A Grounded Theory Investigation Into Data Interoperability In Healthcare

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Abstract

Clinicians and hospital administrators rely on healthcare information systems (HIS) for decision-making. Typically, HIS need to aggregate data from a network of geographically dispersed healthcare facilities and specialized departments of medical practice. However interoperability issues in the data arise from the diversity of infrastructure, specialized practices, underlying systems, procedures and personnel in healthcare facilities. Silos of medical practice create both systemic and semantic interoperability issues. Using grounded theory, this research draws on interviews with HIS stakeholders in a large single provider nationalized healthcare network in the USA to formulate a model that explores how knowledge management practices coupled with technology can establish data interoperability standards. Additionally, increased knowledge sharing across the traditional silos of healthcare practices enhances the interoperability of patient data by supporting standards as well as data collection and abstraction procedures and processes.

Keywords: Data interoperability, Healthcare, Knowledge Management, Community of Practice
1 INTRODUCTION

Increased use of Electronic Health Record (EHR) systems in patient care facilities has resulted in a large amount of clinical data being collected and available online. However, building integrated health information systems (HIS) continues to be a challenge because of interoperability issues (Hammond, Bailey, Boucher, Spohr and Whitaker, 2010). Interoperability issues currently create a bottleneck for seamless exchange and use of data. Interoperability is necessary to derive the maximum benefits of health IT. When interoperability is lacking, it impedes access to data, which in turn leads to inefficiencies, increased cost, and poor quality. Lack of interoperability is due to adoption of differing standards. Standards diversity is mainly due to vendor competition and resource based lock-in. However, beyond that, the issue is really agreeing to follow standards while exchanging data across healthcare units. The organization has to take a lead role analyzing the technology and available vendor options. HIS built with clinical data, tend to be fragmented, incomplete, inaccurate and isolated due to inconsistencies in what is recorded and how it is recorded. This has created silos of patient data that cannot be merged and used over a large healthcare network (Hammond et al., 2010). Severe data problems have been cited by many international health systems when health information systems attempt to interface clinical records from multiple medical facilities. For example, within the large UK healthcare network, the realization of a fully connected information led health service has been challenging (McGrath, Hendy, Klecun and Young, 2008). Furthermore, a study of 35 EHR systems found substantial variation in data documentation, retrieval, and content across clinical sites and data systems (Chan, Fowles and Weiner, 2010).

Data interoperability problems arise from the diverse availability of resources in medical facilities. Since not all facilities have state of the art medical technology, the patient data captured in each care setting varies widely. Current and prevailing administrative and financial management practices for healthcare services requires that networks of providers and clinics be established that patients can subscribe to and receive treatment from. Such healthcare care networks can be regional, national or local and can cater to a varying number of patients from hundreds of thousands to several million. The greater the number of providers and patient care facilities in these healthcare networks, the greater the lack of interoperability due to non-uniform data capture and differing standards adoption causing issues in exchanging and aggregating the data across the healthcare network. This research is based on a healthcare network of over 150 acute care hospitals over 350 outpatient clinics in the USA with over 14,000 staff physicians, which serves over ten million patients.

Additionally medicine continues to be practiced in functional silos of specialization with each specialty having its unique clinical data elements and very limited data exchange with other specialties. For example, systemic differences in missing data by practice are common; with some practices not recording data on medications or documentation of patient problems (Chan, Fowles and Wenier, 2010). This results in healthcare silos that exacerbate data interoperability issues. In a typical scenario when patients receive care in multiple facilities from several clinicians, differences in care protocols and workflows result in large variations in the data recorded in the patient’s EHR. Because of the differences in clinical personnel and their interpretation of patient variables and the lack of standardization of data recording practices, the values in the individual EHR systems at different facilities are not suitable for a network wide health information system without adopting data collection and aggregation processes. Integrating data from the individual patient EHR from different facilities is problematic for reasons that include (1) the technological differences in medical equipment calibrations; (2) the lack of standardization of information recording practices, (3) organizational differences in clinical personnel and their interpretation of patient variables, and (4) incompatible interfaces leading to poor integration among EHR systems in a distributed healthcare provider network.

