Risk as a Moderator on the Impact of EMR Systems on Clinical Process Outcomes

Full paper

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Abstract

Electronic medical records have the potential to reduce medical errors and improve clinical outcomes in hospitals. To date, studies measuring the impact of EMR systems on performance outcomes have shown mixed results. A number of clinical studies have called for deeper exploration into the factors that may play a role in determining the success or failure of EMR systems. This study explores the effect of risk as a moderator of the relationship between EMR system use and performance outcomes. Results show that the impact of EMR systems on performance outcomes may be higher when the risk of the treatment being prescribed is higher. The study uses the Dorenfest database from HIMSS and quality measures report to CMS as part of the Hospital Compare Program.

Keywords

Electronic Medical Records, Performance Outcomes, Healthcare Information Systems

Introduction

Electronic Medical Records (EMR) have been proposed as a solution to a number of patient safety issues in hospitals. The Institutes of Medicine (IOM) published a report in 2000 estimating that as many as 98,000 patients may die each year as a result of medical errors (Kohn et al, 2000). A more recent report has estimated that as many as 400,000 patients die each year as a result of medical errors (James, 2013). In more than one report, the IOM has recommended increased use of a number of information technology solutions to help hospitals reduce the number of errors, including EMR systems. While a number of published studies have shown that EMR solutions do lead to reduced error rates (Chaudry et al, 2006; Garge et al, 2005; Ozcan et al, 2008), their adoption has been slow (Jha et al, 2009; Jha et al, 2010; Charles et al, 2014). This may be due to the lack of studies showing an impact of EMRs on measures that are of importance to hospital executives, including financial measures and quality measures reported to the Center for Medicare and Medicaid Services (CMS). As in many other industries, while it seems intuitive that the use of information technology in healthcare will lead to better quality outcomes, there are few clear ties between the implementation of EMR systems and an improvement of financial performance or quality measures.

One such measure of interest is the performance of hospitals with respect to indicators which they are required to report to CMS as part of the Hospital Inpatient Quality Reporting program. With this program, the CMS requires hospitals to report on quality measures based on the Donabedian dimensions of quality: structure, process, and outcome. Structure outcomes are specific to physical or procedural artifacts that a hospital has in place to provide care. These are not of interest in this study because they are not impacted by the presence of an EMR system. Outcome measures are indicators of what happened to patients once they are discharged from a facility. Typical outcome measures are infection rates, complication rates, or mortality rates. These measures are indirectly related to the impact of an EMR system. That is to say that a number of things may happen between when a patient leaves a facility and when one of these outcomes measures are observed, making it difficult to tie outcomes to EMR implementations. Process measures are those measures that relate to what a hospital does with patients.
while they are in the hospital. These measures usually involve the level of adherence to specific evidence based clinical guidelines, usually involving the percentage of patients with specific diagnoses that were prescribed or given treatment that would help improve the health of patients with those diagnoses. Process measures are those measures that are most directly affected by the use of EMR systems. The expectation of EMRs is that they would improve existing processes by, among other things, providing physicians and other clinicians with better information at the point of care. Therefore, it is these measures on which this study is focused for measuring the impact of EMR systems.

While process of care measures should be most closely tied to the use of EMR systems, there has been little support to show a relationship between EMR use and higher levels of adherence to these guidelines. This study provides evidence in support of the use of EMRs for increasing adherence to evidence based guidelines for high risk treatments. The study proposes that an effect is often not seen of the use of EMRs for adherence to evidence based guidelines for low risk procedures because those procedures do not require as much information in a timely manner as do high risk procedures. Such an effect has been observed for adherence to guidelines which involve higher risk treatments. Thus, support is provided for treatment risk as a moderator of the impact of EMR use on clinical process outcomes.

**Background**

Research relevant to this study can be divided into two different categories: clinical studies which have analyzed the impact of EMRs on various clinical outcomes, and information systems studies which have measured the impact of various forms of health information technology including EMRs on the performance of healthcare organizations.

