Hospital Adoption of Information Technologies and Improved Patient Safety: A Study of 98 Hospitals in Florida

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EXECUTIVE SUMMARY

Most of the studies linking the use of information technology (IT) to improved patient safety have been conducted in academic medical centers or have focused on a single institution or IT application. Our study explored the relationship between overall IT adoption and patient safety performance across hospitals in Florida. Primary data on hospital IT adoption were combined with secondary hospital discharge data. Regression analyses were used to examine the relationship between measures of IT adoption and the Patient Safety Indicators (PSIs) of the Agency for Healthcare Research and Quality.

We found that eight PSIs were related to at least one measure of IT adoption. Compared with administrative IT adoption, clinical IT adoption was related to more patient safety outcome measures. Hospitals with the most sophisticated and mature IT infrastructures performed significantly better on the largest number of PSIs. Adoption of IT is associated with desirable performance on many important measures of hospital patient safety. Hospital leaders and other decision makers who are examining IT systems should consider the impact of IT on patient safety.

For more information on the concepts in this article, please contact Dr. Menachemi at nir.menachemi@med.fsu.edu.

Preventing medical errors and improving patient safety are among the most important potential advantages of adopting information technology (IT) in healthcare. For decades, the Institute of Medicine and other experts have been discussing the theoretical and anecdotal benefits of using computers to improve the quality of care (Bates et al. 2001; Dick, Steen, and Detmer 1991; Institute of Medicine 2001; McDonald 1976). Hospital researchers have demonstrated that the use of individual IT applications (e.g., computerized order entry and clinical decision support systems) is associated with desirable outcomes, including reduction of errors (Bates et al. 1998; Kaushal, Shojania, and Bates 2003), improved compliance with published guidelines (Dexter et al. 2001; Teich et al. 2000), and more efficient delivery of care (Bates et al. 1999a; Tierney et al. 1993).

Despite the growing body of literature that links IT to improved outcomes, the generalizability of existing studies has been questioned because many of the studies have been conducted in select academic medical centers, which have advanced resources and a decades-long commitment to IT that are not typical of other U.S. hospitals (Chaudhry et al. 2006). Furthermore, many studies have focused on individual homegrown IT applications and were not designed to measure the collective IT capabilities of a given hospital. Thus, it is not known whether hospitals that adopt a relatively higher number of commercially available information systems truly provide superior care.

This article explores the relationship between IT adoption and patient safety performance among hospitals in Florida. We combined primary IT survey data and secondary administrative discharge data from hospitals in the state, and then we measured overall hospital IT sophistication using a previously derived and validated method (Burke and Menachemi 2004). Patient outcomes were measured using the Patient Safety Indicators (PSIs) developed by the Agency for Healthcare Research and Quality (AHRQ).

CONCEPTUAL FRAMEWORK

The presence of IT does not in itself improve the quality of care. In fact, when improperly implemented, IT may inadvertently increase errors (Koppel et al. 2005). However, when properly designed and implemented, IT systems can ultimately produce better outcomes by improving various aspects of care delivery. For example, Bates and colleagues (1998; 1999b) found that the use of a computerized physician order entry system resulted in a 55 percent reduction in serious medication errors and, when used with a clinical decision support system, an 83 percent reduction in overall medication errors. Overhage and colleagues (1997) showed that automated computer reminders can significantly increase adherence to evidence-based protocols and can significantly decrease the number of pharmacy interventions for inappropriate medication orders in the hospital setting. Kuperman and colleagues (1999) found that computer-generated alerts to physicians from a laboratory information system

resulted in significant decreases in both the time until treatment was ordered and the time until orders were implemented. Wong and colleagues (2003), who studied the effect of computerized documentation on the use of time by nurses in the critical care unit, suggested that an information system can decrease time spent on administrative duties and can increase time spent on direct patient care.

Other patient safety benefits have been identified with the use of various technologies, including bar-coded medication management (Johnson et al. 2002; Meyer et al. 1991), pharmacy information systems (Grams, Zhang, and Yue 1996; Troiano 1999), pharmacy dispensing systems (Kaushal, Barker, and Bates 2001), and clinical decision support systems (Berner et al. 2006). Collectively, these studies show that IT can be used to improve efficiency and timely access to clinical information, enhance the clinical decision-making process, and improve communication between providers. Ultimately, greater efficiency can translate into improved outcomes because it enables clinicians to spend more time with patients.

Although each of these studies examined only one IT application used in only one hospital, we extrapolated from the literature and hypothesized that hospitals that have adopted a greater number of information systems will provide safer care. We also projected that hospitals with more robust IT infrastructures would perform better on patient safety measures.

