcomes and sometimes the outcomes may not be as affected by processes (Proctor, Yarcheski, & Oriscello, 1996). But the system philosophy ideally should be that ‘instead of producing faulty items, improve the process to prevent errors occurring in the first place’ (Gillies, 1997). An example is the use of HIT in pediatric hospitals as a tool to improve quality by reducing medical errors.

Crombie and Davis (1998, p. 32) suggested that the basis of looking at process factors is not only to ask, ' What was done?’, but also ask: ‘Was the action justified? Was it done well? Was it timely? ‘Thus process measures assess and direct towards the quality of care being delivered. Therefore some of the noted advantages of process measures are

(Crombie & Davies, 1998): readily measurable, easily interpreted, sensitive to any deficiencies in care, and indicators for action.

As a result it is possible for process measures to illustrate a variation in health services utilization (Revere, Black, & Huq, 2004) and therefore they need to be addressed along with the outcome measures. It is important to study them as it pertains to the activities carried out by health care providers and staff, such as, correct diagnostic tests, correct prescriptions, accurate drug administration, pharmaceutical care, waiting time to see a physician, and interpersonal aspects of care and delivery are all examples of process (Shi & Singh, 1998). For nursing care in particular, it includes the assessment, planning, delivery, and evaluation of nursing care (Donabedian, 1966, 1988). These are the things done for patients that contribute to the patients' health and well being. Process factors for this study include the automation mechanisms used to enhance delivery of care such as various HIT capabilities, CPOE, integration information systems and CDSS.

Outcome

Researchers have shown preference towards judging quality based upon outcomes (Crombie & Davies, 1997; Relman, 1988; Epstein, 1990; O'Leary, 1995). Donabedian (2005), states that there are many advantages in studying outcome as the criterion of quality in medical care. He affirms that the validity of outcome as a dimension of quality is rarely questioned as it is relatively stable, can usually be measured, and is concrete and valid (Donabedian, 2005). Additionally, a focus on outcomes directs clinical attention towards a specific goal—the patient's health status—rather than various interventions (Goddard et al., 2002). The importance of studying outcomes, according to the Donabedian model, lies in understanding outcomes' relation to the structure and processes that have produced them, as these latter factors can be controlled (Perrin, 2002).

Outcomes in health care had been categorized by Lohr (1988) as “The 5Ds”: death, disease, disability, discomfort, and dissatisfaction. We now see a categorization of outcomes research in health care as clinical outcomes research or more broadly defined to include health services research (Battle & Lilford, 2003). Recent research has focused on a wider range of outcome measures such as improved health status, functional ability, and perceived quality measured by the various scales (Mitchell, Ferketich, & Jennings, 1998; Mitchell, Heinrich, Moritz, & Hinshaw, 1997; Patrick, 1997). Thus, an outcome when considered in the hospital environment is restoration of function and of survival. Outcomes are considered good when they provide the patient with hopes of survival or therapy; and the clinical providers the desired end point in the continuum of care (Davies & Crombie, 1997).

Hence, outcome measures are frequently used as indicators for gauging the quality of medical care (Goddard et al., 2002; Davies & Crombie, 1995). Outcomes measurement has now become an integral part of the accreditation and payment process. The Joint Commission for the Accreditation of Healthcare Organizations had introduced outcome measures as part of its accreditation process in the late 1980s (Schroeder, 1987), while Medicare and other insurance companies have started demanding more precise information on outcomes. However, it is important to note that outcome measures are commonly open to bias as they tend to be influenced by factors other than healthcare intervention (such as patient and staff compliance) (Goddard et al., 2002).

Outcomes pertain to patient health and welfare and may include patient satisfaction, functional status, recovery from illness, mental and social health, management of pain and chronic illness, and other factors. The outcomes can be either positive states such as improved functional status and freedom from illness, or negative states such as acquired infections and injuries (Donabedian, 1966, 1988).

Model Development

The classic Donabedian (1966) evaluation model will provide the framework for the organization of this research, selection of variables, and analysis. Atchley (1991) outlined an SPO system where input factors lead to actions/procedures over time that result in outcomes over time, and each of these feedbacks into the other. Based upon the earlier literature review it will be possible to predict the same relationship in this research model. Therefore, a model with relationships between automation using information technology in children's hospitals with specific quality outcomes will be developed.

As discussed earlier, structure is "the relatively stable characteristics of the providers of care, of the tools and resources they have at their disposal, and of the physical and organizational settings in which they work" (Donabedian, 1980, p. 81). The structural level variable in this dissertation research indicates the pediatric hospitals, and includes type of hospital (not-for-profit, for-profit, and government), hospital status, size and type. Menachemi and co-authors (2009) provided demographic and organizational characteristics of these pediatric hospitals. They surveyed 109 pediatric hospitals of which majority (52.6%) were operating within a larger hospital. The mean bed size was 373, and almost all respondents reported that their hospital had a not-for-profit tax designation. Since there are no major differences between the demographics the structure variable will not be included in the analysis.

The process involved is the automation of the hospital with HIT. Variables included are various clinical information technology applications (Figure 1) and CPOE for medications (Figure 2); and their level of integration with other HIT systems. Figure 1 is a schematic representation of the relationships between these constructs. The diagram illustrates the relationships between clinical information technology capabilities and quality by looking at pediatric quality indicators. While Figure 2, observes the relationship between CPOE for medication and laboratory, and adverse drug events.

Donabedian defines outcomes as “a change in a patient’s current and future health status that can be attributed to antecedent health care” (Donabedian, 1980, p.82-83).This study is designed to look at the relationship of HIT with quality of care. The primary goal is to evaluate the changes in specific quality indicators (adverse drug events and pediatric quality indicators) with the adoption of HIT.

Based on the literature review related to HIT adoption, it is expected that automation of processes should have a positive influence on the quality of care. Clinical information technology systems in hospitals include a wide variety of applications above and beyond EMR and CPOE (Finkych & Taylor, 2005). Overall, it has been observed that they improve safety (Bates & Gawande, 2003; Chaudhary et al., 2006). In accord with this expectation, the following hypotheses are stated:

Hypothesis 1a: Pediatric hospitals with greater information technology capabilities are associated with more desirable performance on the quality of care indicators.

Parente and Dunbar (2001) found that hospitals with integrated information systems show better performance. For example, studies have observed that success of adoption of CPOE in hospitals depends on the degree to which it is linked to other systems, such as pharmacy, radiology, laboratory information systems, EMRs, and other applications (Giannone, 2005; Vaidya et al., 2006; King et al., 2007). The lack of these integrations has been considered serious barriers towards adoption (Kaelber & Bates, 2007; Aarts & Koppel, 2009). Therefore we can state the following:

Hypothesis1b: Pediatric hospitals with greater integration among information technology capabilities are associated with more enhanced difference in the quality of care indicators.

Additionally in this research, we also concentrate on the relationship of CPOE on quality of care. Drawing from the literature, it can be identified that implementation of CPOE is a means to reduce ADEs in both inpatient and ambulatory settings (Bigelow, Fonkych, Fung & Wang, 2005; Upperman et al., 2005a; Giannone et al., 2005; Taylor et al., 2008). Bigelow and co-authors (2005) in their RAND study observed that in the absence of CPOE, about half of the serious medications errors will result in ADEs. Additionally, we see enhancement of benefits when the CPOE includes decision support systems (Holdsworth et al., 2007; McPhillips et al., 2005). In accord with this expectation and earlier literature review, the following hypotheses are stated:

Hypothesis 2.1: The hospital wide implementation of CPOE for medications is associated with a lower number of ADEs.

Hypothesis 2.1a: The effects of hospital wide implementation of CPOE for medications on ADEs are moderated by CDSS.

Hypothesis 2.2: The hospital wide implementation of CPOE for laboratory is associated with a lower number of ADEs.

Hypothesis 2.2a: The effects of hospital wide implementation of CPOE for laboratory are moderated by CDSS.

Table 1
Summary Table of the Pediatric HIT Literature Review Based on the Rogers (2003) Diffusion of Innovation Stages

			Non-empirical		Reviews	Empirical	
			Commentaries/ Editorial	**Case Study**		**Single Institutional**	**Multi-institutional**
I	**Knowledge Stage**						
		1.Recall of information 2.Comprehension of messages 3.Knowledge or skill for effective adoption of the innovation	Spooner & CCIT (2007)[4]; D'Alessandro & Dosa (2001); Ramnarayan & Britto (2002)		Johnson (2001)	Wang et al., (2007)[2]; Peverini et al., (2000)[7]; Koren (2002)[1]; Waitman et al., (2003)[7]; McAlearneya et al., (2006)[1]; Kim et al., (2007)[2]	Fortescue et al. , (2003)[2]
II	**Persuasion Stage**						
		4. Liking the innovation 5. Discussion of the new behavior with others 6. Acceptance of the message about innovation 7. Formation of a positive image of the messages about the innovation 8. Support for the innovation behavior from the system	MacTaggart & Bagley (2009); D'Alessandro & Dosa (2001);		Kaushal, Barker ,& Bates (2001); Johnson & Davidson (2004)	Killelia et al., (2007)[1]	
III	**Decision Stage**						
		9. Intention to seek additional information about the innovation		Upperm -an et al. ,		Walsh et al., (2006)[1]; Vaidya et al., (2006)[6]; Sowan et al., (2006)[6];	McPhillips et al.,(2005)[3]; Fiks et al.,

		10. Intention of trying the innovation		(2005b)		Mullet et al., (2001) [2]; Lehmann et al., (2002)[1]; Porcelli & Block (1997)[1]	(2007)[7]
IV	**Implementation Stage**						
		11. Acquisition of additional information about the innovation 12. Use of the innovation on a regular basis 13. Continued use of the innovation			Van Rosse et al., (2009)[5]	King et al., (2003)[1]; Potts et al., (2004)[2;] Upperman et al., (2005a)[1]; Han et al. , (2005) [1]; Del Becarro, et al., (2006)[1]; Adams, Mann , & Bauchner (2003)[1]; Kim et al., (2006)[1]; Taylor et al., (2008) [2]; Kadmon et al., (2009) [1]	
V	**Confirmation Stage**						
		14. Recognition of the benefits of using the innovation 15. Integration of the innovation into one's ongoing routine 16. Promotion of the Innovation to others	Conway et al., (2009) ; Fairbrother & Simpson (2009); Kim, Lehmann & CCIT (2008); Gerstle et al., (2007)[4] ; Vaidya (2006)	Giaonne (2005); Costakos (2006)	Brian (2007); Mack, Wheeler, & Embi (2009).	Cordero et al., (2004)[1]; Keene et al., (2007)[1]; Potts et al., (2004)[2] ; Sard et al., (2008)[1]; Kirk et al., (2005)[2]; Rosenbloom et al., (2006)[2]; Vaidya et al. , (2006)[6]; King et al., (2007)[1]; Vardia et al., (2006)[2] ; Walsh et al., (2008)[2];Longhurst et al., (2010)[2]	Holdsworth et al. , (2007)[2]; Teufel, Kazley, & Basco (2009) ; Menachemi, Brooks, & Simpson (2007)[1;] Menachemi et al., (2009)

[1] Retrospective cohort , [2] Prospective trial , [3] Randomized control trial , [4] Report , [5] Meta-analysis , [6] Cross over trial , [7] Case Control