**Clinical Studies**

Clinical studies have measured the impact of various types of health information technologies on multiple outcomes, including time spent by practitioners in treating patients, efficiency of the provision of care, adherence to evidence based guidelines, and reduction in medical errors. Studies have shown that use of bedside point of care systems as well as stationary Computerized Physician Order Entry (CPOE) systems have actually increased physician documentation time (Poissant et al, 2005; Wu and Strauss, 2006). Clinical decision support systems (CDSS) have been shown to reduce utilization of healthcare services by avoiding duplication and providing more appropriate care, as well as an increase in adherence to evidence based guidelines, and reductions in medical error rates (Chaudhry et al, 2006; Garg et al, 2005).

Overall, clinical studies have found support for a main effect of EMR systems on clinical outcomes but have not revealed very much about the nature of the impact. Many of the systematic reviews on impact of EMR systems have pointed out that there is additional need for studies which explore the reasons for inconsistent results and the factors that may impact the success or failure of an EMR.

**Health Information Technology and Organizational Performance**

Studies which have been published in information systems journals related to the impact of electronic health records on organizational performance have focused on factors which differentiate successful implementation of electronic health records from those which are not as successful. Studies have shown that the success of the implementation of an electronic laboratory information system was largely dependent on the strategy used for implementation. That is, hospitals which took an incremental approach towards implementation had more success than those which chose to implement the system completely within a short period of time (Huerta et al, 2013a; Huerta et al, 2013b). Studies have also demonstrated that an organizational as opposed to an operational approach can lead to higher increases in net income per patient per day (Spaulding et al, 2013).

A review of the relevant literature has shown that although there is support for the impact of EMR systems on various performance outcomes, the results of these studies are inconsistent and there is little research which explores the factors that may play a role in whether or not an information system is effective in improving organizational performance. There has been no research exploring the role that risk plays on the effectiveness of EMR systems. Thus, the exploration of the impact of EMR systems on clinical outcomes related to high versus low risk treatments is novel research.
Theoretical Framework

This study involves the exploration of risk as a moderator on the effectiveness of an electronic health record system. Information economics is used to provide theoretical support for the effect of risk on the effectiveness of EMR systems. Information economics poses that information holds value in that it helps people make decisions that have a higher expected reward or payoff than would be received in the absence of information (Stigler, 1961). In the EMR context, the theory would support that information regarding patient care, such as diagnostic reports on patients, would be valuable if the information is likely to lead to a more appropriate treatment, thus providing a better outcome for the patient and by connection, the physician. In the event that there is little uncertainty regarding an outcome, the value of information is not as high because it is not expected to change the outcome. However, when the outcome is uncertain, as in with treatments that have more risk associated with them, information is of more valuable and more likely to improve an outcome.

One of the main purposes of electronic health records is to deliver information to physicians at the point of care. This information aids the physician, and is delivered in a more timely manner than with traditional paper systems. Physicians, when faced with a decision of what treatment to prescribe patients, are faced with a certain amount of risk. The wrong decision could lead to a bad outcome for the patient, which could also have a negative effect on physicians should they be held liable for any lapse in judgment. From information economics theory, it is believed that information is likely to have more of an impact in events where uncertainty or risk of treatments is high rather than low. The impact that it will likely have is that physicians will make more appropriate judgments regarding the treatment of the patient than they would in the absence of information.

Research Question and Hypotheses

The goal of this study is to provide insight into why EMR systems have inconsistent results when measuring their impact on quality measures in hospitals. Each year, hospitals are required to report a number of quality measures to the Centers for Medicare and Medicaid Services (CMS). These are the measures against which hospitals are judged in determining payment levels as part of the CMS pay for performance plan. As performance on these measures is likely to impact hospitals financially, improving these measures would be of value to any hospital. There is little evidence to support positive impact of EMR systems on these measures. The purpose of this study, then, is to uncover factors that may be involved in the relationship between EMR use and quality measures. Although there may be many factors involved in this relationship, this study focuses on the risk level of treatments that are tied to quality measures. To what extent does the level of risk of treatments play a moderating role in the impact of EMR use on quality outcomes? That is the research question that is the focus of this study.