METHODS

We used both primary and secondary data. The primary data were collected in 2003 with a survey that targeted all chief information officers (CIOs) of Florida hospitals. The survey included a variety of questions regarding priorities, barriers, and current IT adoption. Secondary data included hospital discharge data for 2003, which were obtained from the Florida Agency for Health Care Administration, the agency responsible for regulating hospitals in Florida. Using the hospital discharge data and software from AHRQ, we calculated outcomes using the PSIs of AHRQ.

Hospital IT Data

The primary survey data were collected as part of a larger study on IT adoption practices among acute care hospitals in Florida (Menachemi et al. 2005a; Menachemi et al. 2005b; Menachemi et al. 2006; Menachemi et al. 2007a; Menachemi et al. 2007b). To identify eligible hospitals, we obtained a list of all hospitals in the state from the Florida Hospital Association. In the original study, the focus was on acute care facilities; thus, Veterans Affairs hospitals, psychiatric facilities, and other specialty facilities (e.g., pediatric hospitals) were excluded.

The mailed questionnaire asked CIOs to indicate which clinical, administrative, and strategic information systems were already implemented at their hospital at the time of the survey (for a complete list of these IT applications, see the appendix at the end of this article). Before administering the survey, we tested the survey instrument

for clarity, readability, and content validity with a panel of IT experts and local hospital CIOs. The survey also included questions regarding facility characteristics and other hospital-level metrics. The survey protocol was approved by the institutional review board at Florida State University.

Of the 198 hospitals targeted in the study, 98 provided usable responses, for an overall response rate of 49.5 percent. Based on a previously validated method (Burke and Menachemi 2004) that has been used frequently by researchers (Bhattacherjee et al. 2006; Burke et al. 2002; Menachemi et al. 2007a; Menachemi et al. 2007b; Wang et al. 2005), we divided measures of IT adoption into three functional categories: clinical, administrative, and strategic. Each of these three measures was composed of a summated scale that represents the total number of individual IT applications adopted by a given hospital for each functional category. For example, the clinical IT summated scale for a given hospital could range from 0 (if that hospital had adopted none of the clinical IT applications examined) to 25 (if that hospital had adopted all clinical IT applications). The administrative IT summated scale ranged from 0 to 21, and the strategic IT summated scale ranged from 0 to 10.

Overall, each hospital received three scores—one for the count of IT applications the hospital adopted in each of the three categories. Higher scores on any scale indicated that relatively more IT applications were adopted. Because strategic applications are designed to make use of and to integrate readily available administrative and clinical information, such applications are typically adopted only after a significant number of administrative and clinical IT systems are present (Burke et al. 2002). Thus, higher scores on the strategic IT scale indicate a higher degree of information system integration and a higher level of overall robustness of a hospital's IT infrastructure. The strategic IT scale is, therefore, a proxy measure for overall information system maturity, as described by the Institute of Medicine (2000; 2001).

Patient Safety Indicators

The PSIs used in our study were developed, refined, and validated by AHRQ contractors as part of the Healthcare Cost and Utilization Project (Stanford-UCSF 2005). The PSIs are algorithms that are applied to routinely collected hospital inpatient discharge data that screen for adverse events patients experience as a result of exposure to the system of care. We focused on provider-level indicators that provide a measure of the potentially preventable complications for patients who received their initial care and experienced a complication of care within the same hospitalization.

AHRQ (2006) has published a complete description of the PSI measures, including how they are calculated. An important advantage in using the PSIs is that the software provided by AHRQ controls for variation in patient severity across hospitals by using the 3M Corporation's All-Patient Refined Diagnosis-Related

Groups (APR-DRGs) method of risk adjustment. This method considers patient age, gender, diagnostic-related group, and potential comorbidities when calculating risk-adjusted rates. Most of the PSIs are risk adjusted similarly. The exceptions are death in low-mortality DRGs, foreign body left during procedure, and obstetric trauma from Cesarean delivery, which do not have a theoretical basis for risk adjustment (AHRQ 2006). Overall, the PSIs provide an important perspective on patient safety events that occur at a given institution, and they have been used extensively by researchers (Clement et al. 2007; Encinosa and Bernard 2005; Miller et al. 2001; Miller et al. 2005; Weiner et al. 2006; Zhan and Miller 2003).

