System Design and its Effect on Selected Components of Meaningful Use for Electronic Health Record (EHR) Software

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ABSTRACT

This study aims to answer three research questions: 1) What role do information system design, implementation and use play in the creation and the maintenance of accurate active medication list (AML)? 2) What elements lead to an accurate AML? 3) What elements lead to an inaccurate AML? Since our study is exploratory and little literature was found on this topic, we took the case study approach. We investigated how the process of creating an AML was carried out by interviewing clinicians directly involved at three hospital sites. Even though the current findings were primitive due to limited data, several things could be noted. First, information system clearly plays a role in the accuracy of the AML. Second, the connectivity of various medical record systems and pharmacy databases needs improvement. Third, the information system should generate and present three distinctive listings: home medication list, inpatient medication list, and discharge medication list.

Keywords

case study, information system design, EHR software, meaningful use, active medication list

INTRODUCTION

An electronic health record (EHR) is a longitudinal record of a patient's health information (EHR Overview, 2012.) It may capture medical, surgical and procedural information, as well as family and social histories. Despite its potential to increase the effectiveness and efficiency in providing health care, healthcare IT adoption is sluggish. As of 2008 only 4% of physicians in ambulatory practice and 1.5% of hospitals reported using a fully functional EHR (Desroches et al., 2008; Jha et al., 2009).

To encourage the use of health information technology, Congress passed the HITECH Act, a component of the American Recovery and Reinvestment Act. To qualify for incentive payments from the Centers for Medicare and Medicaid Services (CMS), health care providers are required to meet stated meaningful use objectives at a specified measure of achievement. Providers who fail to achieve meaningful use requirements will receive decreased payments from CMS for clinical services beginning in 2015 and beyond. The earlier a health provider achieves the meaningful use objectives in their EHR system, the higher the incentive payment.

One criterion for meaningful use is "maintain active medication list." Active medication list (AML) is defined by the CMS as" A list of medications that a patient is currently taking," collected by a variety of clinicians when a patient is admitted to a hospital. Research shows an inaccurate AML could have serious consequences affecting the patient's clinical outcome, and substantial room for improvement in its accuracy exists. Even though several studies identified contributing factors to errors in the collection of the AML on admission, none of the sources we found focused on the elements inherent in the electronic health software. In this research, we explore the effect of information system design, implementation, and use on the creation and the maintenance of an AML. In particular, our study attempts to address the following research questions:

1. *What role do information system design, implementation and use play in the creation and the maintenance of accurate AML?*
2. *What elements lead to an accurate AML?*

3. *What elements lead to an inaccurate AML?*

We adopted the case study approach to address the research questions. Briefly, the case study method is a research strategy that focuses on understanding the dynamics within a single environment. We investigate how the process of creating an AML is carried out in a hospital environment. This process was discovered by interviewing clinicians directly involved in the process.

We believe the results of this study will contribute to the academic and the applied communities. First, we expect to identify elements that affect the accuracy of the AML. Those elements will become constructs in our research model that can be further tested to advance theories in the field. Second, our study will inform clinicians and software engineers regarding what features of the system could lead to a more accurate AML. The guidelines proposed by this study can be adopted by the practitioners to address some system issues in software development.

The remainder of the paper is organized as follows: a literature review; a summary of the theoretical foundations for a research model we are developing and our proposed model. Next we present the methodology used to carry out our research; followed by a presentation of and discussion about preliminary results of the research. Finally we discuss limitations and further research.

LITERATURE REVIEW

Meaningful Use

The 2009 HITECH Act continued the 2004 Executive Order to provide an EHR for every American by the year 2014. Under this provision, health care data will be captured in electronic format, increasing the accessibility and analysis of information, which will enhance the development of "evidence based practice." This should lead to improved patient safety and ultimately to improved health outcomes for individuals.

However, the HITECH Act will not allow for adoption of technology simply for the sake of technology, hence the need for meaningful use. Meaningful use specifies the elements of "proof" in terms of reporting requirements that hospitals and eligible health care providers must follow to demonstrate their EHR system provides quality health care. Simply stated, EHRs must be implemented in such a way that they will improve health care.

