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Maryam Alavi
Emory University, Maryam_Alavi@bus.emory.edu

Steven L. Johnson
Temple University, steven.l.johnson@temple.edu

Terry Willey RN, MN
Emory Healthcare, terry.willey@emoryhealthcare.org

Youngjin Yoo
Temple University, youngjin.yoo@temple.edu

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Research-in-Progress

Maryam Alavi
Emory University Goizueta Bus. School
Atlanta, Georgia
maryam_alavi@bus.emory.edu

Steven L. Johnson
Temple University Fox School of Bus.
Philadelphia, PA
steven.l.johnson@temple.edu

Terry Willey RN, MN
Emory Healthcare
Atlanta, Georgia
terry.willey@emoryhealthcare.org

Youngjin Yoo
Temple University Fox School of Bus.
Philadelphia, PA
youngjin.yoo@temple.edu

Abstract

IT is viewed as integral to achieving substantial quality and efficiency improvements in U.S. healthcare delivery and management. A key idea behind these suggestions is the use of IT to support knowledge management to enhance and facilitate evidence-based clinical decision-making. Yet, it is not clear to what extent IT-enabled knowledge management systems will be effective for physicians who make complex clinical decisions under time pressure and high degree of uncertainty. To address this gap, we are conducting a field study to examine the impact of IT-enabled knowledge management systems in an emergency department at a major university hospital in the Southeast region of the US. The preliminary results of our analyses show that the use of IT-enabled knowledge application tools indeed influence the healthcare professional's clinical decision-making behaviors, which in turn influence the outcome of patient care.

Keywords: knowledge management, healthcare, clinical decision making.

"The U.S. Healthcare industry is arguably the world's largest, most inefficient information enterprise" (Hillestad et al. 2005).

Introduction

Over the last several years, the Institute of Medicine (IOM) has regularly endorsed the use of information technology (IT) to improve the quality of medical care and patient safety. In various reports published by IOM (Institute of Medicine 2001, 2003), IT is viewed as integral to achieving substantial quality and efficiency improvements in U.S. healthcare delivery and management. Similarly, policy makers and politicians often mention IT as a tool that can reduce the healthcare cost and improve the quality of patient care. For example, as a presidential candidate, Barak Obama proposed to spend $50 billion to upgrade the nation's healthcare IT in order to contain the unsustainable growth of national healthcare cost.

A key idea behind these suggestions is the use of IT to support knowledge management to enhance and facilitate evidence-based clinical decision-making. The goal is to apply best available knowledge gained from scientific method and past practices to individual clinical decision-making situations. It seeks the ideal in which all medical professionals should make explicit, conscious and judicious use of all available best evidence-based knowledge in making clinical decisions. Proponents argue that application of evidence-based practice would reduce the inconsistencies and uncertainties in medical decision-making. Many institutions try to implement evidence-based clinical decision-making in the form of policy, recommendations, guidelines and regulations. However, translating such institutional behaviors into actual behaviors practiced by healthcare professionals is a challenging task. IT is seen by many as an integral solution to close the gap in implementing evidence-based clinical decision-making practices. By codifying best available knowledge and integrating it into the electronic medical record (EMR) systems that medical professionals interact with to manage various clinical information, hospitals and medical practices are implementing IT-enabled KM tools in order to support the evidence-based practice more consistently and improve performance.

Two factors, however, warrant more careful examination of the effectiveness of IT-enabled knowledge management tools in the healthcare context. First, recently scholars studying knowledge management in organizations have shown that the use of IT-enabled knowledge management systems influences team members' knowledge application behaviors, which in turn, affect team performance (Choi et al, 2010). Therefore, one can expect that the impact of IT-enabled evidence-based clinical decision-making on medical outcomes will be mediated by the changes in the behaviors by the medical professionals. From a knowledge management perspective, the use of IT-enabled evidence-based practice can be seen as application of codified knowledge that is stored in a knowledge repository (Alavi and Leidner 2001). Therefore, we do not know if the availability of such IT-enabled knowledge management tools for healthcare practice will lead to improvements in performance. Second, medical professionals go through years of highly specialized training and often rely on their own professional expertise and experiences in making clinical decisions. Furthermore, medical professionals must make complex decisions under time pressure and uncertainty with potentially catastrophic outcomes (i.e., death or serious injury) (Roberts, 1990). Taken together, it is not clear to what extent IT-enabled knowledge management systems will be effective for physicians who make complex clinical decisions under time pressure and high degree of uncertainty.