Statistical Analysis

We used descriptive statistics to examine the distribution of each variable. Next, we calculated bivariate correlations with each of the variables of interest. To examine the relationship between IT adoption and the PSIs, we used linear regression analyses. Given the findings from our descriptive statistics, several PSI variables were log-transformed to facilitate analysis.

In a series of regression models, each IT measure was used as an independent variable to predict one of the PSIs as a dependent variable. Given their expected correlation (Burke and Menachemi 2004; Burke et al. 2002), the IT measures were specified in separate regression to avoid violating the assumption of multicollinearity. All models also controlled for several confounding factors. First, using data obtained from the Florida Agency for Health Care Administration, which we also used in our previous work (Menachemi et al. 2006; Menachemi et al. 2007a), we controlled for hospital financial performance. Researchers using data from Florida found that financial performance in hospitals was related to improved performance on select PSIs (Encinosa and Bernard 2005). Thus, a variable measuring total hospital expenses per day was included in each model. Previous studies have also suggested that hospital tax status (for-profit versus not-for-profit) is associated with both overall and clinical IT adoption by hospitals (Burke et al. 2002). Moreover, organization size can influence both IT adoption and other process and performance outcomes (Parente and Van Horn 2007; Warner, Menachemi, and Brooks 2005). Therefore, both tax status and bed size were included as control variables in each regression model.

RESULTS

Ninety-eight hospitals participated in the IT survey, representing a 49.5 percent response rate. All 98 hospitals were matched to their corresponding hospital discharge data. The organizational characteristics of responding hospitals are displayed in Table 1. Briefly, 70 hospitals (71.4 percent) were located in urban areas, 69 (72.6 percent) were not-for-profit, and 69 (71.1 percent) were part of a multihospital system. The average number of beds was 326, with a range of 15 beds to 1,862 beds. Hospitals adopted an average of 11.3 (45.2 percent) clinical IT applications,

TABLE 1
Organizational and Descriptive Statistics for 98 Hospitals in the Study

Hospital	Results	Number of Information Technology (IT) Applications Adopted		
		Clinical IT	Administrative IT	Strategic IT
Beds: Mean (range)	326 (15–1862)			
Beds: Frequency				
< 125 beds	43 (44.3%)	8.2 (33%)	13.7 (65%)	3.7 (37%)
126–300 beds	20 (20.6%)	12.3 (49%)	15.7 (75%)	4.6 (46%)
> 301 beds	34 (35.1%)	14.7 (59%)	18.3 (87%)	7.0 (70%)
Profit status				
Not-for-profit	69 (72.6%)	11.7 (47%)	16.6 (79%)	5.5 (55%)
For-profit	26 (27.5%)	9.8 (39%)	13.1 (62%)	3.6 (36%)
Geographic location				
Urban	70 (71.4%)	12.8 (51%)	16.5 (79%)	5.6 (56%)
Rural	28 (26.6%)	7.4 (30%)	13.8 (66%)	3.4 (34%)
System affiliation				
Yes	69 (71.1%)	11.9 (48%)	16.4 (78%)	5.5 (55%)
No	28 (28.9%)	9.3 (37%)	14.1 (67%)	3.6 (36%)

Note: Each IT measure represents the number of IT applications studied that were adopted by each hospital for a given organizational function. Maximum numbers were 25 clinical applications, 21 administrative applications, and 10 strategic applications. Numbers may not add up to 100 percent because of rounding.

15.7 (74.8 percent) administrative IT applications, and 5.0 (50 perecnt) strategic IT applications.

Overall, the average patient safety event rate of PSIs ranged from .00006 per 1,000 eligible discharges (for *foreign body left in after procedure*) to .1541 per 1,000 eligible discharges (for *obstetric trauma—vaginal with instrument*).

In univariate analyses, most PSI outcome measures were not significantly correlated with any of the IT measures. However, with risk adjustment, *complications of anesthesia* was weakly correlated with clinical IT adoption ($r = .245$, $p = .029$), and *failure to rescue* was weakly and inversely correlated with clinical IT adoption ($r = -.288$, $p = .008$). In addition, risk-adjusted *infections due to medical care* was weakly correlated with clinical IT ($r = .267$, $p = .013$), administrative IT ($r = .256$, $p = .017$) and strategic IT ($r = .341$, $p = .001$) adoption; and risk-adjusted *obstetric trauma (vaginal without instrument)* was weakly correlated with clinical IT adoption ($r = .328$, $p = .024$).