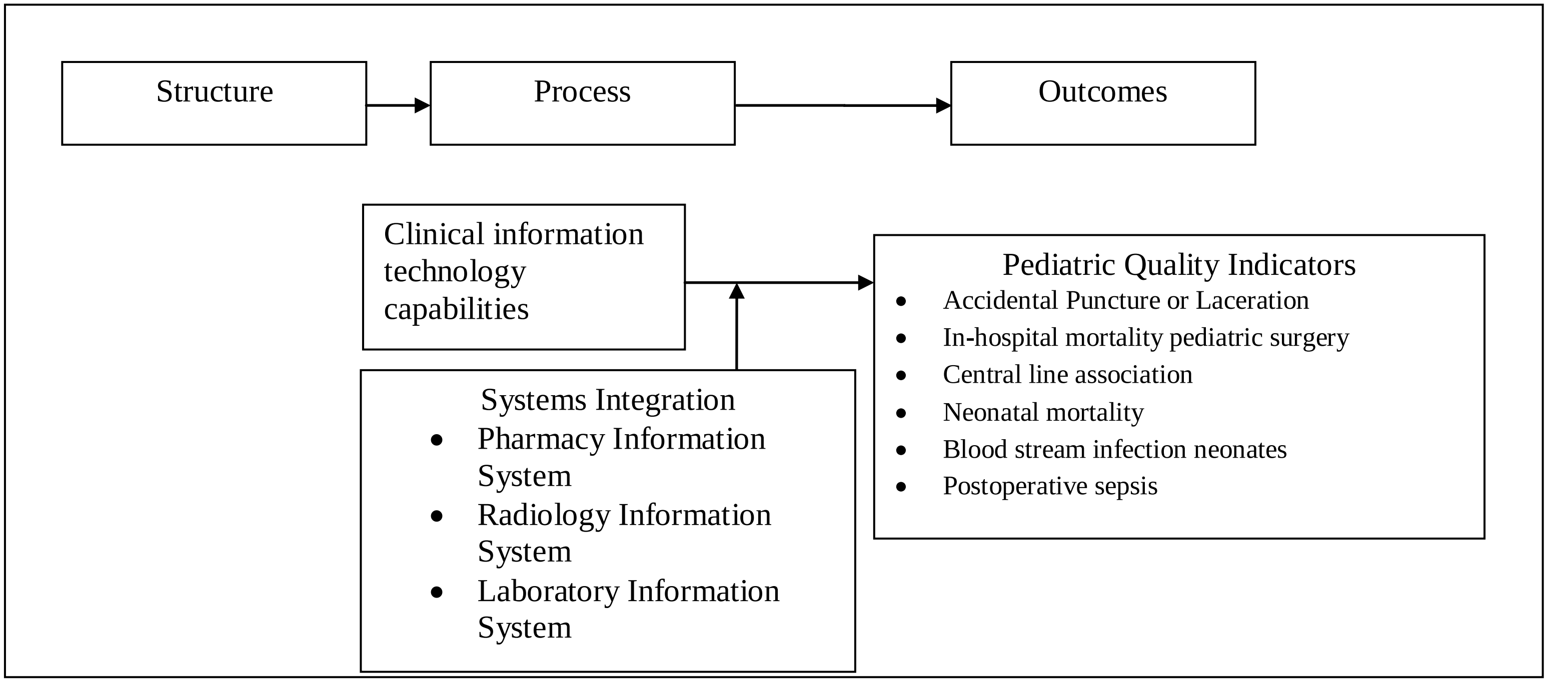

Figure 1. Relationship of Clinical information technology with pediatric quality indicators using the Donabedian model (Donabedian, 1966)

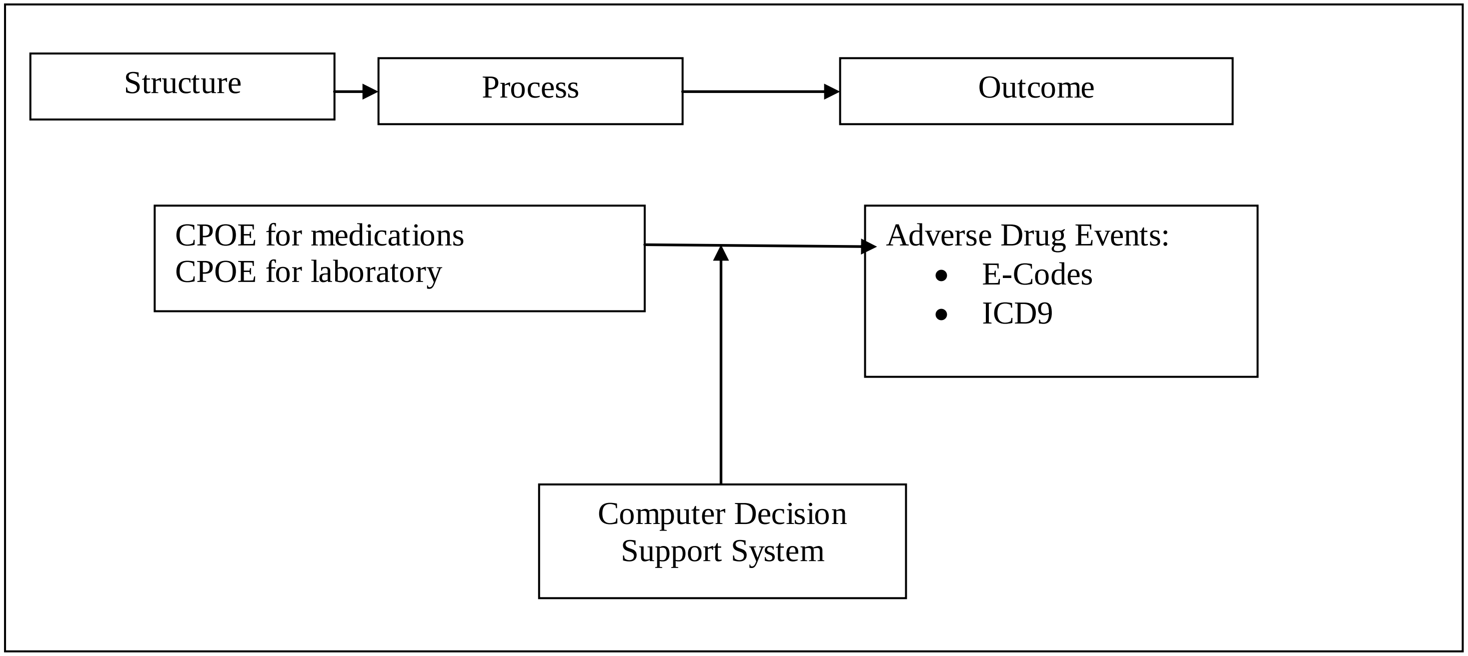

Figure 2. Relationship of CPOE for medications and laboratory with adverse drug events using the Donabedian model (Donabedian, 1966)

CHAPTER 3

METHODOLOGY

This chapter outlines the study design, sources of data, method for merging of the datasets, measurement of variables, and the analytical approach for empirically testing the research model. There are two main questions this research is designed to address: (1) Do hospitals with greater clinical information technology capabilities perform better on a set of pediatric quality indicators (PDIs)? (2) Does the implementation of CPOE for medications and laboratory relate to the number of adverse drug events across hospitals?

Study Design

This study employs an observational, cross-sectional design. This is an appropriate design when there is evidence of logical reasoning that one variable preceded another and when there is a strong theoretical framework guiding the analysis (Polit & Hungler, 1999). Both conditions exist in this proposal. Following are the specific aims of this research:

Specific Aim 1: To determine whether pediatric hospitals with relatively greater HIT capabilities experience a difference in rates of the PDIs.

Hypothesis1a: *Pediatric hospitals with greater information technology capabilities are* *associated with more desirable performance on the quality of care indicators.*

Hypothesis1b: *Pediatric hospitals with greater integration among information technology capabilities are associated with more enhanced difference in the quality of care indicators.*

Specific Aim 2: To determine whether pediatric hospitals with specialized HIT capabilities designed to improve the medication and laboratory ordering processes, experience a lower number of ADEs.

Hypothesis 2.1: *The hospital wide implementation of CPOE for medications is associated with a lower number of ADEs.*

Hypothesis 2.1a: *The effects of hospital wide implementation of CPOE for medications on ADEs are moderated by CDSS.*

Hypothesis 2.2: *The hospital wide implementation of CPOE for laboratory is associated with a lower number of ADEs.*

Hypothesis 2.2a: *The effects of hospital wide implementation of CPOE for laboratory are moderated by CDSS.*

Data Sources

Three secondary datasets have been used in this dissertation. The data sources are the datasets obtained from (1) 2005 HIT Survey of NACHRI hospitals originally collected by Menachemi and colleagues (2009); (2) NACHRI hospital discharge data with pediatric quality indicators for the year 2006; and (3) the NACHRI hospital discharge data with adverse drug events dataset for the year 2006.

Health Information Technology Survey

The first dataset obtained from a survey of Chief Information Officers (CIOs) of NACHRI affiliated hospitals, provides information on the adoption and integration of various HIT applications. The dataset includes HIT information representing 109 children's hospitals nationally. It is a 10-page survey which includes questions about current and future priorities of the organizations use of a variety of clinical and nonclinical HIT applications and their integration (Menachemi et al., 2009). The survey also includes questions regarding barriers to the use of HIT, staffing and budgeting questions, as well as hospital characteristics and CIO demographic features (Menachemi, et al. 2009). For the purpose of this dissertation selected questions from the survey relevant to the research question will be used. The selected questions from the survey questionnaire are included in Appendix A.

NACHRI hospital discharge data with pediatric quality indicators for the year 2006

The second dataset provides information on PDIs for the year 2006. The PDI count is made available through the discharge data reported by the hospitals. The discharge data is the data on the formal release of a patient from a hospital in either an inpatient or outpatient setting.

PDIs are a set of measures that reflect quality of care inside pediatric hospitals and were designed exclusively to screen for problems that pediatric patients experience as a result of exposure to the health care system and that may be prevented by changes at the system or provider level (AHRQ, 2009). The PDIs consists of 13 provider-level indicators. For the purpose of this dissertation six PDIs will be considered: accidental puncture or laceration (PDI 01), in-hospital mortality pediatric surgery (PDI 06), central line association (PDI 12), neonatal mortality (PNQ 02), blood stream infection neonates (PNQ 03), and postoperative sepsis (PDI 10). These PDIs were selected after consideration of missing data, their relevance to the study, and their importance in previous research. The definitions have been described in Table 2.

Table 2

Definitions of Pediatric Quality Indicators

No.	PDI Name	Indicator definition
PDI 01	*Accidental Puncture or Laceration*	Cases of technical difficulty (e.g., accidental cut or laceration during procedure) per 1,000 eligible discharges (population at risk).
PDI 06	*In-hospital pediatric Heart Surgery Mortality*	Number of in-hospital deaths in patients undergoing surgery for congenital heart disease per 1000 patients.
PDI 12	*Central line association*	Number of vascular catheter related infection in any secondary diagnosis field (not present on admission) among surgical and medical discharges.
PDI 10	*Postoperative Sepsis*	Number of patients with post operative sepsis per 1,000 eligible admissions (population at risk)
PNQ 03	*Blood stream infection neonates*	Number of patients with blood stream infection per 1,000 eligible admissions
PNQ 02	*Neonatal mortality*	Number of deaths per 1000 eligible admissions (population at risk).

NACHRI hospital discharge data with adverse drug events for the years 2006

The third dataset provides information on ADEs in 137 NACHRI member pediatric hospitals from the year 2006. An adverse drug event is an injury resulting from the use of a drug, and includes harm caused by the drug (adverse drug reactions and overdoses) and harm from the use of the drug (including dose reductions and discontinuations of drug therapy) (Nebeker, Barach, & Samore, 2004).

The administrative data which helps identify this ADE data are the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9 CM). The ICD9 codes allow standardized classification of disease, injuries, and causes of death, by etiology and anatomic localization and codified into a 6-digit number. They have been developed collaboratively between the World Health Organization and 10 international centers. The external causes of injury (E-Codes) are a subset of ICD-9 CM codes (ICD9). They are used in the physician claims form, generally to report accidents, injuries or diseases.

The ADE dataset includes information about patient encounters, patient days, total event codes, ICD9 codes, and E-codes events. Consistent with the literature for the purposes of this dissertation ADEs with specific ICD9 and E-codes for complications of medications have been used (Yu, Salas, Kim, & Menachemi, 2009). Table 3 and 4 list the E-Codes and ICD9 codes used for this research, respectively.