In order to address this gap in the literature, we are conducting a field study to examine the impact of IT-enabled knowledge management systems in an emergency department at a major university hospital in the Southeast region of the US. Specifically, we ask the following question:

What are the impacts of the use of IT-enabled knowledge management systems on quality of patient care, cost and efficiency in clinical decision-making?

Our research in progress contributes to the Information Systems (IS) literature by looking at the role of IT-enabled knowledge management systems on knowledge application behaviors and the performance outcomes in a healthcare setting. Our research in progress can also make an important contribution to medical practice and public policy by evaluating the potential impact of IT tools in improving quality of patient care and reducing the healthcare cost, which is one of the most important issues in the U.S. today.

Theoretical Background: A Knowledge-based View on Evidence-based Clinical Decision-Making

An extensive body of research on knowledge management systems (e.g., Alavi and Leidner 2001, Nielsen 2006, Sher and Lee 2004,Theriou et al. 2009) suggests that IT can enhance organizational performance through consistent and effective application of knowledge in organizational practices. Considering the knowledge-intensive nature of the healthcare domain, the high rate of change and innovation, tacit nature of knowledge in medical practice, and the wide scope of knowledge needed by the professionals in this field, patient care can greatly benefit from advanced information technologies that facilitate codification, storage, search, and timely access to the best knowledge available.

The literature, however, is clear that mere stocking of knowledge through codification is not enough to improve organizational performance (Alavi and Tiwana 2002). Knowledge needs to be applied in practice in order to produce intended outcomes (Cook and Brown 1999, Orlikowski 2002). Thus, the potential benefit of IT-supported knowledge management cannot be realized through the codification and accumulation of knowledge in IT systems alone. Rather, it is in the ability to apply knowledge to take effective action. Choi et al. (2010) found that knowledge application mediates the impact of the availability of IT tools to support knowledge management on team performance.

In the context of healthcare, IT-enabled evidenced-based clinical decision-making can be understood as an IT-enabled knowledge management system whose goal is to codify available effective practices and make them available to healthcare professionals in an accurate and timely manner. However, previous studies on IT-enabled healthcare systems have seldom investigated IT-enabled knowledge application. This is understandable since most of the IT systems in the healthcare arena have primarily focused on the computerization of patient records and development of hospital/clinical billing, scheduling, and other transaction processing systems. This is because these IT systems represented quick-hit efficiency gains in a number of common healthcare processes.

Table 1: Basic EMR Functions as Defined by the Institute of Medicine

Core Functionalities	Key Elements
Health Information and Data	Medical and nursing diagnosis, medication lists, allergies, demographics, clinical narratives and test results
Results Management	Computerized laboratory test results and radiology procedures report, automatic display of current and previous test results
Order Entry Management	Patient laboratory, microbiology, pathology, radiology orders, electronic prescription of medication orders, nursing order
Decision Support	Screening for correct drug selection, closing and interactions with other medications, preventive health measures, clinical guidelines and pathways for treatment, management of chronic disease
Electronic Communication and Connectivity	Integrated health records, email and web messaging among health care providers and between health care providers and patients
Patient Support	Patient education and self-testing
Administrative Support	Patient scheduling, insurance verification, claim authorization, and billing
Reporting and Population Health Management	Provision of electronic data in the standard format for federal, state and local reporting requirements, organizational quality control reporting

Source: Robert Wood Johnson Foundation (2009)

Lately, the popularity and deployment of EMR (electronic medical records, also referred to as electronic health records, EHR) have been on the rise. EMR systems are integrated IT systems for healthcare information management and process support. The basic functionalities delivered through EMR systems, as identified by the Institute of Medicine, are listed and described in Table 1. We anticipate that the eventual ubiquitous availability of

EMR systems will create the necessary "backbone" that serves as the infrastructure for knowledge codification, storage, search, and delivery for clinical decision-making. Using EMR system underlying infrastructure, hospitals can implement evidenced-based clinical decision-making practices at the bedside. This in turn creates a need for conducting studies that provide the necessary insights and understanding for development and deployment of knowledge management systems for effective and efficient delivery of patient care. In particular, we need to better understanding if and how the application of codified evidence-based knowledge improves the outcome of patient care.