In multivariate regression analyses, hospitals that adopted a greater

number of IT applications were significantly more likely to have desirable quality outcomes on eight PSI measures. For example, an increase in the total number of clinical IT applications was significantly inversely correlated with *death in low-mortality DRGs* ($\beta = -1.82$, $p = 0.024$), risk-adjusted rates of *decubitus ulcer* ($\beta = -1.30$, $p < 0.001$), and risk-adjusted *postoperative sepsis* ($\beta = -1.69$, $p = 0.031$).

An increase in clinical IT was further associated with two additional PSIs—risk-adjusted *postoperative hemorrhage* and risk-adjusted *postoperative pulmonary embolism*—but the trends ($\beta = -1.33$, $p = 0.060$ for *postoperative hemorrhage* and $\beta = -.977$, $p = 0.064$ for *postoperative pulmonary embolism*) did not reach statistical significance. Nevertheless, an increase in the number of administrative IT applications was associated with lower rates of risk-adjusted *decubitus ulcer* ($\beta = -2.49$, $p < 0.001$).

An increase in the adoption of strategic IT applications was significantly inversely related to six PSI measures. Hospitals reporting the adoption of additional strategic IT applications had more desirable risk-adjusted rates of *selected infections due to medical care* ($\beta = -1.00$, $p = 0.044$), *postoperative hip fracture* ($\beta = -2.42$, $p = 0.013$), *postoperative respiratory failure* ($\beta = -2.32$, $p = 0.025$), *postoperative sepsis* ($\beta = -1.75$, $p = 0.015$), *postoperative wound dehiscence* ($\beta = -2.09$, $p = .037$), and *accidental puncture or laceration* ($\beta = -.135$, $p = 0.05$).

Note that no relationship identified in multivariate analyses was in the unexpected direction. In other words, any time that a significant relationship was identified between a PSI outcome and a measure of IT adoption, the relationship was in the anticipated (desirable) direction.

DISCUSSION

A growing body of literature has linked the use of IT to improved patient safety (Bates et al. 1998; Johnson et al. 2002; Kaushal and Bates 2002; Overhage et al. 1997; Poon et al. 2006). Nevertheless, a large number of such studies cannot be generalized to typical hospitals because they were conducted in specialized academic settings with unique circumstances (Chaudhry et al. 2006). Only a small number of studies have considered the entire portfolio of IT capabilities in a set of hospitals, and they found links between IT and improved financial performance (Devaraj and Kohli 2000; Menachemi et al. 2006; Wang et al. 2005), operational performance (Bhattacherjee et al. 2006; Parente and Van Horn 2007), and nonclinical outcomes such as perceptions of quality (Rodger, Pendharkar, and Paper 1999) and attitudes about employee satisfaction (Hatcher 1998).

We explored the relationship between IT adoption and performance on a set of widely used patient safety indicators in a relatively large sample of hospitals. We hypothesized that hospitals with greater IT adoption would perform better on patient safety measures, and our findings support this notion. Eight different PSI measures were statistically significantly related to at least one measure of IT adoption. Moreover, all significant relationships

were in the negative (desirable) direction, suggesting that increases in IT adoption are associated with a decrease in adverse events.

We also hypothesized that hospitals with more sophisticated IT infrastructures would perform best on the set of PSI measures. Indeed, greater adoption of strategic information systems—the proxy measure for *overall IT sophistication*—was significantly related to the greatest number of patient safety outcomes. Many of the outcomes, including *selected infections due to medical care, postoperative respiratory failure,* and *postoperative sepsis,* are conditions that can be prevented when clinicians have access to up-to-date patient information, standardized order sets, and evidenced-based guidelines. Hospitals with sophisticated and integrated information systems are able to ensure that clinicians receive critical clinical information at the point of care and to assist physicians in adhering to proven clinical guidelines (Bates et al. 2001; Bates and Gawande 2003; Schiff et al. 2000; Schiff et al. 2003).

Our analyses and research protocol have several strengths. First, we used validated and widely used measures of IT and patient safety. Second, by combining primary and secondary data, we were able to overcome common method bias, a methodological problem inherent in many single-respondent surveys. Third, we conducted instrument construction, sampling, and statistical analyses using a systematic, rigorous, and scientific approach. Thus, our data were expected to generate findings that were strong in internal validity. Moreover, our approach toward IT measurement did not focus on a specific IT vendor or product. Instead, we examined the homogenous effect of IT by studying a heterogeneous sample of hospitals.