Table 3

E-Codes Used for the Purpose of This Research and Their Definitions

E-Codes	Definition
E850	Codes E850-858 (Accidental Poisoning By Drugs, Medicinal Substances, And Biologicals)
E860	Codes E860-869 (Accidental Poisoning By Other Solid And Liquid Substances, Gases, And Vapors)
E870	Codes E870-876 (Misadventures To Patients During Surgical And Medical Care)
E930	Codes E930-949 (Drugs, Medicinal And Biological Substances Causing Adverse Effects In Therapeutic Use)
E9300	Penicillins
E9305	Cephalosporin group
E9306	Antimycobacterial antibiotics
E9307	Antineoplastic antibiotics
E9308	Other specified antibiotics
E9309	Unspecified antibiotic
E9320	Adrenal cortical steroids
E9323	Insulin and anti-diabetic agents
E9331	Antineoplastic and immunosuppressive drugs
E9342	Anticoagulants
E9352	Other opiates and related narcotics
E9353	Salicylates
E9356	Antirheumatics (antiphlogistics)
E9359	Analgesics, NOS
E9361	Hydantoin derivatives
E9362	Succinimides
E9363	Other and unspecified anticonvulsants
E9390	Antidepressants
E9394	Benzodiazepine-based tranquilizers
E9395	Other tranquilizers
E9397	Psychostimulants

E9398	Other psychotropic agents
E9410	Parasympathomimetics (chlolinergics)
E9411	Parasympatholytics (antichlolinergics and antimuscarinics) and spasmolytics
E9412	Symoathomimetics (adrenergics)
E9413	Sympatholytics (antiadrenergics)
E9420	Cardiac rhythm regulators
E9421	Cardiotonic glycosides and drugs of similar action
E9424	Coronary vasodilators
E9426	Other antihypertensive agents
E9429	Other and unspecified agents primarily affecting the cardiovascular system
E9441	Purine derivative diuretics
E9444	Other diuretics
E9457	Asthma drugs

Table 4

ICD-9 CM Codes Used for the Purpose of This Research and Their Definitions

ICD-9 CM Codes	Definitions
357.6	Neuropathy due to drugs
692.3	Contact dermatitis due to drugs and medicines in contact with skin
693	Dermatitis due to drugs or medicines taken internally
960	Poisoning by antibiotics
961	Poisoning by other anti-infectives
962	Poisoning by hormones and synthetic substitutes
963	Poisoning by primarily systemic agents
964	Poisoning by agents primarily affecting blood constituents
965	Poisoning by analgesics antipyretics and antirheumatics
966	Poisoning by anticonvulsants and anti-parkinsonism drugs
967	Poisoning by sedatives and hypnotics
968	Poisoning by other central nervous system depressants and anesthetics

969	Poisoning by psychotropic agents
970	Poisoning by central nervous system stimulants
971	Poisoning by drugs primarily affecting the autonomic nervous system
972	Poisoning by agents primarily affecting the cardiovascular system
973	Poisoning by agents primarily affecting the gastrointestinal system
974	Poisoning by water mineral and uric acid metabolism drugs
975	Poisoning by agents primarily acting on the smooth and skeletal muscles and respiratory system
976	Poisoning by agents primarily affecting skin and mucous membrane ophthalmological otorhinolaryngological and dental drugs
977	Poisoning by other and unspecified drugs and medicinal substances
978	Poisoning by bacterial vaccines
979	Poisoning by other vaccines and biological substances

Merging of the datasets

Merging NACHRI ADEs dataset with HIT survey database

The original ADE dataset included data from 137 pediatric hospitals for the year 2006. The HIT survey included information about 109 NACHRI affiliated hospitals, therefore 28 hospitals were dropped from the 137 NACHRI hospitals dataset. Within these 109 hospitals, 60 hospitals were deleted due to missing ADE and patient days data. The result was a total of 49 hospitals in the merged dataset. This has been illustrated in Figure 3.

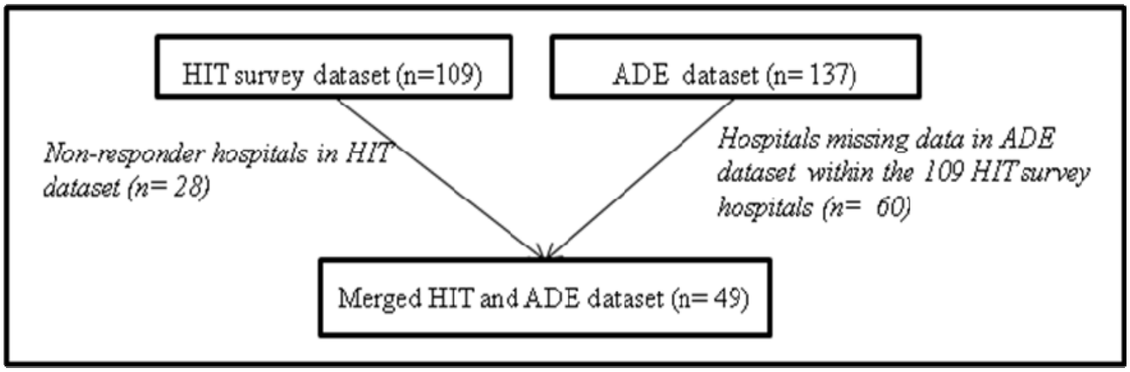

Figure 3. Number of hospitals on merging of the HIT Dataset and the NACHRI ADE dataset for 2006.

The dataset included E-Codes and ICD9 Codes categorized into various age. However for analyzing the relevant hypothesis, HIT applications would be considered hospital wide therefore a new variable for E-code and ICD9 was created by adding all the age groups.

Additionally, the ADE dataset included information about the number of patient days for each hospital. Patient days are regarded as a unit in a system of accounting used by health care facilities and health care planners. Each day represents a unit of time during which the services of the institution or facility are used by a patient; thus 50 patients in a hospital for 1 day would represent 50 patient days. For the purposes of this research the adverse drug events are calculated using rates per 1000 patient days.

In the HIT survey CIOs were asked about the hospital wide deployment of key HIT functionalities, such as CPOE for medications (CPOE Med), CPOE for laboratory (CPOE Lab), and CDSS. After merging the dataset, groups were formed from these HIT applications that included, (1) CPOE Med and CDSS, (2) CPOE Med and no CDSS, (3) no CPOE Med and no CDSS, (4) CPOE Lab and CDSS, (5) CPOE Med and no CDSS, and finally (6) no CPOE Lab and no CDSS.

Merging NACHRI PDIs dataset with HIT survey database

The original PDI dataset included data from 137 NACHRI member pediatric hospitals for the year 2006. The HIT survey included information about 109 NACHRI affiliated hospitals, therefore 28 hospitals were dropped from the 137 hospitals. Within these 109 hospitals, 64 hospitals were deleted due to missing data on the relevant PDIs. The resulting was a total of 45 hospitals in the merged dataset. This has been illustrated in Figure 4.

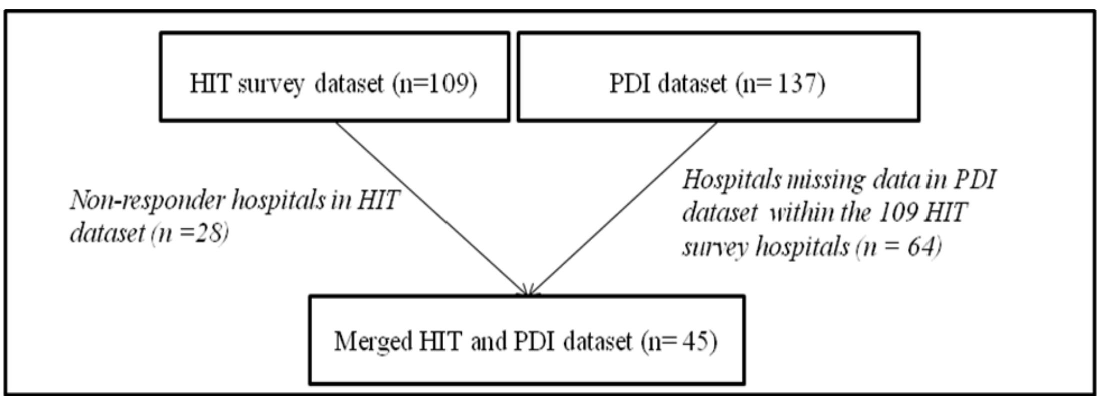

Figure 4. Number of hospitals on merging of the HIT Dataset and the NACHRI PDI dataset for 2006.

Measurement

This section describes the variables used in the research model. The variables are based upon the Donabedian developed SPO model (1966) discussed in Chapter 2. The process and outcomes are within the premise of the pediatric hospital acting as the structure within this model. The independent variables in this study will be operationalized to represent the process of automation of pediatric hospitals with HIT. Outcome variables will be used as measures for gauging the quality of medical care after the implementation of HIT.

Independent Variables (Process Variables)

Clinical information technology capabilities. The independent variable in the first analysis is clinical information technology capabilities (CITC), to be used for analysis of hypotheses 1a and 1b. In the HIT survey, specific question was included to measure whether the pediatric hospital had any of the numerous individual HIT applications. Broadly, these applications represented administrative and clinical functions. Twenty-five HIT capabilities had been included in the HIT survey (Appendix C). The variable was thus developed based upon the score of each hospital. This score was calculated based upon the number of HIT applications each hospital reported. Therefore, the clinical index for a given hospital could range from 0 to 25. Zero indicated that the hospital had no clinical applications available, whereas a score of 25 indicated that the maximum number of clinical applications measured were available.

Hospital wide implementation of CPOE. These are two independent variables, CPOE for medications (CPOE Med) and CPOE for laboratory (CPOE Lab). These variables have been derived from the answer to the question CIOs were asked in the HIT survey: *Please indicate the extent to which the following functionalities are deployed in your facility today?*

Dependent Variables (Outcome Variables)

Pediatric quality indicators. The variable for the first hypotheses operationalizes the variable PDIs (*Hypothesis* 1 and *Hypothesis* 1a). Normally PDIs are reported as raw, risk-adjusted, and smooth. The observed rate is the raw rate reported by the provider (AHRQ, 2005), suggestive of the actual number of events per hospital. The risk-adjusted rate is the difference between the population rate and the expected rate to “adjust” the observed rate to explain the difference between the case-mix of the reference population and the provider (AHRQ, 2005). Smoothed rate is a rate used to determine the difference weighted averages of the population rate and the risk-adjusted rate. The AHRQ PSI software (version 2.1, revision 1) analyzes the data, and the resulting output (numerator, denominator, mean, observed rate, risk-adjusted rate, and smoothed rate) for each of the 13 PDIs with relevant pediatric volume. The PDIs are reported as rates. As discussed earlier we six risk adjusted provider-level indicators will be considered for this analysis (Table 2).

Adverse drug events. The second set of variables is the ADEs (Hypothesis 2.1, 2.2, 2.1a, and 2.2b). The ADEs are represented by ICD9 codes and their subset E-Codes. The ICD9 codes and E-codes to be used for this dissertation have been listed earlier (Table 4). They will be considered at a rate of per 1000 patient days.

Mediator

Information systems integration. Hypothesis 1a will be tested using the mediator variable informing about information systems integration. The variable provides this study the means of ascertaining the qualitative robustness of the information system. The variable was developed from the HIT survey question: *To what extent is each of the following systems integrated with other information systems in your or organization?* The systems to be included for studying integration are: Pharmacy information system, Laboratory information system, and Radiology information system. The variable is dichotomous, grouped according to the hospitals that are very much integrated and those integrated to a lesser amount or did not integrate.

Clinical decision support system. The moderator for hypothesis 2.1a and 2.2b looks at additional HIT support in the form of CDSS. A CDSS is defined as any software designed to directly aid in clinical decision making in which characteristics of individual patients are matched to a computerized knowledge base for the purpose of generating patient-specific assessments or recommendations that are then presented to clinicians for consideration (Hunt, Haynes, Hanna, & Smith, 1998). Table 5 provides a summary of all the variables and their measures discussed above.

Table 5

Summary of the Variables and Their Brief Description

Type of Variable	Construct	Measure	Data Source
Constant			
Structure	Pediatric Hospitals		
Independent Variables			
Process(Hypotheses 1a and 1b)	Relatively greater CITC capabilities	Hospitals with highest number of HIT applications	HIT Survey
Process(Hypotheses 2.1 and 2.2)	Specialized HIT capabilities: CPOE for medications and laboratory hospital wide	CPOE for medications and laboratory hospital wide	HIT Survey
Mediator			
Process(Hypotheses 1b)	Integration of the systems with other information systems	Amount of integration with following information systems: PIS , LIS, RIS	HIT Survey
Process(Hypotheses 2.2a and 2.2b)	CDSS	Clinical Decision support system hospital wide	HIT Survey
Dependent Variable			
Outcome (Hypotheses 1a and 1b 1)	Pediatric Quality Indicators	PDI 01, PDI 02, PDI 06, PDI 12, NQI 03, NQI 02	PDIs from NACHRI
Outcome (Hypotheses 2.1, 2.1a, 2.2 and 2.2a)	Adverse drug events	2009 ICD-9-CM Volume 1 Diagnosis Codes (Table 2) E-Codes (Table 3)	ADEs from NACHRI

Data Evaluation

Merging of the three datasets prepares robust datasets for evaluation. The data will be first analyzed utilizing traditional descriptive techniques which include means, standard deviations, ranges, frequencies and percentages, of characteristics of the three datasets used for this: 2005 HIT Survey NACHRI hospital discharge data PDI dataset and ADE dataset for the year 2006. All analyses will be conducted using SPSS version 18 (SPSS, Inc., Chicago, IL).

Structure has been considered a constant for this study. The data from the 2005 HIT Survey of NACHRI hospitals to be discussed in Chapter 4 reported no variation in the hospitals based on demographic and organizational characteristics.

Data Analysis

Hypotheses 1 and its subsets data analysis: Multiple linear regression was the primary statistical method used to analyze hypotheses 1 and 1a. Multiple linear regression was considered appropriate for this design as it will test an association between several independent variables (i.e., clinical information technology capabilities and integration with information systems) and a dependent variable (i.e., pediatric quality indicators). Considering the limited sample size, bootstrapping method will be applied to the regression model. Boostrapping involves resampling the data by replacement many, many times for generating an empirical estimate (Efron, 1979; Mooney & Duval, 1993). Its main strength lies in estimating standard errors and in constructing confidence intervals (DiCiccio & Romano, 1988).