Organizational HIS can be particularly critical in establishing evidence-based medicine programs and delivering high quality care in settings where patients’ lives are at risk. However, the lack of
interoperability in healthcare data limits healthcare organizations in building and deploying such network wide HIS. Pitfalls are not only from a technological standpoint, but also from an organizational standpoint. Technical solutions, such as database tools and data validation scripts, can be used to address specified needs, such as data organization, data cleaning and formatting. On the other hand, non-technical approaches are necessary to address the unspecified differences in the practice protocols inside medical specializations that threaten semantic data interoperability (Ure, Hartswood, Wardlaw, Procter, Anderson, Gonzales-Velez, Lin, Lloyd and Ho, 2009). An example of a non-technical approach is improving coordination and multi-disciplinary communication across the healthcare organization over different specializations and sites. Issues related to the meaning of the data elements create barriers to effective information sharing (Gupta, Martin, Avanavadi and Sarnikar, 2007). This is is much more difficult than technical issues and requires the alignment of semantics to enhance interoperability of medical data and protocols (Avison and Young, 2007).

1.1 Research Question

Although data practices and extraction methods exert strong effects on data quality, particularly data completeness Chan, Fowles, Wenier (2010), current IS research has not focused on the organizational practices that can improve the broader interoperability of clinical patient-care data inside Electronic Health Records (EHR). Our research begins to address this gap by modeling the impact of knowledge management practices and technology together on establishing data interoperability standards in a setting where clinical data is aggregated from multiple facilities and medical specializations. Given the paucity of research and models in this area, our research uses grounded theory to discover how data interoperability can be improved in a HIS that spans a large distributed and diverse healthcare network.

2 GROUNDING THEORY

This study uses qualitative research with interpretative methods based on semi-structured interviews. Interpretive research is appropriate in the early stages of research on a topic, because it is inductive and does not rely on previous literature or prior empirical evidence (Eisenhardt, 1989; Strauss and Corbin, 1990). The objective of grounded theory is to generate constructs and discover relationships among the constructs using qualitative data. Rather than start with a pre-conceived model and hypotheses to test, grounded theory uses an inductive approach. This approach is data driven and uses simultaneous data collection and analysis to discover patterns and concepts underlying the phenomena. In this approach data is analyzed by comparing incidents and connecting emerging concepts in concert with theoretical research. This recursive activity employs theoretical sampling whereby further data collection builds around the occurring findings while narrowing the scope of the study until theoretical saturation is reached. At this point no new data changes the emergent constructs. This methodology places emphasis on abstracting participants’ accounts of experiences and events and relating those to existing literature to explain the phenomena (Strauss and Corbin, 1990; Suddaby, 2006).

2.1 Case Selection

A large distributed national healthcare organization in the USA was selected for this case study. The healthcare system comprises over 150 acute care hospitals and 750 outpatient clinics. It has over 14,000 staff physicians and provides treatment for 24 million annual patient visits. The facilities in the distributed healthcare system, range from “standard” rural centers with limited scope of medical practice to highly “advanced” urban hospitals with state of the art medical technology for patient care. The organization recognized the opportunity, early on, to introduce evidence-based medicine by implementing an organization-wide information system based on clinical information from all its surgical programs. Recently, the healthcare network has been recognized as a leader in the use of HIS
such as patient record systems and decision support systems. Personnel at multiple levels rely on this HIS to create and deploy statistical models that facilitate decision-making. For example, surgical program chiefs and facility directors need models to track resource usage and outcomes of selected treatment and procedures and plan unit based resource allocation and standardized procedures, estimate patient loads and plan resources for medical departments (Epstein, 2006). Healthcare system policy makers need information from across a healthcare network to make strategic decisions on standardization of treatment protocols and procedures. Clinicians need historical outcome information to facilitate decisions on elective surgery and judge the suitability of treatment options and procedures for a presenting patient.