Below, we report on preliminary results of a field study on IT-enabled knowledge application in an emergency department (ED) of a hospital. More specifically, we investigate the IT-enabled knowledge application behaviors of ED physicians and the related diagnostic and patient care outcomes of hospital admission, emergency room charges, and time spent in the emergency department.

An Empirical Study: IT-Enabled Knowledge Application in an Emergency Department

Emergency departments of hospitals, particularly in large urban areas, are high-pressure environments in which fast-paced life-and death decisions are made on a frequent basis (Faraj and Xiao, 2006). The effectiveness and outcomes of these decisions depend on timely and accurate diagnosis and delivery of appropriate treatments. These decisions are in turn impacted by the timely availability of the requisite knowledge such as the knowledge of diagnostic tests and their outcomes, treatment protocols, and accurate presentation of the patient's condition and symptoms. As such, clinical decisions in emergency departments can benefit from the codification, accumulation, and delivery of knowledge to augment physicians' tacit knowledge and know-how.

We conducted a field study to investigate the effectiveness and impact of IT-supported knowledge application in an acute care university hospital's ED department located in the Southeast region of the United States. The ED serves the 573-bed university hospital and is staffed by 38 physicians, working between one to fifteen 8-hour shifts per month. The ED treats approximately 93 patients per day and in 2009, a total of about 34,000 patients were treated at this facility.

The IT infrastructure in the ED consisted of an EMR system, FirstNet, by Cerner Corporation in Kansas City, Missouri. FirstNet functionalities include most of the functionalities displayed in Table 1 including electronic records and notes, results management (e.g., lab and radiology reports), clinical provider order entry (e.g., test orders), and decision support (e.g., standing orders and clinical guidelines and protocols). The decision support module, which includes the computerized physician order entry (CPOE) component, provides physicians with recommended diagnostic tests and medication order sets ("standard care sets"), based on the patient's symptoms. As such, this module can enhance the accuracy of diagnosis and delivery of appropriate patient care.

The standard care sets are developed by expert physicians at the hospital based on the codification of the best available evidence-based knowledge and their past experiences, which used to remain as tacit knowledge. Physicians and nurses, however, can place their own orders or modify the recommendations by adding their own choices or removing some of the recommended choices. Given our interest in studying IT-supported knowledge application by ED physicians, we focused our investigation on the impact of the use of standard care sets in the CPOE module of the EMR system on patient care outcomes.

The Emergency Department in our field study routinely collects and maintains patient records in a data warehouse. The records of all adult patients (18 years and older) who visited the ED in a 321 day period between January 2009 and November 2009 were used in this study (the precise dates were masked to protect patient anonymity). For the purpose of this study, we analyzed the records of ED patients who complained of abdominal pain as their primary symptom. We chose to focus on abdominal pain complaints because they represent relatively ambiguous cases and can potentially benefit the most from the recommendations and use of the CPOE component of FirstNet. Considering patient privacy issues and the HIPPA regulations, we used a de-identified data sample. This was accomplished by creating new data sets from the warehouse patient records by excluding all identifying fields, assigning appropriate aliases, and copying the remaining data fields. The data fields used in our analyses are described in Table 2.

Table 2: Emergency Department (ED) Patient Stay Data Fields	
Field	Description
Admitted to Hospital	Outcome of ED stay resulted in admission to hospital for in-patient care
Duration of ED Stay	Length of stay in ED
Total Charges	Total of doctor charges and hospital charges for this ED stay (available only for a subset of patients)
Acuity	Level of acuity of patient condition as assessed at time of arrival
Age	Age of patient on date of admission
Gender	Gender of patient
First Diagnostic Order "In Care Set"	During this ED stay was the first diagnostic order placed via a standard care set?
Total Number of Diagnostic Orders	Total number of diagnostic orders placed during this ED stay
Number of Care Set Diagnostic Orders	Of the total number of diagnostic orders placed during this ED stay, the number placed from a standard care set
Care Set Diagnostic Ordering Rate	Number of diagnostic orders from care sets divided by ED stay duration
Average Diagnostic Order Placement as % of ED Duration	Considering all diagnostic orders placed during this ED stay, the average time of order placement as a percentage of stay duration

In order to control for the exogenous impact of the severity of the conditions that affect the outcome of the ED visit, we only focused on two most prevalent acuity levels (urgent and emergent), resulting in a sample of 2238 emergency department visits. A small number of immediate, stable, and non-urgent cases were dropped. Furthermore, since previous research (Bird and Rieker 2008, and Lasser et al. 2006) has found some health disparities (i.e., differences in healthcare access and outcomes) based on patient gender, we included gender as a variable in our study. Table 3 shows basic descriptive statistics and the correlations between variables. All correlations with an absolute value of 0.07 or greater are significant at the $p < 0.05$ levels.