In addition, the meaningful use criteria are used to certify the EHR systems from various vendors. It is hoped that this process of certification and incentives for adopting certified EHRs will lead to a standardization of function and data representation across EHR systems provided by vendors.

Two sets of meaningful use criteria and their associated measures exist. One set is for eligible professionals (e.g. M.D.s) and the other is for eligible hospitals. Each set has multiple elements that make up the criteria for that set. We present one objective and its measure directed to both groups. This objective is the subject of our research.

Eligible Hospital and CAH Meaningful Use Objective 4 and its Measure (EHR Incentive Programs – Hospitals 2012):

Objective: Maintain active medication list.

Measure: More than 80 percent of all unique patients admitted to the eligible hospital's or Critical Access Hospital's (CAH) inpatient or emergency department (POS 21 or 23) have at least one entry (or an indication that the patient is not currently prescribed any medication) recorded as structured data.

Active Medication List

A review of the literature on the accuracy of the active medication list on admission to the hospital shows there is substantial room for improvement. Accuracy of the AML was identified differently by various researchers. Balon (2011) identified accuracy as having the correct name, strength, route and frequency of administration. Others defined a break in accuracy if any difference between the medication use history and the admission medication orders occurred (Cornish et al,, 2005; Murphy et al., 2009) or if any discrepancy resulted in a medication order change (Gleason et al., 2010).

In the various studies reviewed, the list of home medications may have been obtained by different clinicians including pharmacists, admitting resident physician, medical student, or admitting nurse. Clinicians may have used one or a combination of methods to obtain the list of home medications, including patient/family interview, reviewing the prescription medication brought in by the patient, contacting an outpatient pharmacy or the primary care physician.

Regardless of the method used to gather an AML, inaccuracies occur, often with the potential for serious consequences. One study found that nearly 56% of admitted patients had at least one unintended discrepancy between the AML and the medications ordered, 46% of those discrepancies being errors of omission. Furthermore, 48.6% of these discrepancies were

judged to have the potential to cause moderate and severe discomfort or clinical deterioration (Cornish, 2005). Gleason (2010) reported errors originated from medication histories in 85% of patients, almost half of those errors being ones of omission. The results of inaccuracy of the AML may have serious consequences affecting the patient's clinical outcome. One study (Gleason, 2010) identified the most common medication classes involved in errors to include cardiovascular agents, antidepressants, gastrointestinal agents, neurological agents and anti-diabetes medications.

While several studies identified factors that may contribute to errors in the collection of the AML on admission, none of the sources that we could find focused on the elements inherent in the electronic health software. Factors such as time constraints, interview skills of the clinician, the skill of the patient/family as an historian to relate medication, the cooperation of outpatient pharmacies and the medication themselves with look-alike, sound-alike names may be contributing factors that promote inaccuracies in the AML.

Proposed Health Care Technology (HIT) Solutions to the Accuracy of Active Medication List

A search of the directory of Certified Health IT Products list reveals that 392 EHR systems satisfy the meaningful criterion for an AML. However, the meaningful use criterion does not specify accuracy as a measure. We find few references address the accuracy of AML. In general, there are three broad categories of solutions: patient centered, e-prescribing, and IT based reconciliation of medication lists.

Patient Centered Solutions

Walsh and Cussen (2010) investigated what effect a ten minute medication review by a General Practitioner with a patient had on medication errors. They reported that inappropriate medications were detected in 54% of patients interviewed.

Schnipper et al. (2008) reported the results of designing and implementing a patient portal into an EHR system. A medication module was designed to improve the accuracy of AML within the EHR. Based on usage and satisfaction data, patients felt it led to more accurate information about their AML for their health care provider.