Ensuring data interoperability is critical for the HIS that supports decision making and management of surgery programs since such programs are particularly resource intensive and risky. Hence this case provides a rich environment to explore how a large-scale HIS can be built by addressing the data interoperability issues. The flow of patient data and aggregation of medical records into the network wide HIS is illustrated in Figure 1 below. The HIS collected input data by extracting aggregate clinical patient case data from EHR systems using a secure data feed (Figure 1). Because of variations in recording standards across the variety of healthcare facilities and medical specializations, the aggregated medical records exhibited data interoperability issues, such as (1) incomplete patient records, (2) lack of required data variables, and (3) inconsistent classification of pre-operative and post-operative variable codes. The inherent diversity and dynamic nature of the medical data collected from multiple sources meant that a fully automated solution to achieve data interoperability was not feasible. The automated procedure involved database servers that ran a battery of validation checks on the patient care data. Successful validation resulted in delivery of the patient case record to the data warehousing engine. Validation failures which were listed on reports as inconsistencies needed manual procedures to correct. Manual procedures involved additional medical judgment by a team of recording nurses. Recording nurses re-assessed patient variables and conditions during follow-up visits. They manually checked new data and resolved inconsistencies in the patient case data and resubmitted the case for validation.

![Figure 1. Patient data collection, aggregation and processing in the HIS](image)

### 2.2 Data Collection

The objective of this research is to generate theory, which explains how to enhance data interoperability for a large distributed network-wide healthcare information system. To accomplish this goal, we conducted 21 interviews with multiple stakeholders (Table 1). A pilot interview was
conducted with a system data manager, an administrator and a nurse recorder followed by 3 subsequent stages of interviews. In all, eleven nurse recorders, five physicians, two regional leaders, the national nurse executive and one system administrator along with the community leader were interviewed over several weeks. Concurrently, we searched and analyzed the relevant literature. Including more than one participant’s perspective and incorporating multiple theoretical perspectives at multiple levels of analysis into our discussion strengthens the generalizability of the findings.

<table>
<thead>
<tr>
<th>Interviewee’s role</th>
<th>Number of interviews</th>
<th>Number of hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical Nurse recorders</td>
<td>11</td>
<td>12.75</td>
</tr>
<tr>
<td>Regional Nurse leaders</td>
<td>2</td>
<td>2.25</td>
</tr>
<tr>
<td>National nurse executive</td>
<td>1</td>
<td>1.25</td>
</tr>
<tr>
<td>System Manager, Administrator</td>
<td>2</td>
<td>1.0</td>
</tr>
<tr>
<td>Physicians, Service Chiefs</td>
<td>5</td>
<td>1.67</td>
</tr>
</tbody>
</table>

Table 1. Interviewees’ roles and hours

Although the interviews were open-ended, questions on data aggregation challenges and the impacts of knowledge sharing on data collection guided the theory building.

Four categories of questions were asked during the interviews to stimulate the data collection:

- What are the challenges in clinical data capture and aggregation?
- What types of knowledge management practices address these challenges?
- What role does technology play to support these practices?
- What are the outcomes of these practices and use of technology on clinical data capture and aggregation?

2.3 Data Analysis

We coded the information using the Ask Sam, a freeform database software package. Each interview was transcribed to a separate document and the documents uploaded into the software tool. This tool has a sophisticated search engine and features that enable saving search terms and outputting search results for specific codes. Although the text needs manual interpretation, the software is useful for organizing the coding and for finding occurrences of the terms. Two researchers coded independently and any discrepancies were discussed and resolved. The inter-rater reliability was acceptable at 0.75.

Coding in grounded theory has three stages: open coding, axial coding and deriving explanations from the coding. In the open coding phase, the transcripts from the interviews were listed as quotes and analyzed line by line to identify concepts and their attributes. Four major concepts were identified: (1) technology-enabled knowledge acquisition, (2) knowledge management practices, (3) knowledge sharing and (4) knowledge coding practices. Each concept was decomposed into attributes by repeating the analysis at a more detailed lower hierarchical level. Since grounded theory methodology is highly data driven, in conjunction with coding, a literature search was used to define the identified concepts and relationships with rigor. The concepts and attributes in Table 2 occurred with high frequency in the interviews. For example, data collection and knowledge coding were discussed in 50% of the interviews. The “bible” (metadata) standards were explained in detail by three interviewees and ten interviewees discussed the community of practice. The reliability of the data is high given the extent of repetition by multiple interviewees.