Hypotheses 2 and its subsets data analysis: To test the second proposed hypotheses and its subsets, the study used univariate analysis of variance to identify significant associations among variables. This test was selected as the independent variable (CPOE for medications and laboratory) was grouped depending on the presence or absence of CDSS. Thus this methodology would test the difference in means of the dependent variables (E-codes and ICD9 codes). Considering the limited sample size, bootstrapping method was applied to the model.

Summary

This study was conducted using 2005 data from the HIT Survey of NACHRI member organizations and 2006 NACHRI datasets providing information on specific quality indicators (PDIs and ADEs). The sample was drawn by linking these three datasets. The research design used the Donabedian model to empirically study the relationship between HIT and quality in pediatric hospitals. The variables have been defined in Table 5 and include measures for constructs from the hypotheses presented in Chapter 2. The independent variable studies the process and is defined in two different hypotheses as the amount of clinical IT capabilities and the extent of deployment of CPOE in the pediatric hospitals, respectively. The dependent variables based upon the outcomes include the PDIs and ADEs. The analysis will be conducted using multiple linear regression (hypotheses 1 and 1a) and univariate analysis of variance (hypotheses 2.1, 2.1a, 2.2, and 2.2a).

CHAPTER 4

RESULTS

The purpose of this chapter is to present results for the analyses outlined in Chapter 3. The sample is drawn from three datasets to answer the research questions. The chapter is therefore presented in three sections followed by a summary.

Section one, provides information about the NACHRI hospitals HIT survey conducted in 2005 (to be referred to as HIT survey in this chapter). Descriptive statistics related to the institutional characteristics of the participating hospitals, and survey responses to the question about various HIT applications are presented in tabular format. This information will be used for analyses presented in sections three and four of this chapter.

Section two is divided into two parts. The first part presents descriptive statistics of the merged HIT survey dataset and the NACHRI PDI dataset (to be referred to as merged HIT and PDI dataset). Second, this section reports the results of the analyses conducted using univariate analysis of variance. The main variables of interest are risk-adjusted PDIs, with selected HIT applications and their integration levels. The last section, first presents descriptive statistics about the merged HIT survey dataset and the adverse drug events dataset (to be referred to as merged HIT and ADE dataset) collected by NACHRI. The main variables studied include patient days, E-codes, ICD9 codes, and CPOE related variables. The next part of this section presents results of the analyses conducted using multiple linear regression using bootstrapping methodology.

Section 1: Health Information Technology Survey

This section includes two tables discussing the demographics of pediatric hospitals and various HIT applications implemented in these hospitals.

Table 6, displays information on demographics of pediatric hospitals that participated in the HIT survey (n= 109), merged HIT survey and ADE dataset (n= 49), and merged HIT survey and PDI dataset (n= 45). The majority of hospitals had a not-for-profit status in all the three datasets (HIT survey = 88.5%; merged ADE dataset =93.9%; merged PDI dataset = 95.2%). It is also observed that a large number of hospitals were children's hospitals operating within larger hospitals (HIT survey = 52.6%; merged ADE dataset =32.7 %; merged PDI dataset = 31.7%). These are followed by freestanding hospitals (not in a hospital system) and next those within a system.

Table 6

Institutional Characteristics of the Respondent Pediatric Hospitals

Institutional Characteristics	HIT Survey (n =109)	Merged HIT and ADE Survey (n= 49)	Merged HIT and PDI Survey (n= 45)
Not for profit	85 (88.5%)	43 (93.9%)	40 (95.2%)
For profit	3 (3.1%)	1 (2.0%)	0 (0%)
Government	8 (8.3%)	2 (4.1%)	2 (4.8%)
Freestanding, NOT system	19 (20%)	16 (32.7%)	15 (36.6%)
Freestanding, SYSTEM	8 (8.4%)	7 (14. 3%)	7 (17.1 %)
Children hospitals within hospital	50 (52.6%)	16 (32.7%)	13 (31.7%)
Specialty Children	15 (15.8%)	4 (15.8%)	4 (9.8%)
Other	3 (3.2%)	2 (4.1%)	2 (4.9%)

In the HIT survey, the CIOs were asked to select from a list of HIT applications the ones currently implemented in the hospital. These HIT applications have been discussed in Chapter 3. Table 7 presents the percentages of the responses from the HIT survey (n=109), the merged HIT and PDI dataset (n= 45) and the hospital not included in the merged HIT and PDI survey (n= 64). The merged HIT and PDI dataset is studied as these applications will be used during analysis of hypotheses 1a and 1b.

A total of 86.2% (n=94) hospitals reported the implementation of scheduling systems in the HIT survey and 88.9% (n= 40) hospitals reported the implementation of scheduling systems in the HIT and PDI dataset. The HIT application for transcription ranked next (HIT survey = 85.3%; HIT and PDI survey = 86.7%). The other systems that followed each other closely were PIS, LIS, and chart tracking or locator systems. Comparison between the hospitals included in the merged HIT and PDI dataset, and those not included, was conducted using crosstabulation. Chart deficiency, EHR and CDSS were significant at $p < 0.01$ level. A few of the HIT applications were significant at $p < 0.05$ level (chart tracking, abstracting, CPOE, etc.).

Table 7

Comparison of HIT Applications in the HIT Survey and HIT and PDI Merged Datasets

	Column A	Column B	Column C	p-values
HIT Applications	HIT Survey hospitals (n= 109)	Frequency of merged HIT and PDI Survey hospitals (n= 45)	Frequency of hospitals absent in merged HIT and PDI Survey (n =64)	Comparing Column B and C
Scheduling	94 (86.2%)	40 (88.9%)	54 (82.8%)	0.057
Transcription	93 (85.3%)	39 (86.7%)	54 (82.8%)	0.039*
PIS	89 (81.7%)	39 (86.7%)	50 (78.1%)	0.133
LIS	88 (80.7%)	37 (82.2%)	49 (76.6%)	0.093
Chart Tracking/Locator	87 (79.8%)	35 (77.8%)	52 (79.7%)	0.015*
Chart Deficiency	86 (78.9%)	34 (75.6%)	52 (79.7%)	0.009**
Abstracting	87 (78.9%)	36 (80.0%)	50 (78.1%)	0.047*
RIS	85 (78.0%)	37 (82.2%)	46 (71.9%)	0.214
Order Communication Results	81 (74.3%)	34 (75.6%)	47 (73.4%)	0.059
PACs	79(72.5%)	35 (77.8%)	44 (68.8%)	0.020*
Pharmacy Dispensing	77 (70.6%)	31 (68.9%)	46 (71.9%)	0.024*
Clinical Data Repository	72 (66.1%)	28 (62.2%)	42 (65.6%)	0.028*
Operating Room	70 (64.2%)	30 (27.5%)	40 (62.5%)	0.128
Emergency IS	58(53.2%)	24 (53.3%)	34 (53.1%)	0.095
Telemedicine Systems	55 (50.5%)	22 (48.9%)	33 (51.6%)	0.056
EHR	53 (48.6%)	17 (37.8%)	36 (56.3%)	0.001**
Medical Record Imaging	49 (45.0%)	22 (48.9 %)	27 (42.2%)	0.419
Medical/Surgical Bed Side Terminals	48 (44.0%)	22 (48.9%)	26 (40.6%)	0.540

Nurse Charting/Care Planning	46 (42.2%)	16 (35.6%)	30 (46.9%)	0.006*
Scanning clinical documents	45 (41.3%)	21 (46.7%)	24 (37.4%)	0.673
CPOE	44 (40.4%)	16 (35.6%)	28 (43.8%)	0.019*
CDSS	39 (35.8%)	13 (28.9%)	26 (40.6%)	0.006**
Critical Care Bed Side	25 (22.9%)	11 (24.4%)	14 (21.8%)	0.572
Bar Coded Medication Management	23(21.1%)	11 (24.4%)	12 (18.8%)	1.000
BDSS	16 (14.7%)	9 (20.0%)	7 (10.9%)	0.724

*p < .05, **p< .01

Correlations analysis was conducted to examine the relationship between these HIT applications (Appendix C). These correlations are presented using Phi. This analysis indicates a substantial level of correlation among the HIT variables.

Section 2: Descriptive Statistics of Merged PDIs and HIT Dataset

This section, first presents the descriptive statistics of the relevant variables in the merged PDI and HIT dataset. Second, it analyses the data to answer the research question whether hospitals with greater clinical information technology capabilities perform better on a set of PDIs.

In the HIT survey CIOs were asked about the extent to which some of the listed systems were integrated with other information systems in their hospitals. After merging the dataset with PDI, it was observed that 71.1 % hospitals were reported as having more integration of LIS (Table 8). This was closely followed by RIS (64.4%) and PIS (57.8%).

Table 8

Number of Hospitals and the Amount of HIT Integration (n=45)

HIT Applications	Very Much Integrated
PIS	26 (57.8%)
RIS	29 (64.4%)
LIS	32 (71.1%)

Appendix D presents the descriptive statistics of the PDIs. They are presented for the year 2006 as observed (raw) rates, risk-adjusted rates, and smoothed rates. Overall, neonatal mortality (PNQ02) reports the highest count among all the PDIs. This is followed by birth trauma injury to neonate (PPS17) and in-hospital mortality pediatric heart surgery. Post-operative failure and postoperative sepsis rank next in higher incidence.

Multiple linear regression was employed to help determine the effect of higher clinical information technology capabilities on six pre-selected pediatric quality indicators. Since no a priori hypotheses had been made to determine the order of entry of the predictor variables, a direct method was used for the multiple linear regression analyses. The independent variables were interacted with the mediator variables (pharmacy information systems, laboratory information systems, and radiology information systems) as separate equations. Table 9, 10 and 11 summarizes the analysis results. The multiple regression model with both predictors produced low R-squares and

17 of the 18 regressions were non-significant. The only exception was observed when information technology capabilities variable was interacted with laboratory information system a decrease in the rate of blood stream infection of neonates was observed. Given the low effect size and the non conformance with other results it was concluded that no trend of association was detected.

Table 9

Test Results of Hypothesis 1 Using Pharmacy Information Systems

Dependant Variable	Independent Variable	B	B	t	P-value	Confidence Interval Lower	Confidence Interval Upper	R
Accidental Puncture and Laceration								
Model 1	CITC	6.26E-06	0.018	0.114	0.871	-9.79E-05	9.84E-05	0.003
	PIS	0.000	0.053	0.335	0.703	-0.001	0.001	
Model 2	CITC	-2.00E-05	-0.057	-0.236	0.804	0.000	0.000	0.007
	PIS	0.000	0.048	0.300	0.739	-0.001	0.001	
	CITC*PIS	4.60E-05	0.099	0.410	0.636	0.000	0.000	
In-Hospital Mortality Pediatric Heart Surgery								
Model 1	CITC	0.003	0.127	0.780	0.459	0.000	0.008	0.027
	PIS	0.021	0.116	0.711	0.493	-0.01	0.07	
Model 2	CITC	0.001	0.042	0.167	0.375	-0.001	0.004	0.032
	PIS	0.02	0.109	0.662	0.472	-0.009	0.064	
	CITC*PIS	0.003	0.112	0.449	0.577	-0.003	0.014	
Postoperative sepsis								
Model 1	CITC	0.000	0.104	0.661	0.452	-0.001	0.001	0.012
	PIS	0.001	0.045	0.285	0.767	-0.008	0.009	
Model 2	CITC	0.001	0.383	1.605	0.062	0.000	0.002	0.069
	PIS	0.002	0.058	0.376	0.713	-0.007	0.009	
	CITC*PIS	-0.002	-0.365	-1.538	0.105	-0.004	0.000	
Central Line Associated								
Model 1	CITC	-3.46E-05	-0.035	-0.221	0.827	0.000	0.000	0.009
	PIS	0.001	0.085	0.541	0.592	-0.002	0.003	

Model 2	CITC	2.41E-05	0.024	0.099	0.921	-0.001	0.000	0.012
	PIS	0.001	0.088	0.557	0.581	-0.002	0.003	
	CITC*PIS	0.000	-0.077	-0.32	0.751	-0.001	0.001	
Blood Stream Infection Neonate								
Model 1	CITC	-0.001	-0.054	-0.326	0.692	-0.003	0.002	0.003
	PIS	-0.001	-0.013	-0.08	0.944	-0.032	0.028	
Model 2	CITC	0.000	0.025	0.097	0.913	-0.006	0.004	0.008
	PIS	-0.001	-0.007	-0.044	0.971	-0.033	0.028	
	CITC*PIS	-0.001	-0.104	-0.409	0.632	-0.009	0.010	
Neonatal Mortality								
Model 1	CITC	0.000	0.069	0.450	0.655	0.000	0.002	0.042
	PIS	-0.011	-0.185	-1.203	0.236	-0.038	0.000	
Model 2	CITC	0.001	0.17	0.716	0.478	0.000	0.004	0.049
	PIS	-0.01	-0.179	-1.148	0.258	-0.035	0.000	
	CITC*PIS	-0.001	-0.132	-0.561	0.578	-0.007	0.000	