E-Prescribing Based Solutions

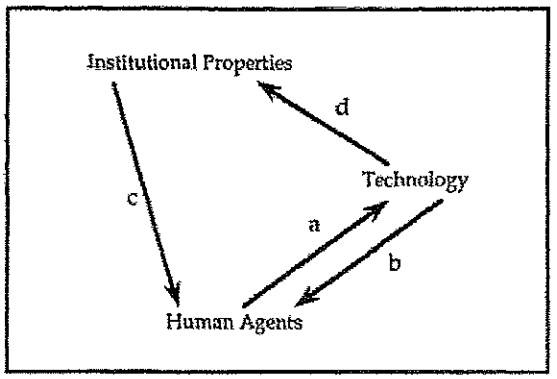
Electronically prescribing medications (E-prescribing) has the advantage of electronically recording any medications prescribed for a patient. It is believed this process would lead to accurate AMLs. However, a case study of eight physician practices (Crossen et al., 2012) and another case study of 24 physician practices (Grossman et al., 2011) found that in majority of the cases e-prescribing did not lead to an accurate AML. The patient's home medication was not available or was unable to be reconciled with the medication list resulting from e-prescribing.

Reconciliation of Mediation Lists Solutions

Beckman et al. (2010) propose clinical decision support system (CDSS) to reconcile the various mediation lists (active or home medication list, in-patient medication list, and discharge medication list) associated with a patient. Although this design has not been implemented, it does reveal the complexity of an HIT solution to the problem of medication reconciliation. It illustrates he solution to the accuracy of a patient's AML is complex and requires a deeper understanding of the causes of an inaccurate as well as an accurate AML.

THEORETICAL FOUNDATION AND RESEARCH MODEL IN DEVELOPMENT

Through the lens of Giddens' structuration theory, Orlikowski (1992) developed the structurational model of technology. See Figure 1 below. To provide support for the theory, Orlikowski employed the ethnographic techniques and conducted a case study in a software development company to examine software developers' interactions with CASE tools. Along with other findings, Orlikowski demonstrated the role of technology as both an enabler of, and a constraint on, human action. On one hand, tools allowed the consultants to design screens more quickly than before. On the other hand, the tools constrained the consultants in that they were limited to options available in the tools' repertoire with which some screen designs simply could not be done. This was illustrated with the b arrow in the diagram - technology as a medium of human action, which is described as "technology facilitates and constrains human action through the provision of interpretive schemes, facilities, and norms" (p 13).



- Technology as a product of human action (a)
- Technology as a medium of human action (b)
- Institutional conditions of interaction with technology (c)
- Institutional consequences of interaction with technology (d)

Figure 1 Structurational Model of Technology (Orlikowski, 1992)

Following this theory, the goal of the first study of this research is to identify information technology related enablers and constrains for the creation and the maintenance of accurate medication list.

Figure 2 below is our research model in development. We argue accurate active medication list will lead to accurate inpatient medication list. The accurate inpatient medication list leads to accurate discharge list. These in turn improves patient outcome. Discharge medication list can be viewed as an updated AML when the patient is re-admitted to the hospital. We are aware many other factors contribute to patient outcome (Joint Commission Standards, 2012; Hojat, 2011; McGee, 2010; Nembhard, 2007; Cosgrove, 2005; Engemann, 2005; Paoloni, 2004; Kollef, 1997). They are listed in the Other Factors box. The focus of this study is to identify factors that contribute to the accuracy of active medication list. We hope to develop a concrete research model at the end of this study and empirically test this model through survey and/or experiment.