<table>
<thead>
<tr>
<th>Concept</th>
<th>Attributes</th>
<th>Example Interview Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge Acquisition (Technology-enabled)</td>
<td>Data Collection Templates/Devices</td>
<td>“Some fields are extremely important – e.g. “Out of OR time” - if this value is not entered, then system treats it as if surgery never occurred.” – Nurse Recorder</td>
</tr>
<tr>
<td></td>
<td>Data Validation</td>
<td>“SQL Server database programming and exception reports are used”</td>
</tr>
<tr>
<td>Knowledge Management Practices</td>
<td>Metadata</td>
<td>“Nurse needs to go back to the Bible [aka. Metadata] and try and figure out the intent for each required clinical variable and why they are collecting this variable.” – Regional Nurse Leader</td>
</tr>
<tr>
<td>Prospective Review of Electronic (patient) Charts</td>
<td>“A lot of nursing judgment goes into determining the “functional status [of a patient]”. Functional status is an important variable for our morbidity models. We have to read into the charts to determine this variable – where does the patient live, wheel chair yes/no, etc.” – Nurse Recorder</td>
<td></td>
</tr>
<tr>
<td>Training and Certification</td>
<td>“We do inter-rater reliability tests among nurses. They pick a number of charts, assess them, then they see if they matched what I gave them. Need to do more chart reviews and audits so that we can understand each other and help each other improve.” – Regional Nurse Leader</td>
<td></td>
</tr>
<tr>
<td>Community of Practice</td>
<td>“Lots of sites are so small that the nurse may not need to assess a particular variable or face a complicated case in years. This is when community and conference calls help in sharing knowledge.” – System Administrator</td>
<td></td>
</tr>
<tr>
<td>Knowledge Sharing</td>
<td>Process Knowledge Sharing (“how to collect data”)</td>
<td>“Some hospitals have really good EHR systems and that help the nurses to collect information. Other centers do not have all the subsystems functional. Often the conference call between nurses can convey this information and then the nurse can go back and request that IT implement the particular feature at their location.” – Nurse Recorder</td>
</tr>
<tr>
<td>Patient Case Knowledge (“what data to collect”)</td>
<td>‘We are doing chart review prospectively, so any knowledge shared to help us interpret the patient charts in a uniform way can help. We usually come to a true assessment of variables like wound infection, by reading the full chart and the progress notes. If something like “organ space repair” is noted then it is a severe infection” – Nurse Recorder</td>
<td></td>
</tr>
<tr>
<td>Data Definition Knowledge</td>
<td>“Some 124-140 variables are collected on surgeries for the system. If we change the data definition for any variable, then we can’t compare that variable with earlier periods or between facilities.” – System Administrator</td>
<td></td>
</tr>
<tr>
<td>Knowledge Coding Practices for Interoperability</td>
<td>Standardized Naming and Format</td>
<td>“Everyone needs to know the names of the available variables – including the OR nurse, residents, attending surgeons. Judgment is built up among the nurses and helps better information reporting. How to say YES/No on peripheral vascular disease? There is not one variable that will give this information, rather several things (in [the system]) need to be consulted to say yes or no.” – Nurse Recorder.</td>
</tr>
<tr>
<td>Standard Definitions for Coding</td>
<td>“We have 140 nurses glued together doing the same thing using the same definitions – regardless of all the changes in their environments” – National Nurse Executive</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Concept Development from Coding

4 FINDINGS

The grounded theory approach culminated in a theoretical model that sheds light on a fresh perspective for improving the interoperability of clinical data in a distributed healthcare information system. The relationships between the concepts emerged from axial coding, a technique that links the constructs. Analysis continued until no further concepts emerged - the point at which theoretical
saturation was reached. The theoretical model relates the four concepts and is illustrated in Figure 2. Four propositions (P1 to P4) are shown on the model and explained in the next four sections 4.1 to 4.4.