Table 10

Test Results of Hypothesis 1 Using Radiology Information Systems

Dependant Variable	Independent Variable	B	β	t	p-value	Confidence Interval Lower	Upper	R
Accidental Puncture and Laceration								
Model 1	CITC	9.78E-06	0.028	0.180	0.794	-8.58E-05	9.23E-05	0.025
	RIS	0.001	0.160	1.030	0.326	0.000	0.001	
Model 2	CITC	0.000	0.341	1.170	0.120	-6.40E-05	0.001	0.063
	RIS	0.001	0.184	1.186	0.208	0.000	0.002	
	CITC*RIS	0.000	-0.367	-1.264	0.100	0.000	-4.23E-05	
In-Hospital Mortality Pediatric Heart Surgery								
Model 1	CITC	0.003	0.130	0.797	0.448	-0.001	0.009	0.027
	RIS	0.023	0.117	0.719	0.448	-0.007	0.074	
Model 2	CITC	0.001	0.032	0.096	0.486	-0.001	0.004	0.030
	RIS	0.021	0.107	0.640	0.440	-0.007	0.069	

	CITC*RIS	0.003	0.113	0.345	0.517	-0.002	0.010	
Postoperative sepsis								
Model 1	CITC	0.000	0.076	0.505	0.616	-0.001	0.001	0.096
	RIS	-0.008	-0.294	-1.947	0.111	-0.018	0.000	
Model 2	CITC	0.001	0.416	1.458	0.192	-0.003	0.002	0.139
	RIS	-0.008	-0.274	-1.829	0.171	-0.019	0.000	
	CITC*RIS	-0.001	-0.398	-1.397	0.196	-0.004	0.004	
Central Line Associated								
Model 1	CITC	-4.01E-05	-0.040	-0.255	0.719	0.000	0.000	0.004
	RIS	0.000	0.042	0.269	0.808	-0.003	0.003	
Model 2	CITC	-8.43E-05	-0.084	-0.279	0.794	-0.001	0.000	0.004
	RIS	0.000	0.039	0.242	0.834	-0.003	0.003	
	CITC*RIS	6.13E-05	0.052	0.173	0.854	-0.001	0.001	
Blood Stream Infection Neonate								
Model 1	CITC	-0.001	-0.083	-0.519	0.560	-0.004	0.002	0.067
	RIS	-0.023	-0.256	-1.598	0.127	-0.054	0.006	
Model 2	CITC	0.000	-0.039	-0.121	.906[b]	-.014[b]	.004[b]	0.068
	RIS	-0.023	-0.251	-1.526	.159[b]	-.052[b]	-.004[b]	
	CITC*RIS	-0.001	-0.050	-0.156	.880[b]	-.011[b]	.022[b]	
Neonatal Mortality								
Model 1	CITC	0.000	0.069	0.450	0.534	0.000	0.002	0.054
	RIS	-0.013	-0.216	-1.417	0.454	-0.041	0.000	
Model 2	CITC	0.002	0.268	0.920	0.536	0.000	0.009	0.070
	RIS	-0.012	-0.201	-1.301	0.448	-0.038	0.001	
	CITC*RIS	-0.002	-0.233	-0.805	0.533	-0.011	0.000	

Table 11

Test Results of Hypothesis 1 Using Laboratory Information Systems

Dependant Variable	Independent Variable	B	β	t	P-value	Confidence Interval		R
						Lower	Upper	
Accidental Puncture and Laceration								
Model 1	CITC	2.05E-05	0.058	0.369	0.635	-7.81E-05	9.86E-05	0.035
	LIS	0.001	0.191	1.209	0.262	-0.001	0.002	
Model 2	CITC	0.000	0.759	1.261	0.177	-2.49E-06	0.001	0.068
	LIS	0.001	0.324	1.687	0.026	0.000	0.002	
	CITC*LIS	0.000	-0.705	-1.206	0.178	-0.001	8.97E-05	
In-Hospital Mortality Pediatric Heart Surgery								
Model 1	CITC	0.003	0.147	0.877	0.456	0.000	0.009	0.028
	LIS	0.026	0.123	0.737	0.455	-0.004	0.076	
Model 2	CITC	0.000	0.023	0.030	0.810	-0.003	0.005	0.029
	LIS	0.021	0.097	0.425	0.451	-0.006	0.056	
	CITC*LIS	0.003	0.124	0.171	0.520	-0.003	0.010	
Postoperative sepsis								
Model 1	CITC	0.000	0.096	0.594	0.538	-0.001	0.001	0.010
	LIS	-0.001	-0.018	-0.113	0.902	-0.011	0.010	
Model 2	CITC	0.000	0.150	0.237	0.829	-0.004	0.005	0.011
	LIS	0.000	-0.009	-0.045	0.970	-0.018	0.015	
	CITC*LIS	0.000	-0.055	-0.089	0.947	-0.004	0.004	
Central Line Associated								
Model 1	CITC	3.04E-05	0.030	0.197	0.845	0.000	0.000	0.09
	LIS	0.003	0.306	1.992	0.053	-1.23E-05	0.006	
Model 2	CITC	0.000	-0.198	-0.334	0.740	-0.002	0.001	0.094
	LIS	0.003	0.263	1.387	0.173	-0.002	0.006	
	CITC*LIS	0.000	0.230	0.399	0.692	-0.001	0.001	
Blood Stream Infection Neonate								

Model 1	CITC	-0.001	-0.112	-0.683	0.499	-0.004	0.002	0.058
	LIS	-0.024	-0.242	-1.470	0.150	-0.058	0.009	
Model 2	CITC	-0.015	-1.541	-2.221	0.033	-.030[b]	-.001[b]	0.162
	LIS	-0.055	-0.543	-2.558	0.015*	-.089[b]	-.021[b]	
	CITC*LIS	0.014	1.422	2.114	0.041*	.002[b]	.025[b]	
Neonatal Mortality								
Model 1	CITC	0.000	0.029	0.189	0.636	0.000	0.001	0.067
	LIS	-0.016	-0.251	-1.614	0.448	-0.053	0.000	
Model 2	CITC	0.004	0.555	0.931	0.594	-0.002	0.027	0.086
	LIS	-0.010	-0.151	-0.796	0.433	0.000	0.001	
	CITC*LIS	-0.004	-0.529	-0.913	0.585	-0.021	0.001	

*p < .05, **p< .01

Section 3: Descriptive Statistics of Merged ADEs and HIT Dataset

This section first provides descriptive statistics on the relevant ADE variables in the merged HIT survey and NACHRI ADE dataset. It then reports frequencies and significance based upon one way analysis of variance (ANOVA). The third part of this section presents the results of the analyses answering the research question whether the implementation of CPOE for medications and laboratory is related to the number of ADEs. A total of 45 pediatric hospitals were included in this dataset.

The following part of this section presents the ADE variables and their groupings. Table 12 shows the descriptive statistics of patient days, E-Codes and ICD9 codes used to calculate the ADEs per 1000 patient days. The mean of patient days was 61514.78. The hospitals reported more E-Codes than ICD9 codes (E-codes mean 2006 = 15.21; ICD9 mean 2006 = 10.46).

Table 12

Descriptive Statistics of the ADE variables from the ADE and HIT Merged Dataset (n=49), 2006

Variables	Mean	Median	Std. Deviation
Patient days	61514.78	63562.50	27532.12
E-Codes per 1000 patient days	14.22	13.36	9.31
ICD9-Codes per 1000 patient days	9.35	8.07	5.94

Table 13 and 14 present frequencies and the ANOVA results of the CPOE groups formed in this merged dataset. The HIT and PDI dataset reported CPOE Lab had been deployed in 30.6 % hospitals, closely followed by CDSS (26.5 %) and CPOE for medications (26.5 %). The hospitals when grouped reported 18.4% hospitals with CPOE Med and CDSS, and 20.4 % hospitals with CPOE Lab and CDSS. A large number of hospitals did not implement both CPOE Med and CDSS, and both CPOE Lab and CDSS (n=32; n=31), respectively. ANOVA was calculated on E-codes and ICD9 codes. The results for CPOE for medication with E-codes and ICD9 codes were not significant, $F(2, 48) = 2.060$, $p = 0.139$; and $F(2, 48) = 3.029$, $p = 0.921$, respectively. Additionally, the results for CPOE for laboratory with E-codes and ICD9 codes were not significant, $F(2, 48) = 1.579$, $p = 0.217$; and $F(2, 48) = 0.177$, $p = 0.839$, respectively.

Table 13

Descriptive Statistics and ANOVA Table of CPOE for Medications Groups

n=49	CPOE Medications + CDSS	CPOE Medications + No CDSS	No CPOE Medications+ No CDSS	p-value
Sample size	9 (18.4%)	8 (16.3%)	32 (65.3%)	
Mean of E-Codes per 1000 patient days	25.29	16.48	13.46	0.139
Mean of ICD9 Codes per 1000 patient days	10.06	10.71	10.46	0.921

Table 14

Descriptive Statistics and ANOVA Table of CPOE for Laboratory Groups

n=49	CPOE Laboratory + CDSS	CPOE Laboratory + No CDSS	No CPOE Laboratory + No CDSS	p-value
Sample size	10 (20.4%)	8 (16.3%)	31 (63.3%)	
Mean of E-Codes per 1000 patient days	19.00	15.43	12.92	0.217
Mean of ICD9 Codes per 1000 patient days	8.68	9.63	9.57	0.839

All the hypotheses (2.1, 2.1a, 2.2, and 2.2a) were tested using univariate analysis of variance. The models were constructed to measure the association between CPOE and adverse drug events with CDSS as a mediator. Table 15 shows the results of this analysis. Of the 4 comparisons, none were statistically significantly related (P < 0.05). These results suggests that, there is insufficient evidence to show an associated between CPOE and ADEs.

Table 15

Univariate Results for Hypotheses 2 and its Subparts

		E-codes 2006			ICD9 Codes		
Independent Variable		Sum of Squares	F-Value	P-Value	Sum of Squares	F-Value	P-Value
Hypothesis 2a	CPOEMed	383.262	2.310	0.111	13.855	0.183	0.834
	CDSS	138.057	1.664	0.204	17.863	0.471	0.496
	CPOEMed*CDSS	76.919	0.927	0.341	2.281	0.06	0.807
	Adjusted R-square		0.042			0.075	
Hypothesis 2b	CPOELab	187.817	1.088	0.346	52.208	0.707	0.498
	CDSS	34.227	0.397	0.532	1.422	0.039	0.845
	CPOELab*CDSS	39.927	0.463	0.500	47.527	1.288	0.263
	Adjusted R-square		0.004			0.047	

Summary

This chapter presented descriptive statistics of the variables and the models. Data were available for 45 and 49 pediatric hospitals out of the 109 in the HIT survey. Hypotheses 1 and 1a were tested using multiple linear regression, while hypotheses 2.1, 2.1a, 2.2, and 2.2a were tested using univariate analysis of variance. All of the primary hypotheses in this study were not supported. Table 16 summarizes the hypotheses.

Table 16

Summary of Results by Hypotheses

Hypotheses number	**Hypotheses**	**Supported (Yes/No)**
H1a	*Pediatric hospitals with greater information technology capabilities are associated with more desirable performance on the quality of care indicators.*	No
H1b	*Pediatric hospitals with greater integration among information technology capabilities are associated with more enhanced difference in the quality of care indicators*	No
H2.1	*The hospital wide implementation of CPOE for medications is associated with a lower number of ADEs.*	No
H2.1b	*The hospital wide implementation of CPOE for medications with clinical decision support services (CDSS) is associated with an even lower number of ADEs.*	No
H2.2	*The hospital wide implementation of CPOE for laboratory is associated with a lower number of ADEs.*	No
H2.2b	*The hospital wide implementation of CPOE for laboratory with CDSS is associated with an even lower number of ADEs.*	No

CHAPTER 5

DISCUSSION AND CONCLUSIONS

The purpose of this chapter is to discuss the findings from the study, the limitations, implications and recommendations for future research. The chapter will be presented in various sections. Section one discusses the findings related to the first set of hypotheses, the significance of these findings, and its relation to the existing literature. Similarly section two, discusses the findings related to the second set of hypotheses, significance and relation to the existing literature. Section three reviews the limitations of the study. Section four, discusses theoretical implications and implications for managers. Section five, suggests recommendations for future research.

Section 1: Explanation of Findings for Hypothesis 1

The first part of this study assessed whether pediatric hospitals with relatively greater HIT capabilities experienced a difference in rates of the PDIs. The first primary hypothesis proposed that pediatric hospitals with greater number of information technology capabilities are associated with more desirable performance on a set of specific pediatric quality of care indicators. Overall, there was no support for this relationship.