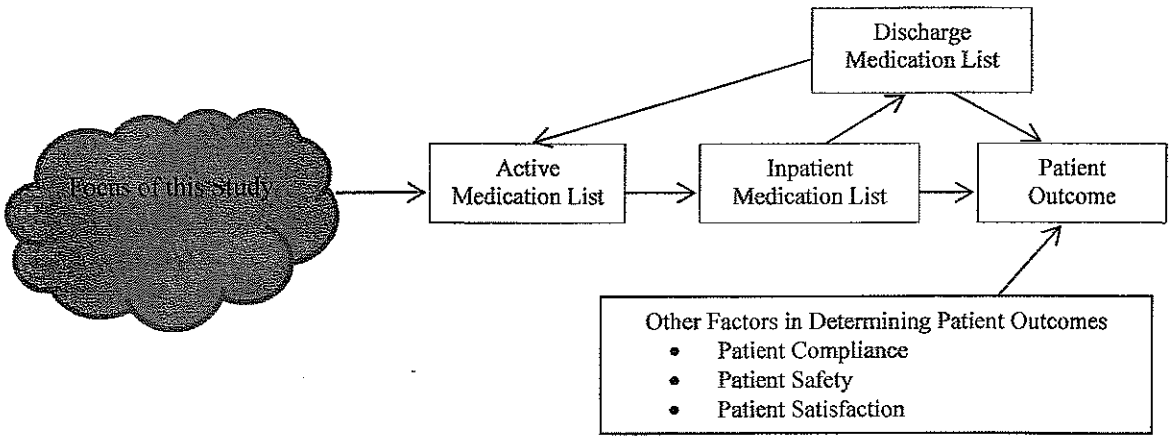


Figure 2 Research Model in Development

METHODOLOGY

We take the case study approach to answer the research questions. Case study is a research strategy that focuses on understanding the dynamics within single settings. It is one of the several ways of doing social science research. Other ways include surveys, experiments, computer simulations, and analysis of archival data. Case study is used extensively in social science research such as sociology, history, management science, and education (Yin, 2003). Even though in information systems research, case study is not as dominant as other empirical methods, such as experiments or surveys, its scientific

nature and rigor have been extensively discussed and widely accepted (Benbasat et al., 1987; Lee, 1989; Dubé and Paré, 2003).

Case study is a preferred strategy given three conditions (Yin, 2003). The three conditions consist of 1) the type of research questions posed, 2) the extent of control a researcher has over actual events, and 3) whether it focuses on contemporary or historical events. In general, the case study method is preferred when "how" and "why" questions, or exploratory "what" questions are posed, when the research has little control over events, and when the focus is on a contemporary phenomenon within real-life context. We believe this study meets these three criteria. Our "what" questions are exploratory, little prior literature was found. We study information systems within hospital settings, and since we are not part of the organization, we have no control over what happens there. The phenomenon we study is relatively new and is occurring in real-life context. Furthermore, the goal of our first study is to identify constructs and eventually theories for subsequent studies. Eisenhardt's seminal paper (1989) suggests building theory using the case study approach is fruitful with many strengths. Therefore, we conclude the case study methodology is an appropriate one for this study.

Following guidelines provided by Yin and other experts in case study research, we chose a multiple-case design as opposed to a single-case design. Multiple-case designs have been proven to be more robust and to have more substantial analytic benefits. We selected three hospitals and each hospital became one case study. The first site (Hospital A) was selected based on convenience from the personal relationships of one of the authors to the organization. Using these relationships, we made personal requests to employees to participate in this research. The other two sites (Hospital B and Hospital C) and subjects were identified and recruited through professional relationships with Hospital A participants through snowball sampling. We chose Hospital B and C from a fairly long list of potential hospitals, because they used different electronic medical record systems supplied by different vendors. Table 1 below describes the characteristics of the three hospitals selected for this study.

Hospital	Type	Licensed Bed size	Staffed Bed size	Admissions	Ownership	Medicare Designation	Classification	Stand Alone	HIT Vendor	HIT Implementation
A	Acute Care	173	140	6,258	Non Profit City	GEO	Rural	Yes	A	2004
B	Acute Care	586	357	19,070	Non Profit Private	HHA	Urban	Yes	B	2008
C	Acute Care	378	91	9,973	Non Profit Church	HHA	Urban	No	C	2009

Table 1 Hospital Characteristics

We compiled a list of questions and conducted a pilot interview with a pharmacist at Hospital A. We learned several lessons from the pilot. First, some questions required rephrasing, and others needed to be removed or added. Second, in order for the interviewee to share information more thoroughly, we should send out the questions to the interviewee at least one day before the meeting. Third, we noticed it was easy to get sidetracked so great effort was needed to bring the interviewee back to the information that was directly related to our research questions.