Table 3: Correlations (n=2238)

		mean	s.d.	1	2	3	4	5	6	7	8	9
1	Admitted to Hospital (1=Yes)	0.40	0.49									
2	Duration of ED Stay (Day)	0.38	0.23	0.43								
3	Acuity (1=Higher)	0.34	0.47	0.29	0.07							
4	Age	44.6	18.2	0.23	0.09	0.16						
5	Gender (1=Female)	0.67	0.47	-0.13	0.02	-0.17	-0.09					
6	First Diag. Order "In Care Set" (1=Yes)	0.69	0.46	0.05	0.03	0.04	0.03	-0.01				
7	Total Number of Diagnostic Orders	11.0	4.6	0.45	0.29	0.20	0.20	-0.02	0.23			
8	Number of Care Set Diagnostic Orders	4.00	4.56	0.08	0.07	0.02	0.09	-0.04	0.59	0.20		
9	Care Set Diagnostic Ordering Rate	13.1	14.3	-0.12	-0.31	-0.02	0.01	-0.02	0.47	0.02	0.76	
10	Average Diagnostic Order Placement as % of ED Duration	0.22	0.14	0.08	-0.13	-0.04	-0.00	0.03	-0.15	0.19	-0.09	-0.06

Preliminary Results

We ran three separate analyses to answer our research question. In the first analysis, we examined if the use of recommendations from CPOE affect hospital admissions. In particular, we focused on the impact of the use of the system (represented by In-Set Diagnostic Ordering Rate) and specific clinical decision-making behaviors (represented by Total Number of Diagnostic Orders, Average Diagnostic Order, and First Diagnostic In-Set Order). Since hospital admission is a binary variable, we used the logistic regression. Table 4 presents the logistic regression results for the predictors of hospital admissions. Model 1 contains three significant control variables related to the inherent complexity of patient care: acuity, age, and gender. The parameter estimates for acuity and age have the expected signs and magnitude: higher acuity patients are far more likely (~ 3x as likely) to be admitted to the hospital than lower acuity patients; each additional year of patient age is associated with a very slight (~ 1.02x) increase in hospital admission. Model 1 has an AIC value of 2739 and a log-likelihood of -1365 (df=4). Model 2 is a full test with our explanatory variables. It has an AIC value of 2294 and a log-likelihood of -1138 (df=9). This is a statistically significant improvement over model 1 in model fit ($p<0.001$). Our results show that the use of IT-enabled knowledge applications in clinical decision-making is positively associated with the reduction of hospital admissions. Furthermore, if the first diagnostic order follows the recommendation from the system, the reduction of the admission rate is even larger.

Table 4: Logistic Regression for (In-Patient) Hospital Admission (n=2238)								
	Model 1: Controls				Model 2: Full Model			
	Est.	Exp (Est.)	Std. Error	Sig.	Est.	Exp (Est.)	Std. Err.	Sig.
(Intercept)	-1.58	0.21	0.18	***	-3.72	0.02	0.25	***
Acuity	1.10	3.02	0.10	***	0.91	2.49	0.11	***
Age	0.02	1.02	0.00	***	0.02	1.02	0.00	***
Gender	-0.37	0.69	0.10	***	-0.55	0.58	0.11	***
First Diagnostic Order "In Care Set"					-0.12	0.89	0.15	
Total Number of Diagnostic Orders					0.26	1.30	0.02	***
In-Set Diagnostic Ordering Rate					-0.08	0.92	0.02	***
Average Diagnostic Order Placement as % of ED Duration					0.23	1.26	0.41	
Interaction: First Order In-Set * □In-Set Diagnostic Ordering Rate					0.05	1.06	0.02	**

** $p < 0.01$; *** $p < 0.001$

In the second analysis, we explored if the use of recommendations from CPOE affected patient care cost. Since the total charge does not follow the normal distribution, we used a log transformation. The results of an OLS regression model of predictors of total charges (log transformed) are presented in Table 5. This model includes only the 788 emergency room encounters for which both physician charges and emergency department hospital charges are available. For those patients who were eventually admitted to the hospital, hospital charges were not available as the charges were rolled into other hospital charges incurred during the in-patient care. Because a portion of total charges are directly associated with the duration of an emergency department stay, duration is included as an additional control variable. As expected, our results show that the duration of stay and total number of orders are the main drivers of the total charges. Our results also show that if the physician starts with a diagnostic order following the recommendations of the CPOE module, it is associated with a significant reduction in total charges.