When interpreting our results, some research limitations should be considered. First, our study had an observational cross-sectional design that is not suitable for detecting causality. We merely identified a significant relationship between IT adoption and improved patient safety outcomes. An unobserved variable (e.g., effective management) might be associated with both IT adoption and superior patient safety in hospitals and, thus, affect the results presented. Other limitations of the study include the fact that our data were based on 98 hospitals, representing a response rate of approximately 50 percent. Although the sample of hospitals is relatively large, especially compared to previous studies of this kind, and the participation rate is acceptable, we recognize that response bias is a possibility. Finally, by design our study focused exclusively on acute care hospitals in one state. As such, any attempt to generalize our findings to other types of healthcare settings or to acute care hospitals in other states must be undertaken with caution.

In conclusion, we believe this study provides healthcare managers with important evidence regarding the relationship between IT adoption and patient safety in hospitals. The nature of returns associated with IT investments is multifaceted. Managers must consider both financial and clinical impacts that stem from IT adoption decisions. We hope that with a clearer

understanding of how IT may relate to important patient outcomes, hospital leaders will be able to make better-informed decisions and to offer their patients better quality care.

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Appendix:
Information Technology (IT) Applications Categorized by Function

Clinical IT (25 Items)	Administrative IT (21 Items)	Strategic IT (10 Items)
Computerized physician order entry	Patient scheduling	Outcome and quality management
Electronic medical record	Patient registration	Case-mix analysis
Pharmacy information system	Patient billing	Managed care software
Pharmacy dispensing	Customer relationship management or call center	Managed care contract management
Radiology information system	General ledger	Cost accounting
Laboratory information system	Accounts payable	Executive information system
Medical record imaging	Benefits administration	Flexible budgeting
Transcription	Payroll	Enterprise resource planning system
Nurse charting or care planning	Personnel administration	Nurse staffing system
Bar-coded medical management	Time and attendance	Business intelligence or decision support systems (e.g., data warehouse)
Clinical decision support system	Electronic mail	
Clinical data repository	Two-way web-based applications	
Clinical resource scheduling	Credit or collections	
Chart tracking and locator	Electronic claims	
Chart deficiency	Eligibility	
Picture archiving and communication systems	Premium billing	
Bioterrorism disease-surveillance system	Supply chain management	
Abstracting	Materials management	
Critical care bedside	Encoder	
Telemedicine system	Data repository	
Emergency department medical system	Master patient (person) index	
Medical/surgical bedside terminals		
Operating room system		
Order communication results		
Scanning clinical documents		

PRACTITIONER APPLICATION

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At Tallahassee Memorial HealthCare, we are frequently concerned with the impact that investments in information technology (IT) will have on patient safety. Even though several studies have been published suggesting that IT is associated with improved outcomes, it seems that most studies have been conducted in an academic medical center, where the operational environment is very different from the environment in community hospitals. This article by Menachemi and colleagues is a welcome addition to the patient safety literature because it is more applicable to the typical hospital.

The patient safety committee at our hospital frequently considers the Agency for Healthcare Research and Quality's Patient Safety Indicators (PSIs) when examining trends in the hospital's performance. We have considered various IT solutions when we were dissatisfied with trends on a given indicator. One of the difficult questions posed by members of the patient safety committee is, "How do we know that investing in a new IT system will have a measurable impact on our patient safety outcomes?" Until now, we have typically assumed, and hoped, that our well-intentioned and expensive investments would pay off. The study by Menachemi and colleagues has demonstrated that significant differences in performance on the PSIs exist, and some of these differences can be explained by the level of IT systems in place at hospitals.

The concept of reducing reliance on vigilance by "hardwiring" solutions and overcoming barriers was originally described by James Reason, who spoke of the "Swiss cheese" model of system accidents. In his widely cited book, *Human Error,* Dr. Reason suggested that many errors occur because barriers designed to avoid errors are porous. These imperfect barriers can include human variables such as attention span, ability to focus in crises, fatigue, and technical knowledge.

When IT systems are thoughtfully selected and properly implemented, vulnerability to human fallibility can be mitigated. For example, in transfusion medicine, the use of bar-coding technology when collecting blood samples and labeling blood types has reduced reported errors, from 1 in 3,000 (when relying on human-driven processes) to 1 in 3,000,000 (when the process is automated). In addition, integrated IT systems—including computerized physician order entry, laboratory results reporting, pharmacy systems with alerts for drug interactions and allergies, and "smart pumps" for infusion therapy—all provide additional hardwired barriers that can improve patient safety. Given these relationships, the findings of this study are not surprising; hospitals that have adopted IT systems in an effort to reduce the barriers that prevent optimal care are performing better on the PSIs. Studies like this one are very valuable when considering difficult decisions about IT investments.