We revised the questionnaire, conducted another interview with a pharmacist at Hospital A. We recorded the interview, used Dragon Naturally Speaking to transcribe the recording into text. We randomly picked conversations at the beginning, in the middle, and at the end to ensure the transcription was correct. We also sat down together and listened to the recording to summarize the key points. We followed the same procedure for interviews with other employees at Hospital A.

Four tests have been commonly used to establish the quality of any empirical social research. They are: reliability, construct validity, internal validity, and external validity. Reliability means when the same operations are replicated within a study, one can produce the same results. Construct validity ensures the correct operational measures are used. Internal validity builds and proves causal relationships. External validity establishes an area where study's findings can be generalized. Following Yin's guidelines (2003), we have adopted several measures to improve the reliability and the validity of our study. We created a case study protocol and shared it among all the investigators. We developed a case study database to store and organize all case related materials such as notes, documents, and narratives. We acquired multiple sources of evidence through interviewing staff in different positions at different sites. We had the key informants review our case study reports.

In addition, for data analysis, we plan to adopt replication logic, pattern-matching, and explanation-building, as specified by Yin (2003). We hope to address rival explanations and use logic models as well.

RESULTS

The results presented here is limited to one interview. Due to limited amount of data, we cannot do much analysis. Therefore, we present the data in its raw format. We will finish more interviews and have more to share during the conference.

We asked eight questions during the interview. The following is a summary of the answers from a pharmacist called Dave (not his/her real name.)

Question 1 - Are you confident that the active medication list is accurate? Using a Likert scale of 1-5, how would you rate the accuracy of the active medication list if 1 = not very accurate and 5= very accurate?

Dave was very confident that the active medication list was accurate if a pharmacist collected the information. He rated 5 for the list compiled by a pharmacist, and 2 if a nurse collected the list. He mentioned the nurse would usually record the name of the medication, but not the frequency or dosage. He also stated different clinicians (e.g. nurse, pharmacist, and physician) may have different definitions of what an accurate medication list means. For example, a pharmacist thinks the list is accurate when it reflects what medications a patient is *actually* taking while a physician may view accuracy when it lists what a patient is *supposed* to take.

Question 2 - How do you measure the accuracy of the active medication list?

The accuracy is measured and assured through several means: conversation with the patient, medication bottles the patient brings to the hospital, and checking with retail pharmacies and physician offices. The pharmacists re-check 75 percent of the medication lists.

Question 3 - What are the elements that may lead to an active medication list being accurate?

Dave identified three elements that would lead to the AML being accurate. The first was patient involvement. He stated some information could be only provided by patients, for example, the use of over-the-counter medication. The second was to tap into the medication history by using computer systems of participating retail pharmacies. Through this route, the clinicians would get information about prescription and filling, even though that does not indicate whether patients were actively taking those medications. The third was checking with the physician's office. Based on Dave's experience, the information in the physician's offices isn't always updated. E-prescribing may help with this situation.

Question 4 - What are the elements that may lead to the active medication list being inaccurate?

Dave identified two major elements. One is associated with the patient, and the other is related to computer systems. He stated patient's memory was a contributor. A patient may not remember what he takes and why he is taking it, or a patient simply doesn't know the names of the medications he is taking.

There are several areas in the computer system that may cause the list being inaccurate. First, the system has retrospective medication data from the patient's last discharge. Upon a patient's re-admission, a clinician could sign off the list without confirming it. Secondly, the use of free text comments could lead to conflicting information. For example, a medicine could have one dose selected from the order sentence with a different dose information listed in the comment area. In addition, some physicians leave instructions in the free text field when prescribing medications. Converting that to a real order requires appropriate entry by someone else. Every time a person "touches" a medication order, the potential for error exists. Thirdly, the system allows the capturing of general information when specific information is needed. For example, a frequency of "weekly" is too vague. The specific day of the week is needed.

Question 5 - Does an accurate medication list lead to a reduction in medication prescribing errors? Medication dispensing errors? Medication administration errors?