The findings of this study are not congruent with several studies in acute care settings that report positive effect of various HIT capabilities on quality of outcomes (Poon et al., 2006; Amarasingham et al., 2006; Zhou et al., 2009). Additionally, these results do not support most of the existing pediatric HIT literature that suggests the benefits of HIT on quality (King et al., 2003; Upperman et al., 2005; Benin et al., 2003; Thompsons et al., 2004). However the study does support two studies that suggest there is no association between HIT applications and some quality outcomes (Del Beccaro et al., 2006; McPhillips et al., 2005). McPhillips and colleagues (2005) in a review of outpatient pediatric pharmacy administrative data, found no difference in rates of potential overdosing or underdosing errors between clinics that used basic CPOE and those that did not use CPOE. Del Becarro and coauthors (2006) found no association between the implementation of CPOE in the PICU and mortality.

Other pediatric literature included case studies, reviews of the literature and commentaries emphasizing the role of HIT in pediatric quality (Koren, 2002; Fortescue et al., 2003; D'Alessandro & Dosa, 2001). For example, Kaushal, Barker and Bates (2001) conducted a review of the HIT literature that described the benefits of HIT in decreasing pediatric medication errors in both inpatient and outpatient settings. Johnson and Davison (2004) supported this by providing an overview on the general utilities of different HIT applications.

Despite the innumerable discussions on the positive impact of clinical information technologies on improved clinical outcomes, very few studies have examined the relationship between the overall automation of a hospital and its effect on quality across multiple institutions (Amarsingham et al., 2009; Devaraj & Kohli, 2000; Menachemi, Chukmaitov, Saunders, & Brooks, 2008). The few studies that provide a generalizable view in pediatric settings studied the relationship between pediatric volume and HIT adoption (Menachemi et al., 2009a); the rate of adoption of HIT applications

(Menachemi et al., 2007); and rate of adoption of CPOE in pediatric hospitals (Teufel et al., 2009).

A comparison of the results of this study with other research using a similar context is inappropriate and will require cautious interpretation. The studies have actually evaluated the effect of a single feature or intervention on a related measure of quality (King et al., 2003; Walsh et al., 2008), and have focused on individual homegrown HIT applications (Ash, Stavri, Dykstra, & Fournier, 2003). Additionally, the variables representing HIT and outcomes used in this research have not been presented in other studies.

However without comparison there are several probable explanations for these results. The approach used by this study of considering applications and outcomes at the institutional level and across various hospitals, may not have been able to establish a direct relationship between HIT and HIT specific quality outcomes. Therefore, these results may be directing researchers towards studying and understanding the ‘meaningful use’ of specific clinical information technology applications at the point of use and its effect on specific outcomes. The results may also be suggesting that specific features of HIT must be made available before an increase in institution wide quality improvement might be observed. The observations also suggest that HIT measured as a summated scale may not be able to capture meaningful differences in the contribution of individual HIT applications for improved outcomes. Therefore, the presence of more HIT applications is not necessarily better and is not the only panacea towards quality improvement. These findings highlight the need for highly HIT sensitive measurement of outcomes, such as linking specific HIT applications to specific quality indicators.

The next part of the first hypothesis (1a) proposed that pediatric hospitals with greater integration among information technology capabilities are associated with more enhanced difference in the quality of care indicators. Laboratory and pharmacy information systems were considered as mediators. Overall, the results showed no association. On a promising note when the information technology capabilities variable was interacted with laboratory information system a decrease in the rate of blood stream infection of neonates was observed. Given the low effect size and the non conformance with other results it was concluded that no trend of association was detected.

The idea to examine this association was similar to several other studies that have assessed HIT interventions with integrations (Muller et al., 2001; Grams, Zhang, & Yue, 1996; Troiano, 1999). Many studies have reported the usefulness of linking various systems, such as pharmacy, radiology, laboratory information systems, EMRs, and other applications (Giannone, 2005; Vaidya et al., 2006; King et al., 2007). There are a few studies in the pediatric literature that have also reported the advantage of having integrated systems (King et al., 2007; Vardia et al., 2006).

Researchers have also discussed a lack of information system integration as a serious barrier towards effective adoption of HIT (Kaelber & Bates, 2007; Aarts & Koppel, 2009). Vardia and colleagues (2006) observed that CPOE integrated with CDSS completely eliminated errors in filling in the forms and significantly reduced time to completing the form. The results from this study cannot be compared with this research it is studies a single institution, an individual HIT application, and like most other studies is from an academic hospital that has more resources and more experience (Amarasingham et al., 2009; Chaudhary et al., 2003). Most of the studies are also based on a before/after design (Vardia et al., 2006; McAlearneya et al., 2006; King et al., 2007) limiting the generalizability of these studies (Van Rosse, 2009).

The observations of this study suggest certain quality measures may not be particularly amenable to improvement through HIT automation and higher integration. The relatively broader use of pediatric HIT applications and quality indicators may have limited the ability to detect differences which might be significant with more specificity. Additionally, certain HIT applications may be less useful than others for improving quality and therefore averaging the effect of some of the superior performers.

The non significant findings also reflect on the dilemma that remains about the "productivity paradox of IT" (Brynjolfsson, 1991, p. 1). This is explained as the inability of both researchers and managers to document unambiguously the performance effects of information technology (Brynjolfsson, 1991; Bettis & Hitt, 1995). Various explanations have been offered. A few relevant to this study include mis-measurement because of pre-compiled data sets with a higher variety of variables that can lack good quantitative measures for the output and value created by technology; and the issue of trying to measure outcomes that are really too far from the IT application being implemented (Gurbaxani & Mendelson, 1989; Brooke, 1991). Another reason is related to the organizational mindset that includes quality valued culture, flexibility to adopt and deployment of effective strategies for achieving effective outcomes (Bettis & Hitt, 1995).

Section 2: Explanation of Findings for Hypothesis 2

The purpose of the second part of this study was to determine whether pediatric hospitals with CPOE designed to improve medication and laboratory ordering processes, experienced a lower number of specific ADEs relevant to pediatrics. A set of four hypotheses were proposed based on theoretical and empirical insights from the literature review. Hypotheses 2.1 and 2.2 proposed that hospital wide implementation of CPOE for medications and CPOE for laboratory is associated with a lower number of ADEs (studied here as E-codes and ICD9 codes), respectively.

Despite the theoretical and empirical evidence of positive relation between CPOE and quality (Bigelow et al., 2005; Upperman et al., 2005; Giannone et al., 2005; Taylor et al., 2008), this study found no significant association. This is contrary to the view that CPOE systems are crucial for reducing ADEs (Bates et al., 1998; Bates, Kupperman, & Teich, 1998; Teich et al., 2000). It has also been endorsed by various quality seeking organizations such as Leapfrog Group (Milstein, Galvin, Delbanco, Salber, & Buck, 2000; Bates et al., 1999), and Medicare Payment Advisory Commission (Bates et al., 1995). Additionally, a systematic review of the literature provides a glimpse at the promise of CPOE in improving the efficiency, quality, and safety of medical care delivery in pediatric settings (Vaidya et al., 2006; Sowan et al., 2006; Shulman et al., 2005). Van Rosse and authors (2009) reviewed various effects of CPOE on medication prescription errors, ADEs, and mortality in inpatient pediatric care and neonatal, pediatric or adult intensive care settings. They found that there was significant decreased risk of medication prescription errors with the use of CPOE. However, they noted there was no significant reduction in ADEs or mortality rates.

On further review of the literature, it is noted that very few studies are available on the role of CPOE for laboratory (Georgiou & Westbrook, 2006). Most of these studies have focused on the impact on test volumes using a variety of measures including the number of tests ordered per patient, per admission or per doctor (Westbrook, Georgiou, Dimos, & Germanos, 2005; Kilpatrick & Holding, 2001), permitting no comparison with these results. Unfortunately, there is only one study in the pediatric setting that measured the effect of CPOE on timeliness of urgent laboratory and imaging tests (Thompson et al., 2004). They observed that the time from ordering and obtaining laboratory specimens reduced on implementation.

Studies about CPOE, however, are inhibited by their granularity, lack of ability to track continuity, and limited dissemination (Ash et al., 2004; Ferner, 2004). Thus given well-documented, promising benefits of CPOE from other studies and the contrary results of this study, more focused research documenting the impact of CPOE on specific medication errors and ADEs is warranted. Despite the enthusiasm for CPOE, a few studies have also reported additional errors and no significant association with quality (Koppel et al., 2005; Berger & Kichak, 2004; Kaushal, Kaveh, & Bates, 2003; Shane, 2002; Horsky, Kuperman, & Patel, 2005). Additionally, research has found it difficult to capture CPOE-facilitated error risks, as the problems may be due to insufficient training or noncompliance, erratic error-reporting mechanisms, and focus on technology rather than on work organization (Woods & Cook, 2002; Tucker & Edmondson, 2003; Rasmussen, 1986).

To enhance these findings, the addition of variables explaining the human factors would add a new dimension to the consequences of CPOE adoption (Woods, 1994; Cook, Render & Woods, 2000). This information is essential as quite often deployment of CPOE in pediatric settings has been reported to lack the knowledge or training to use it effectively (Johnson, 2001). Upperman and co-authors' (2005b) paper documented the introduction of CPOE-centered changes in an academic tertiary care center and discussed that CPOE implementation process is more than a technological change; it involves an organizational cultural transformation such as creating a realistic, positive, work environment, hospital wide participation and integration.

Another possible explanation for the findings relates to quality outcome measures. The consideration of a group of pediatric relevant ADEs may not necessarily demonstrate the effectiveness of CPOE due to lack of concentration at specific outcomes relevant to the CPOE. This re-emphasizes the importance for both practitioners and researchers to use and study applications that are focused towards specific quality outcomes.

The subparts of the main hypotheses (2.1a and 2.2a) proposed that the hospital wide implementation of CPOE for medications and CPOE for laboratory with CDSS is associated with lower numbers of ADEs, respectively. Again the findings did not support the hypotheses.

Acute care hospitals literature has suggested that the introduction of CPOE with CDSS changes the medication ordering system resulting in the reduction of medication-related errors (Leape et al., 1995; Kaushal & Bates, 2001). Studies have reported that decision support also manages large amounts of incoming data, introduces guidelines adherence, and helps physicians in decision making (Hofer & Hayward, 2002; Kaushal, Shojania, & Bates, 2003).

The results of this study also contradict a few studies in pediatric setting that reported CPOE with CDSS reduced ADEs (Fortescue et al., 2003; Potts et al., 2004; King et al., 2003; Cordero et al., 2004; Kadmon et al., 2009). However, some studies reported negative effects due to the introduction of new medication errors (Walsh et al., 2006) or increased mortality after implementation of CPOE/CDSS in pediatric hospitals (Han et al., 2005). Similar to the results of this study, Del Beccaro and colleagues (2006) reported no association; and McPhillips and colleagues (2005) found no difference in rates of potential overdosing or underdosing errors. However, these studies cannot be easily compared with the findings of study because of difference in the sites, sample size and outcomes considered.

These results raise many questions. One question seeks information on the impact of institutional culture and clinical workflow on the implementation of sophisticated new clinical information systems (Massaro, 1993; Oostendorp, Hoekstra, & Aarts, 1999). In addition, the efficiency of individual decision support elements may be questioned too. To be effective CDSS associated with CPOE systems in pediatric settings is required to at the least, display age-specific dosing regimens, dosage check for above or below the usual range, alerts based upon laboratory values for individual patients, and screen for allergies and drug–drug interactions to improve the ordering process (Potts et al., 2004).

Section 3: Limitations of the Study

There are several limitations worth mentioning. First this study used a cross-sectional design that cannot determine direct causality. The HIT survey was conducted in 2005 and requested information about the implementation of various HIT applications then used. Information about the maturity of the HIT applications was unavailable and therefore could not be study as a time-series model.

Second, though the HIT survey requested substantial HIT information

(Menachemi et al., 2009a) as compared to any previous surveys on pediatric HIT, it is subject to two important limitations. First, dichotomous variables have been used for some of the HIT adoptions that may artificially inflate or deflate the implementation rate. Some hospitals may own the HIT applications but usage may vary. However an attempt is made to address this concern through the analysis of quality indicators one year after the survey period. Second, data collection often leads to the possibility wherein respondents differ in some important ways than non-respondents. Moreover, consistent with survey research concerns, the observations in the HIT dataset may reflect the respondents' willingness and ability to respond to individual survey questions and respondents' desire to give correct answers.

The other concern is about the low sample size resulting in low power. Despite the high response rate (55%), the data size was limited to 109 pediatrics hospitals, with 45 and 49 hospitals analyzed for each of the hypotheses. Though considered a small sample size, this is the first study in pediatric literature that observes the implementation of HIT and its effect on quality at a multi-institutional level. Bootstrapping methodology was used to address this issue. However, small cell sizes may still lead to false negatives.