Table 5: OLS Regression for Total Charges (Log Transformed) (n=788)			
	Estimate	Std. Error	Sig.
(Intercept)	6.18	0.10	***
Acuity	0.04	0.05	
Age	0.00	0.00	**
Gender	-0.09	0.05	*
Duration	2.02	0.19	***
First Diagnostic Order "In Care Set"	-0.22	0.07	***
Total Number of Diagnostic Orders	0.12	0.01	***
In-Set Diagnostic Ordering Rate	0.00	0.00	
Average Diagnostic Order Placement as % of ED Duration	-0.87	0.17	***
Interaction: First Order In-Set * In-Set Diagnostic Ordering Rate	0.00	0.00	

*$p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; Adj. $R^2 = 0.47$

Given that duration is one of the key variables that affects the total cost, in the third analysis, we examined if the use of recommendations from a CPOE can contribute to the reduction of the duration. The results of an OLS regression model of predictors of duration of stay in the emergency department are presented in Table 6.

Table 6: OLS Regression for ED Duration (n=2238)

	Estimate	Std. Error	Sig.
(Intercept)	0.30	0.02	***
Acuity	-0.03	0.01	***
Age	0.00	0.00	
Gender	0.04	0.01	***
Admitted to Hospital	0.19	0.01	***
First Diagnostic Order "In Care Set"	-0.03	0.01	**
Total Number of Diagnostic Orders	0.01	0.00	***
Average Diagnostic Order Placement as % of ED Duration	-0.36	0.03	***

** $p < 0.01$; *** $p < 0.001$; Adj. $R^2 = 0.24$

Taken together, our analyses show several statistically significant relationships for emergency department encounters with patients who arrive with a chief complaint of abdominal pain. The variables of acuity, age, and total number of diagnostic orders all increase the likelihood of an encounter resulting in a hospital admission. Also, female patients are less likely to result in hospital admission. However, we found that when a physician places a higher rate of diagnostic orders via standard care sets, it significantly reduces the chance that the patient gets admitted to the hospital. Furthermore, this relationship is strengthened when the first diagnostic order is placed via a standard care set.

In the subset of patient encounters where hospital charge data are available, patient age, the duration of emergency department stay, and the total number of diagnostic orders are all associated with higher charges. Female patients and encounters where the diagnostic orders are placed earlier in the stay are all associated with lower charges. If the physician starts the diagnostic orders following the recommendations from the system, the model predicts a significant reduction of total cost.

In the full data set the measures associated with a longer duration of emergency department stay were gender (female), admission to hospital, and the total number of diagnostic orders. Encounters with higher acuity and encounters where the diagnostic orders were placed earlier in the stay had lower durations. Again, if the physician starts the diagnostic orders following the recommendations from the system, the model predicts a significant reduction in the duration of patient stay in the ED.

Future Plan

The preliminary results from our analyses show that the use of IT-enabled knowledge application tools indeed influence the healthcare professional's clinical decision-making behaviors, which in turn influence the outcome of patient care. We plan to conduct further analyses in two different areas. First, we will further explore factors that influence healthcare professionals' decisions to follow the recommendation from the system. Here, we will consider demographic variables of the healthcare professionals and the contextual variables that capture the uncertainty and time pressure at the time of patient care. Second, we will explore in more detail the temporal dynamics of healthcare professionals' clinical decision-making and its impact on patient care outcome. In particular, we plan to use the optimal matching technique (Abbott 1990, 1995) to map the sequence of decisions to uncover the underlying temporal patterns in clinical decision-making that might systematically influence the quality of patient care and the cost.

Conclusion

As electronic medical records are increasingly adopted, there will be an even greater opportunity to implement evidence-based care. An open question—and one that Information Systems researchers are well situated to help address—is when knowledge management systems may actually impact practice. It is merely not enough to identify best practices; it is a greater challenge to consistently enact them. Our study provides preliminary evidence in how the implementation of evidence-based diagnostic testing is associated with positive patient outcomes. In the lives of these patients, IT truly does matter.

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