An accurate medication list is going to help with prescribing errors. Once the prescription is correct in the system, dispensing or administration errors should be minimal.

Question 6 - Does an accurate active medication list lead to better patient outcomes?

An accurate medication list will lead to better patient outcome by avoiding potential dosing errors. It helps patients maintain their chronic disease state while being treated for acute symptoms. Dave suggested emergency room patients tend not to have an accurate medication list because the clinicians are busy treating multiple patients.

Question 7 - Before the Meaningful Use mandate for an electronic active medication list, how was the active medication list recorded? Which do you think lead to a more accurate active medication list, the paper or electronic version? Why?

Before the mandate, paper was used. Dave stated it was hard to say which one was worse, the paper or electronic version. It depends on who does the history. In the paper version, a delay may occur to sort out previous and current medications from the paper file. The error is usually an error of omission. The electronic version may have too many medications listed, including ones the patient is no longer taking. Currently, hospital A's procedure is to print out the medication list for a physician's signature. The medications are entered into the electronic medical record system by someone else. This process is error-prone. However, Dave was positive that the electronic system provided a starting point.

Question 8 - What aspects of the electronic system can be enhanced to create and maintain an accurate active medication list?

Several aspects were mentioned. First, the system should clearly differentiate three different medication lists: the home medication list, the inpatient medication list, and the discharge medication list. Currently these are combined and updates take place on top of each other. Secondly, a centralized server/database of all information being connected and shared would help. For example, a patient who resides in Texas may need medical treatment in Utah. If the healthcare professionals can see the medication list from any state, they will be able to treat the patient more efficiently and effectively. In addition, more retail pharmacies need to participate in the database. Finally, a way to accurately link and track over-the-counter drugs would be beneficial.

DISCUSSION

Even though the findings are primitive due to the limited data, several things could be noted. First, information system clearly plays a role in the accuracy of the AML. The interview pointed out several areas for system improvement. The connectivity of various medical record systems and pharmacy databases needs improvement. Currently, most medical record systems are stand-alone systems with little communication to each other. Also, the number of retail pharmacies participating in the database is limited. Pharmacy information is unavailable if a patient uses a pharmacy outside the database. E - prescribing will help with the accuracy of the medication list from physician offices. Furthermore, it is important that the system generates and presents three distinctive listings: home medication list, inpatient medication list, and discharge medication list to eliminate bundling and difficulty viewing the medication history. Finally, free text fields should be minimized. Linking over-the-counter medications to the pharmacy database is a plus.

Second, two major elements were identified as leading to a more accurate AML. One is information system related, the other is non-system related. Information system related areas are: more connectivity among the medical record systems and pharmacy databases, e-prescribing, creating and maintaining three distinctive medication listings, minimal free text fields, and linking over-the-counter medications to the pharmacy database. Non-system related areas are: more extensive patient involvement in list creation. According to Dave, who compiles the listing makes a difference as well.

Third, several elements lead to the medication list being inaccurate. As expected, those system related issues are opposite of what was discussed in the previous paragraph: lack of connectivity, lack of e-prescribing, different medication lists, too many free text comments. Non-system issues are patient memory, paper version of medication list signed off by the physicians and re-touch of the medication orders.

We are not in the position to derive constructs for our research model yet. As we gather more data, we will start to propose a more concrete research model for further empirical testing.

LIMITATIONS AND FUTURE RESEARCH

This study has several limitations. First, the data we presented reflect the input of clinicians at one hospital. Additional sets of interviews will be done with other hospitals and vendors for a more complete database. Second, we couldn't apply many of the analysis techniques suggested by Yin because of the limited data. Third, we hope to compare intended use versus actual use, but have not arranged an interview the software engineers at the vendor's site as yet. We hope to share more information during the conference.

There are several areas for future research. We will finish all the interviews at all the three sites and analyze the data by adopting replication logic and addressing rival explanations. We will propose a research model based on the interview data and empirically test the model through methods such as survey, or experiment. Finally, besides active medication list, we will investigate other criteria for meaningful use.

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