The quality measures used in this study involve adherence to clinical guidelines of prescribed treatment for specific conditions. The expectation is that all patients with certain conditions will need the treatments associated with the guidelines. However, some of these treatments have higher risks associated with them than others. According to economic theory on risk aversion and the economics of information, individuals are less likely to make decisions where the uncertainty of the outcome is high (Pratt, J.W. 1964). For treatments with higher levels of risk, the outcomes of the patients are more uncertain. Therefore, it is likely that providers will be less likely to prescribe treatments with higher levels of risk. There is an assumption in this study, supported by prior literature, that physicians tend to be risk averse in assigning treatments to patients (Turner and Laine, 2001). Physicians will be less likely to prescribe a given treatment if risk levels of that treatment are known to be high. Therefore, there is an expectation that there will be lower levels of adherence to guidelines which involve the prescription of higher risk treatments. This leads to the first hypothesis.

H1: Hospitals will have lower levels of adherence to clinical process guidelines that require the prescription of higher risk treatments.

Information plays a role in this decision process. The decision of prescribing treatment to a patient with a known level of risk is a complicated one, and requires information regarding the patient’s condition. Many risks associated with treatments are contingent on patient diagnostic results. In a paper based system, these diagnostic results may be incomplete and may not be delivered in as timely a fashion as in an
electronic system. According to the theory of information economics, information is of value if it improves the outcome of any given decision. The information used in an EMR system is intended to provide information that will aid providers in making decisions that are more clinically appropriate. Therefore, higher levels of use of EMR systems for retrieval of diagnostic results should lead to higher adherence to clinical guidelines. This leads to hypothesis 2.

H2: Increased use of EMR systems for retrieval of diagnostic results leads to greater adherence to clinical guidelines.

The first two hypotheses involve the main effects of risk and of the use of EMR systems on adherence to clinical process guidelines. The interesting finding in this study is the role that risk plays on the impact of EMR systems on adherence to clinical process guidelines. The theory of information economics says that information is more valuable if it increases the outcomes of decisions. Improvement of an outcome is more likely to occur if uncertainty regarding that outcome is high. Therefore, information will be of more use in improving outcomes in cases where the risk involving a given treatment is higher, rather than low. This leads to hypothesis 3.

H3: Risk will have a positive moderating effect on the impact of use of EMR systems on adherence to clinical guidelines.

Method

The data for this study come from two sources: the HIMSS Dorenfest Database and the CMS Hospital Compare data. The HIMSS Dorenfest Database contains information gathered in surveys administered to executives at hospitals in the United States in 2012 regarding many aspects of information technology use in hospitals including levels of use of various components of EMR systems by physicians, one of the measures used in this study. CMS Hospital Compare data contains information reported by hospitals on different measures of quality for 2013.

Quality Measures

The dependent variable in this study is a quality measure. As discussed in the introduction, this paper focuses on process of care measures.

There are 98 process of care measures that were reported to CMS in the time period relevant to this study. These measures can be divided up into five different categories: measures of the percentage of patients who received a recommended drug or treatment upon the discharge of a patient, measures of the percentage of patients who received a recommended drug or treatment within a certain period of time after being admitted to the hospital, measures of the percentage of patients who received a recommended drug or treatment during their stay in the hospital, measures of the percentage of patients who received specific information upon being discharged from the hospital, and measures of the amount of time it took for patients to receive a recommended drug or treatment after being admitted to the hospital. For the purposes of this study, the focus was on measure of the percentage of patients who received a drug or treatment within a certain time period after being admitted to the hospital. These measures were chosen because it is believed that these measures would be most likely to benefit from having information delivered at the point of care. One of the most important benefits of an electronic system is that it can deliver information much more quickly than traditional methods of information delivery, such as paper records which are often used in hospitals. Therefore, it follows that treatments which are expected to be delivered a short amount of time after a patient arrives at a hospital would be those which would most likely be impacted by the use of an EMR system.

Of the 98 measures available from the CMS Hospital Compare Dataset, only 51 measures were reported on by the hospitals in the HIMSS Dorenfest Dataset. Of these measures, only 8 were measures in which therapies had to be given within a specific amount of time of the patient’s arrival. These 8 measures are listed below in Table 1.

<table>
<thead>
<tr>
<th>Measure ID</th>
<th>Measure Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMI_7a</td>
<td>Fibrinolytic Therapy Received Within 30 Minutes Of Hospital</td>
</tr>
</tbody>
</table>
Table 1. CMS Process of Care Measures Used

The time dependence of most of these measures are apparent from the names of the measures, with the exception of STK_1 and VTE_1, both of which requires therapy to be administered the day of or day after hospital admission. For each of these measures, the numeric value used in the analysis is the percentage of patients discharged from the hospital for which the hospital complied with the guideline specified by the measure.