Since, the sample analyzed was multi-institutional, generalizability to specific pediatric settings and comparison with previous results must be undertaken with caution. Additionally, the institutions considered were NACHRI member hospitals limiting the ability to compare these results with the HIT implementation of others who are not NACHRI members. Another limitation was the exclusion of organizational confounders that explain quality outcomes, most notably a hospital's emphasis on safety and quality. But the model adjusted for those hospitals with higher number of HIT applications, as a hospital's higher investment in clinical information technologies is often reflective of an innovative and quality driven organization (Amarasingham et al., 2009). Additionally, though the model was designed based upon extensive literature research and theoretical support it was not been subjected to formal psychometric evaluation.

Additionally, the HIT survey dataset was linked with well-recognized and validated quality outcomes designed by AHRQ in 2006. However, the results indicated the complexity in establishing the HIT sensitiveness to these outcomes. The casual link between quality and HIT needs to be studied with consideration of specificity.

Finally, the study used secondary data that is often regarded as a limitation because of concerns such as coding errors and quality of data indented for administration purposes.

Section 4: Strategic and Theoretical Implications

This study was based on strong conceptual framework, to address the lack of theory-driven evaluations in pediatric HIT literature. The hypotheses were empirically tested and discussed with existent literature. Theoretical and practical implications are discussed in this section.

Implications for Research

This is the first conceptually framed study in the pediatric literature that attempted to study the relationship between HIT and quality outcomes in children's hospitals. The commonality of all the findings provides some support for the conceptual premise that structure, process, and outcome may be related but that such relationships can be difficult to demonstrate (Donabedian, 1980). The nomology of relationships cannot be deciphered until the introduction of specificity and validity. For example, often neither structural nor process variables show consistent relationships to patient outcomes such as mortality or adverse events, when either structure or process is examined alone (Mitchell & Shortell, 1997). It is therefore important to understand all the factors that influence this process and outcome relationship in order to develop a strong causal link. This study clearly highlights these concerns of ambiguity and that more does not necessarily mean better unless specialized.

Additionally, the findings necessitate the discussion about not significant findings. Research has often shown that non significant findings do not necessarily mean no findings. These findings may be because of lack association between HIT and quality or certain significant factors affecting the relationship were omitted from the model. Thus the results may be suggesting future research addressing factors such as strategic behavior of an organization towards quality HIT adoption and its effect on superior quality outcomes. This behavior has been known to have a greater impact on performance than just demographics and usage of technology, as it influences availability of resources (Menachemi, Burke, Clawson, & Brooks, 2005; Marlin, Huonker, & Sun, 2002), and the culture of quality improvement. Thus it can be observed that only presence of HIT does not in itself improve the quality of care (Diamond & Shirky, 2008). Additionally research suggests that to sustain itself, hospitals will conduct resource transactions with their environment making strategic choices concerning alternative actions they will take to adapt to HIT environmental forces (Child, 1997). The exploration of these strategic transactions is important to extend the area of research from a focus on process and outcome measures.

The other implication of this study is towards the theoretical and empirical view that a better way to determine quality is by studying broader data sets that contain hundreds or even thousands of observations (Brynjolfsson, 1998). The idea is that it usually allows benchmarking within organizations, and provides a clearer picture of the underlying relationship. However, it has limitation such as it may average out the superior or inferior results, and eclipse the huge variation across organizations and different datasets.

The findings also suggest that multi-institutional benchmarking of the productivity of HIT using quality outcomes, capturing the health information outcomes, and reporting of clinical quality measures needs more focus and attention. However, usage of various quality outcomes' datasets to evaluate a relationship with HIT, does not necessarily support the nomological view and provide adequate answers. One way to think about this conundrum is to consider the measurement of quality outcomes at the point of use using HIT sensitive measures.

Implication for Managers

A major deliberation for policymakers, developers, hospitalists and health care executives, has been establishing and unraveling of the complex relationship between HIT and quality outcomes. However, though this multi-institutional, conceptually framed, empirically driven study observed no association between various HIT applications and specific quality of care indicators in pediatric hospitals there are several important implications to be discussed.

First, and foremost, the results suggest that simply having HIT applications is not sufficient for improving quality. Health care managers based upon these findings would want to take a cautious approach towards thinking that more HIT applications yield quality improvement. The challenge of considering HIT as a tool and not a goal towards the achievement of quality improvement (Diamond & Shirky, 2008) is re-emphasized by this study. An explanation can be provided by the strategy management literature that discusses the importance of technological tools such as HIT in formalizing, specializing, standardizing and regulating the work flow design (Minztberg, 1979; Child, 1974). Organizations employ these tools to reduce variation (Henderson & Venkatraman, 1993), eliminate “human factor” issues (Davenport, 1993), and ultimately predict and control quality (Bates & Gawande, 2003). Thus adoption of HIT is an opportunity to align organizational needs (Burke & Menachemi, 2004; Neumann, Blouin, Bryne, & Reed, 1999), and monitor the hidden cultural assumptions built into these tools (Forsythe, 1996). Most importantly, benefits of the technology will only be evident when it is coupled with new strategies, new work-flow design, and efficient tool usage. Quality improvement managerial mindset requires flexibility, championship, and knowledge in appropriate implementation of HIT to improve quality (Bettis & Hitt, 1995).

Additionally, more of HIT may not necessarily optimize quality outcomes unless meaningfully used. Presence of leading-edge HIT applications needs to be linked to specific solutions. For example, defining quality improvement strategies related to the technology, and the new work processes should be made compatible with the needs and desired outcomes. Moreover, implementing technology to improve quality is an ongoing process that requires strong leadership in implementation, as well as training and resource support, dissemination of information, and surveillance of outcomes. As HIT gets more broadly applied to manage clinical processes in pediatrics it becomes essential to integrate clinical information across departments to provide information to support decision making at any point in the clinical process (Gordon, et al. 2005). This study suggests managers to address the need to support research for answering basic questions on HIT and quality. Second, is to not make the common misstep of focusing on technologies versus solutions.

Last, policymaking bodies, should ensure that when considering benchmarking of hospitals whether the data used is comparable and focused towards the process and outcomes. The aim is to improve quality therefore it is crucial that the strategic reasons behind their institution's engagement with the technology are clear. Consistent with the requirements of most quality improvement processes ongoing evaluation should be monitored to accompany the implementation and to fine tune the effort and to be able to present a balanced assessment of the effect (McLaughlin & Kaluzny, 1995).

Section 5: Recommendations for Future Research

This dissertation has contributed to the body of scholarly work on HIT in pediatric hospitals and its relationship to quality of care indicators. Many more studies like these are needed, examining robust global measurements of HIT in pediatric hospitals which have a direct link to focused quality outcomes.

This study was unable to clearly delineate the various stages of HIT applications. Future research should integrate the duration and specific components of various HIT applications. The research can be further analyzed as a time-series design to evaluate the longitudinal effects of the various HIT applications, taking into account factors that affect this implementation. Comprehensive surveys can be conducted to study the implementation period of the HIT applications to improve the explanatory capability of its relationship with quality over an extended time period. Additionally, more information about specific pediatric functionalities used for enhancing HIT systems, the extent of deployment, and degree of usage of the application would enrich the research. In the context of this study, a more current report of HIT application status in the responding and non-responding hospitals would update the study.

Furthermore results reporting no association between HIT and quality outcomes create a strong case for demanding more theoretical underpinnings to understand the association between HIT and quality. Virtually no studies found in the pediatric literature reviewed examined adoption through various stages of implementation and the strategic behavior of pediatric hospitals influencing this process. Thus, there is a particular need to investigate the influence of an organization's strategic orientation (Miles & Snow, 1978; Porter, 1980) on the quality culture as this might be a major factor influencing decisions to implement and effectively use the technology. Mixed or qualitative and quantitative methods including culture variables at multi-institutions may provide a better insight. This research would be meaningful in furthering the study of strategic tools in the improvement of quality, and particularly, in furthering the understanding of HIT in pediatric hospitals.

Another study could involve ranking the relative importance of individual HIT applications in comparison with each other. In future this may assist in grouping of hospitals based upon the essential applications deployed, and relating the effect on quality. A few studies have conducted research on identifying main technology-related measures that indicate the key HIT applications in hospitals (Poon, et al. 2006; Burke & Menachemi, 2004). However, Janna and co-authors (2009) discuss that these efforts remain piecemeal and therefore are inhibited by limitations about categorizing and prioritizing the tools essential for hospitals. Therefore a survey conducted with HIT experts would prioritize these HIT applications and provide a better ranking system.

Additional studies need to evaluate HIT sensitive measures at the point of use. These measurements can provide more granularity and specificity to the quality outcomes. Consistent with this study previous researchers suggestion holds valid for the development of uniform standards for the reporting of research on implementation of HIT, similar to the Consolidated Standards of Reporting Trials (CONSORT) statements for randomized, controlled trials and the Quality of Reporting of Meta-analyses (QUORUM) statement for meta-analyses (Chaudhary, et al. 2006; Begg, Cho, Eastwood, Horton , Moher, Olkin, et al. 1996; Moher, Cook , Eastwood, Olkin, Rennie, & Stroup, 1999).

In summary this study requests that future research should be focused on what are the specific HIT capabilities that will improve specific quality outcomes? What are the quality issues that can be effectively resolved by specific HIT applications? What are the organizational factors such as leadership, quality culture that affect the adoption and implementation of HIT? What specific outcomes do individual HIT applications target? How does the meaningful use of these applications affect the quality performance of the organization? And last but not the least work on development of a robust, global tool for evaluating the effects of HIT on quality.

Summary

The dissertation made new contributions to the pediatric HIT research literature. This was the first study that used a conceptual framework for empirically examining the relationship between various types of HIT applications and well-defined, specific outcomes focused towards quality of care in pediatrics. This study also emphasized the importance of multi-institutional research that focuses attention on generalizability. Three secondary datasets were used to test hypothesized relationships using regression method and univariate analysis of variance.

It was found that HIT applications considered in the study reported no association with specific quality of care outcomes. Results from this study are useful to both researchers and practitioners. Researchers can use these results to extend knowledge on the importance, implications and limitations of theoretically driven, multi-institutional study on pediatric settings. Particularly compelling is the need for future research to find a robust, global measurement of HIT effectiveness using quality outcomes. This study also calls for research on nomological development of HIT sensitive quality measurements. Practitioners can note that HIT is not the complete solution towards improvement in quality outcomes. The recommendation is to start by articulating a clear strategy towards addressing specific solutions using specific technology. This will be the most efficient, timely, and straightforward way to understanding the meaningful use of HIT for improving quality.

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APPENDIX A

HEALTH INFORMATION TECHNOLOGY SURVEY (SELECTED QUESTIONS)

(4) Please indicate which of the following **clinical** IT applications your facility is ***currently*** using and which you believe it will be using ***within the next 2 years***. (Please select all that apply)

Clinical IT Applications *(Select all that Apply)*	**Currently Using**	**Will be impleme nting within 2 years**
a) Picture Archiving and Communication Systems (PACS)	□	□
b) Computer-Based Practitioner Order Entry (CPOE)	□	□
c) Bar Coded Medication Management	□	□
d) Pharmacy	□	□
e) Pharmacy Dispensing	□	□
f) Radiology Information System	□	□
g) Transcription	□	□
h) Electronic Health Record	□	□
i) Bioterrorism Electronic Disease Surveillance System (Syndromic Surveillance)	□	□
j) Scheduling	□	□
k) Chart Deficiency	□	□
l) Chart Tracking/Locator	□	□
m) Abstracting	□	□
n) Critical Care Bed Side	□	□
o) Telemedicine Systems	□	□
p) Emergency Department Information System	□	□
q) Laboratory Information System	□	□
r) Medical Record Imaging	□	□
s) Medical/Surgical Bed Side Terminals	□	□
t) Nurse Charting/Care Planning	□	□
u) Operating Room	□	□
v) Order Communication Results	□	□
w) Clinical Decision Support System (CDSS)	□	□
x) Clinical Data Repository	□	□
y) Scanning clinical documents	□	□

(9) Please indicate which of the following technologies your facility is ***currently*** using or will be using ***within the next 2 years***. (Please select all that apply)

Technologies at your Facility *(Select all that apply)*	**Currently Using**	**Will be Implementing within 2 years**
a) Wireless information systems	□	□
b) Handheld personal digital assistants	□	□
c) Speech recognition	□	□
d) Bar coding technology	□	□
e) Radio Frequency Identification (RFID) technology	□	□
f) Automated alerts/paging to clinicians	□	□
g) Web-enabled business transactions (e-business)	□	□
h) Personal Health Records (PHR)	□	□
i) Intranet (linking internal users behind a firewall)	□	□
j) Extranet (linking external users over a secure connectio	□	□
k) High-speed networks (LANs, WANs)	□	□
l) Data warehouse	□	□
m) Client-server systems	□	□
n) Thin clients (e.g. a stripped down PC designed specific to be a client in a client/server network)	□	□
o) XML (Extensible Markup Language)	□	□
p) CCOW (Visual integration)	□	□
q) Data security technologies	□	□
r) ASP Services	□	□
s) Other (Please specify):_______________________________	□	□

(10) To what extent is each of the following systems **integrated** with other information systems in your organization?