**Risk of Treatment**

Each of the measures above was assigned to a high or low risk group, coded as a binary variable. This coding was based on recorded complication rates of each treatment. Therapies which had complication rates for severe outcomes of 3% or less were coded as low risk. Those which had complication rates for severe outcomes of more than 3% were coded as high risk. The complication rates as well as the risk coding assigned to each measure are listed below in Table 2.

<table>
<thead>
<tr>
<th>Measure ID</th>
<th>Complication Rate</th>
<th>Risk Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMI_7a</td>
<td>5-10% (Almoosa, 2002)</td>
<td>High</td>
</tr>
<tr>
<td>AMI_8a</td>
<td>3% (Stathopoulos et al, 2009)</td>
<td>Low</td>
</tr>
<tr>
<td>SCIP_INF_1</td>
<td>&lt;1% (Bratzler et al, 2013)</td>
<td>Low</td>
</tr>
<tr>
<td>STK_1</td>
<td>3.9% (Leonardi et al, 2006)</td>
<td>High</td>
</tr>
<tr>
<td>VTE_1</td>
<td>3.9% (Leonardi et al, 2006)</td>
<td>High</td>
</tr>
<tr>
<td>OP_2</td>
<td>5-10% (Almoosa, 2002)</td>
<td>High</td>
</tr>
<tr>
<td>OP_4</td>
<td>&lt;1%</td>
<td>Low</td>
</tr>
</tbody>
</table>

Table 2. Measure Complication Rates and Risk Categories

**Physician Use**

The HIMSS Dorenfest dataset contains a data element that tracks the percentage of physicians who use specific components of EMR systems. The components assessed in the survey include: retrieving diagnostic results, entering orders, electronic signatures, clinical documentation charting, pre-registration, scheduling, bill payment, access to diagnostic tests, and personal health record. In this study, the component of interest was the use of EMR for retrieval of diagnostic results, as this seems to be the most relevant component when it comes to assessing whether or not a patient should be prescribed a specific treatment. Respondents to the survey were asked to indicate the percentage of physicians who use each specific component in their organization, based on available ranges of 1-25%, 26-50%, 51-75%, and 76-100%.
Covariates

In this study, size seemed to be an important covariate to include, as often hospitals of larger size have more resources and are thus better able to achieve higher scores on quality measures. Size as measured by the number of inpatient beds in the hospital is the only covariate included in this study.

Results

The hypotheses in this study were tested using a multiple regression and fitting the data to a Poisson distribution. Although a binomial distribution may seem more appropriate for this dependent variable as it does measure the proportion and not the count of successful occurrences for each measure, the data did not fit a binomial distribution but rather fit the Poisson distribution. A plot of the data can be seen in Figure 1. In this figure, the score represents the percentage of time that hospitals were not adhering to practice guidelines. The regression model used the quality measure score as the dependent variable, and the risk level of the treatment, percentage use, and size as independent variables. The results of the regression are shown below in Table 3.

![Figure 1. Distribution of Dependent Variable](image)

The regression model tested is as follows:

\[
Score = \beta_0 + \beta_1 \times LowUse + \beta_2 \times MedUse + \beta_3 \times HighUse + \beta_4 \times Risk + \beta_5 \times Size + \beta_6 \times LowUse \times Risk + \beta_7 \times MedUse \times Risk + \beta_8 \times HighUse \times Risk + \epsilon
\]

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept $\beta_0$</td>
<td>4.57</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>26-50% Use $\beta_1$</td>
<td>.00446</td>
<td>.68</td>
</tr>
</tbody>
</table>
Table 3. Regression Results

As the regression coefficients are difficult to interpret because they were transformed to account for Poisson distribution, the odds ratios are reported below in Table 4.

Table 4. Odds Ratios

The results do not support a main effect of the use of EMRs for retrieving diagnostic results on process control measures, thus failing to provide support for Hypothesis 2. All three levels of use were found to be non-significant compared to the reference group of 1-25% use.

The results do support a main effect of the risk category on the quality outcome score, providing support for Hypothesis 1. Risk level of the recommended treatment was found to be significant at α=.01. The odds ratio of .933 indicates that recommended procedures which fall into the high risk category are likely to have scores that are 6.7% lower than those which are low risk. The level of risk associated with a treatment, or the likelihood of complication associated with, will lower the quality measure score for that treatment. This means that physicians are less likely to adhere to a clinical guideline when the outcome associated with that guideline involves a higher complication rate.

The results also support an interaction effect between the risk level of treatments and the level of use of EMRs for retrieval of diagnostic results, providing support for Hypothesis 3. Although use of 26-50% is
non-significant compared to the reference group of 1-25% for high risk treatments, use of 51-75% and 75-100% were both shown to be significant at $\alpha=.05$ and $\alpha=.01$, respectively. This suggests that while increased use of an EMR for retrieval of diagnostic results may not always provide increased adherence to clinical guidelines, it does increase adherence when the level of risk of the treatment involved with the guideline is higher.

**Discussion**

This study contributes to information systems literature in two important ways: 1) this adds to the existing body of work exploring factors which may have an impact on the success of EMR systems 2) the study identifies risk as a factor in the interaction of decision makers with decision support systems.

In the question of whether or not EMR systems can demonstrate value to healthcare organizations, this study provides some insight as to when or what factors might influence the impact of an EMR on clinical practice guidelines. For practice guidelines that involve the routine prescription of low-risk treatments, EMR systems are likely to provide limited value. However, for guidelines which involve the prescription of treatments of higher risk, EMR systems may lead to stronger adherence to practice guidelines. This finding is of importance to providers, information systems vendors, and healthcare information systems researchers. Providers will benefit from this knowledge in that they will be able to better evaluate where EMR systems are likely to have the largest impact. If EMR systems are being rolled out in phases, and providers are wishing to prioritize implementation by the level of impact that the systems are likely to have, the level of risk of treatments supported by the EMR could play a role. Vendors will also be able to demonstrate the success of their products by accounting for risk as a factor in the impact on outcomes. Healthcare information systems researchers will have more insight in building models that account for all factors which may impact the success of an EMR system on performance outcomes.

It is within reason to expect that these results are generalizable to information systems outside of the healthcare domain. One purpose of an EMR system is to increase adherence to clinical guidelines (Wager et al, 2009). In this sense, EMR systems may serve the role of providing suggestive guidance (Silver, 1991). There are a number of other systems which may serve the role of providing suggestive guidance, whose effectiveness may be determined by the level of adherence to suggested decision paths. It is worth exploring whether risk may serve as a moderator of the effectiveness of such systems as well.

**Limitations**

The results of this study are subject to some limitations. First, the lack of a standard measure of risk required the author to develop a subjective measure of the level of risk. This provides support for development of a better standard regarding the measure of risk in a clinical procedure. Although this may be difficult as each treatment is different from others, a review of the literature on complication rates showed that there are commonly used terms as minor and major complications, and severe and mild reactions. As the measures are reported and tracked by the Hospital Inpatient Quality Reporting program and information is made available to the public regarding each measure, its associated guideline, and the treatments associated with those guidelines, it would be beneficial if the HIQR could provide a standard level of risk associated with each guideline based on some objective measure. This would be helpful to patients as well as researchers.

The Hospital Compare Outcomes data are lagged from the HIMSS Dorenfest data by as much as two quarters depending on the measure. Although this is not likely to affect the results, it is possible that the level of use of EMR components could have changed during this time. Since process of care measures are not very far downstream from the use of EMR systems, it is possible that this could have an impact on outcomes.

The estimate of the percentage of use of EMR systems is subjective and not taken directly from physicians but rather from executives who agree to participate in the survey. This could affect the accuracy of the level of use.
Future Research

The findings of this study are interesting and lead to further questions which are of interest to healthcare providers as well as information systems professionals working in healthcare. This study uses archival data to explore risk as a moderator of the effectiveness of EMR systems on adherence to guidelines. It was limited by the data available through the HIMSS Dorenfest dataset and the CMS Hospital Compare dataset. Follow up studies could drill down into more specific relationships. Such studies could involve directly surveying physicians to measure the effect of perceived risk on the use of other components of EMR systems, such as clinical decision support systems.

The generalization of this study to other domains could also be explored by gathering data on systems used outside of healthcare whose effectiveness can be measured by adherence to specific decision paths, with varying levels of risk for each type of decision.

REFERENCES