	Very Much Integrated	**Somewhat Integrated**	**Not at all Integrated**	**N/A**
Pharmacy Information system	□	□	□	□
b) Laboratory information system	□	□	□	□
c) Administrative information system	□	□	□	□
d) Radiology information system	□	□	□	□

e) Emergency Department information system	☐	☐	☐	☐
f) Intensive care unit (ICU) information system	☐	☐	☐	☐
g) Nursing information system	☐	☐	☐	☐

(16) Please indicate the extent to which the following functionalities are deployed in your facility **today**?

	NICU	**PICU**	**Med/ Surg**	**Ambul. Clinics**	**Emergency Department**	**Hospital Wide**
a) CPOE* for medications	☐	☐	☐	☐	☐	☐
b) CPOE* for laboratory orders	☐	☐	☐	☐	☐	☐
c) CPOE* for radiology orders	☐	☐	☐	☐	☐	☐
d) Electronic health records (EHR)	☐	☐	☐	☐	☐	☐
e) Clinical Decision Support Systems	☐	☐	☐	☐	☐	☐

(27) Which of the following best describes your hospital? **(Please select only one)**

a) Freestanding acute care children's hospital, <u>not part of a system</u>, children's hospital has its own Medicare provider number
b) Freestanding acute care children's hospital, <u>part of a system</u>, children's hospital has its own Medicare provider number
c) Children's hospital <u>within a hospital</u>, part of a larger hospital or system, children's hospital does not have its own Medicare provider number
d) Specialty children's hospital
e) Other (please specify): ____________________________

(28) Which of the following best describes your hospital's tax status? **(Please select only one)**

a) Not-For-Profit
b) For-Profit
c) Government

APPENDIX B

Clinical HIT applications with definitions

No	Clinical IT Applications	Definitions
1	Picture Archiving and Communication Systems (PACS)	A system that converts the standard storage of x-ray films into digitized electronic media that can later be retrieved by radiologists, clinicians and other staff to view exam data and medical images.
2	Computer-Based Practitioner Order Entry (CPOE)	A computer application that accepts the provider's orders for diagnostic and treatment services electronically instead of the clinician recording them on an orders sheet or prescription pad.
3	Bar Coded Medication Management	A system for medication administration management in conjunction with bar-coding equipment and software to avert medication administration errors.
4	Pharmacy Information System	Information system that deals with pharmacy. Such systems can be linked to prescribing system for electronic processing of requests for medications and can provide inventory control.
5	Pharmacy Dispensing System	Systems that allow hospitals to store and dispense drugs near the point of use. These systems, which can be compared with the automated teller machines used by banks, provide nurses with ready access to medications while maintaining tight control of drug distribution.
6	Radiology Information System	The components of radiology software, hardware and network infrastructure to support patient documentation, retrieval and analysis.
7	Transcription	Converting voice-recorded reports as dictated by physicians and/or other healthcare professionals, into text format.
8	Electronic Health Record System	A longitudinal electronic record of patient health information generated by one or more encounters in any care delivery setting. Included in this information are patient demographics, progress notes, problems, medications, vital signs, past medical history, immunizations, laboratory data and radiology reports.

9	Bioterrorism Electronic Disease Surveillance System (Syndromic Surveillance)	A secure online framework that allows one to quickly recognize and respond in real-time to disease outbreaks or bioterrorism attacks and allows healthcare professionals and government agencies to communicate about disease patterns and coordinate national response to outbreaks.
10	Information System for scheduling clinical resources	A system capable of automatically scheduling clinical resources
11	Chart Deficiency	A system capable of automatically identifying deficiencies in charting by physicians without the involvement of an analyst.
12	Chart Tracking/Locator	A medical records management tool designed to manage the paper records of a facility. It has the potential to significantly reduce the current workload associated with records management, while increasing a facility's confidence that client records are well-controlled, up-to-date, and accountable.
13	Abstracting	A system that extracts a brief summary about patients history and current chief complaints.
14	Critical Care Bed Side	A bedside system that can automatically acquire and integrate patient information such as time-stamped monitor, ventilator and infusion pump data, with patient data from labs, specialty devices, and bedside observations.
15	Telemedicine Systems	The use of medical information exchanged from one site to another via electronic communications to improve patients' health status.
16	Emergency Department Information System	A system in the ED that provides electronic charting of nursing assessments, physician charting and other clinical documentation of patient visit; including admission notes, allergies, and prescription.
17	Laboratory Information System	Group of programs capable of managing all production needs of laboratories, such as customized physician test panels, and bar-coding.
18	Medical Record Imaging	This system scans the paper based medical records, thus making them available as electronic records for future reference and storage.
19	Medical/Surgical Bed Side Terminals	This system allows bedside entry and retrieval of drug prescription, clinical, surgical and administration data about the patient.
20	Nurse Charting/Care Planning	Programs that allow the nurse to create nurse care plans for the management of the patient, and chart on the computer actions and information which support the documentation of the management of the patient.
21	Operating Room information system	Information systems for operating room management. A computerized system implemented to schedule, monitor, and display the status of operating rooms

22	Order Communication Results	Order Communications is an integrated solution that enhances communication between departments by allowing users immediate access to order details and results.
23	Clinical decision support system (CDSS)	Any software designed to directly aid in clinical decision making in which characteristics of individual patients are matched to a computerized knowledge base for the purpose of generating patient-specific assessments or recommendations that are then presented to clinicians for consideration.
24	Clinical Data Repository	A structured, systematically collected storehouse of patient-specific clinical data.
25	Scanning clinical documents	It is securely scanning and routing documents to network destinations. Additionally scan patient updates into EMR files in a timely fashion and reduce turnaround time for accounts receivable with easy access to supporting documentation for insurance claims.

APPENDIX C

CORRELATION OF HEALTH INFORMATION TECHNOLOGY APPLICATIONS

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y
a. PACS	1																								
b. CPOE	0.245	1																							
c. Bar-coded medication management	0.000	0.000	1																						
d. PIS	0.189	0.189	0.204	1																					
e. Pharmacy dispensing	-0.019	-0.019	0.131	0.320	1																				
f. RIS	0.394*	0.394*	0.038	0.464	0.426**	1																			
g. Transcription	0.265	0.265	-0.102	0.167	0.287	0.673**	1																		
h. EHR	0.033	0.033	0.200	0.093	0.082	0.165	0.111	1																	
i. Bioterrorism surveillance	0.066	0.066	0.152	-0.031	0.094	0.207	0.139	.139	1																
j. Scheduling	0.200	0.130	0.180	0.110	0.200	0.313	0.211	0.370*	0.163	1															
k. Chart deficiency	0.320	0.189	0.000	-0.167	-0.053	0.464**	0.458**	0.257	-0.031	0.367*	1														
l. Chart tracker/ locator	0.253	0.088	0.038	0.031	0.079	0.397**	0.402**	0.316	0.006	0.790**	0.681**	1													
m.Abstracting	0.320**	0.189	0.204	0.067	0.133	0.464**	0.167	0.420*	-0.031	0.623**	0.767**	0.681**	1												
n. Critical care bed side	0.197	-0.113	0.033	0.053	-0.103	0.094	0.180	.441**	0.079	0.211	0.240	0.268	0.240	1											
o.Telemedicine systems	0.415*	0.167	-0.289	-0.189	0.019	0.219	0.147	0.314	0.241	0.052	0.306	0.066	0.141	0.245	1										
p. ED info system	0.510*	0.099	-0.115	0.281	-0.015	0.496**	0.334*	0.141	0.265	0.211	0.117	0.191	0.117	0.409*	0.132	1									
q. LIS	0.320**	0.189	-0.204	0.300	0.320*	0.681**	0.750**	0.093	0.186	0.367*	0.300	0.464	0.300	0.240	0.141	0.445	1								
r. Medical record imaging	0.310	-0.033	0.229	0.070	0.310	0.442**	0.298	0.144	0.316	-0.010	0.233	0.139	0.233	0.344*	0.149	0.433*	0.397*	1							
s. Medical/surgical bed side terminals	0.182	0.290	0.207	-0.024	-0.089	0.193	0.235	0.274	0.121	0.276	0.314	0.350	0.314	0.495*	-0.051	0.231	0.145	0.318	1						
t. Nurse charting/ care planning	-0.019	0.183	0.114	-0.306	0.113	0.088	0.265	0.264	0.219	0.130	0.189	0.088	0.024	0.415*	0.283	-0.017	0.024	0.083	0.410**	1					
u. Operating room info system	0.207	0.292	0.000	-0.077	0.062	0.384	0.258	0.018	0.120	0.369*	0.284	0.384*	0.284	0.372*	0.091	0.181	0.284	0.108	0.355**	0.420**	1				
v. Order communication results	0.426*	0.394	0.038	0.464	0.426**	0.799	0.673**	0.013	0.207	0.313	0.284	0.397*	0.284	0.094	0.219	0.343	0.681*	0.442*	0.193	0.088	0.384**	1			
w. CDSS	-0.137	-0.213	-0.123	-0.603	-0.418	-0.541**	-0.364*	-0.007	-0.112	0.088	0.101	0.112	0.101	0.137	-0.036	-0.268	-0.251	-0.239	0.066	0.036	0.156	-0.541*	1		
x. Clinical data repository	0.264	0.261	0.060	0.221	0.264	0.470**	0.424**	0.262	0.169	0.308	0.221	0.310	0.221	0.150	-0.017	0.062	0.393*	0.100	0.057	0.139	0.476**	0.310	-0.082	1	
y. Scanning clinical documents	0.245	0.067	0.289	0.189	0.113	0.211	0.265	0.264	0.372	0.130	.354*	0.241	0.354*	0.283	0.167	0.215	0.354*	0.660**	0.171	-0.050	-0.091	0.394*	-0.231	0.139	1

**. Correlation is significant at the 0.01 level (2 - tailed)

* Correlation is significant at the 0.05 level (2- tailed)

APPENDIX D

PEDIATRIC QUALITY INDICATORS

Descriptive Statistics of smoothed PDIs for 2006

PDI Nos.	Pediatric quality indicators	Mean	Median	Standard Deviation
PPD01	Accidental puncture and laceration	0.0011	0.0010	0.0005
PPD06	In-hosp mortality pediatric heart surgery	0.0418	0.0420	0.0011
PPD10	Postoperative sepsis	0.0231	0.0217	0.0081
PPD12	Central line association BSI	0.0043	0.0044	0.0021
NQI02	Neonatal mortality	0.0036	0.0037	0.0008
NQI03	Blood stream infection neonates	0.0677	0.0603	0.0325

Descriptive Statistics of observed PDIs for 2006

PDI Nos.	Pediatric quality indicators	Mean	Median	Standard Deviation
PPD01	Accidental puncture and laceration	0.0018	0.0013	0.0015
PPD06	In-hosp mortality pediatric heart surgery	0.0506	0.0372	0.0862
PPD10	Postoperative sepsis	0.0230	0.0217	0.0132
PPD12	Central line association BSI	0.0073	0.0066	0.0043
PNQ02	Neonatal mortality	0.0696	0.0629	0.0463
PNQ03	Blood stream infection neonates	0.0787	0.0739	0.0422

Descriptive Statistics of Risk-adjusted PDIs for 2006

PDI Nos.	Pediatric quality indicators	Mean	Median	Standard Deviation
PPD01	Accidental puncture and laceration	0.0013	0.0010	0.0011
PPD06	In-hosp mortality pediatric heart surgery	0.0463	0.0411	0.0352
PPD10	Postoperative sepsis	0.0220	0.0214	0.0123
PPD12	Central line association BSI	0.0042	0.0040	0.0022
PNQ02	Neonatal mortality	0.0047	0.0044	0.0025
PNQ03	Blood stream infection neonates	0.0733	0.0698	0.0368

APPENDIX E

IRB FORM

THE UNIVERSITY OF ALABAMA AT BIRMINGHAM

Institutional Review Board for Human Use

DATE: June 7, 2010

MEMORANDUM

TO: Gouri Gupte
Principal Investigator

Richard Shewchuk
Faculty Advisor

FROM: Sheila Moore, CIP
Sheila Moore, CIP
Director, UAB OIRB

RE: Request for Determination—Human Subjects Research
IRB Protocol # N100603009 Information Technology and Quality of Care in Pediatrics Hospitals1

An IRB Member has reviewed your application for Designation of Not Human Subjects Research for above referenced proposal.

The reviewer has determined that this proposal is **not** subject to FDA regulations and is **not** Human Subjects Research. Note that any changes to the project should be resubmitted to the Office of the IRB for determination.

SM

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