4.1 Technology-enabled knowledge acquisition supports knowledge coding practices for Interoperability

There is a substantial technology infrastructure in the healthcare organization consisting of database servers, SharePoint portal servers and underlying networking and coding standards (e.g. ICD-9, CPT, HL-7) and protocols which support the data collection, aggregation, transmission and processing procedures in the HIS. The interviewed personnel mentioned the need for technology in supporting activities around data interoperability in the healthcare organization:

Information systems and tools help prevent data interoperability issues. The following quote is from a nurse who appreciates the technology.

“The system forms and tabs can be setup to help us collect and organize the data.”

Technology helps to support the organizational practices through validation checking during data entry, and data interoperability exception reports during the submission and aggregation of the data. The nurse in the following quote explains how tailored forms prevent conflicting data entry by physicians.

“We have had the IT department tailor some forms so that conflicting data is not entered by the physicians and this validation, cross checking built into the system, helps data interoperability and improves our system.”

The technology helps to drive data cleaning and aggregation procedures through periodic reports. After data validation scripts are executed on a batch of peri-operative data from surgeries in the network, the “exceptions report” lists issues found with the submitted case data.

“The Nurse recorders work on resolving their data exceptions for the cases that they have worked on. Sometimes the exceptions are allowed after the nurse does further investigations.” – System Administrator

![Figure 2. Knowledge Management Framework of Data Interoperability for Health Information Systems](image)

The System Manager also points out the use of other administrative databases to ensure the accuracy of longer term mortality counts (e.g. 180-days post surgery), which may not be recorded in the EHR.
“The aggregate counts, such as mortality rates from various surgical procedures are checked with the benefits database since any errors in mortality counts can skew the statistical models.”

The system also produces periodic data interoperability reports that list completeness, timeliness and interoperability of the surgical case data that is submitted for a given period. However, the users sometimes distrust the system and this may lead to additional work, as a Regional Lead describes below:

“Some nurses try to verify everything, when a lot of the fields are good and do not need to be re-verified. The recording nurses want to make sure that they do not show up on the data interoperability reports as incomplete for their assigned surgeries with missing fields or having values that conflict or are out of range data. They are very careful in their data transmittals.”

Consequently, the interviews support the first proposition as follows:

**Proposition P1: Technology-enabled knowledge acquisition supports knowledge coding practices for interoperability.**

### 4.2 Knowledge management practices support knowledge coding practices for interoperability

To ensure semantic interoperability of the data in the HIS, knowledge management practices were established. Four specific knowledge management practices were described in our interviews – (1) Metadata, (2) Prospective Review of Electronic Patient Charts, (3) Training and Certification and (4) establishing a Community of Practice (CoP) among the nurses. A CoP (Community of Practice) is loosely defined in the IS research literature as a group of individuals bound together by shared expertise with a passion for joint enterprise towards a shared goal (Wenger and Snyder, 2000). The established knowledge management practices help to enhance data interoperability. The nurses are trained and work inside a community that support each other and review each other work to allow them to collect and enter complete case data timely and with intrinsic value. As the national nurse executive mentions:

“Our nurses do their due diligence and uncover the pre operative and post operative variables that are needed in creating the statistical models. They work with others to ensure they understand what data to enter and do it quickly to keep to the schedule.”

The meaning of the clinical variables collected by the nurses is very important. Many of the perioperative outcome measures require clinical judgment and careful understanding and uniform interpretation of the patient’s symptoms. The nurses need to be on the “same page” as they prospectively review the patient’s charts as the following quotes suggest:

“Blood pressure meds are used for a lot of different reasons – one might be small vessel disease. So if blood pressure meds are in the system, and the doctor does not document why, it is difficult to judge the charts.” – Regional Nurse Leader

The knowledge management practices allowed interoperability standards through common formats and names for the variables, beyond their clinical names. As procedures are added, nurses need to be capable of collecting newer pieces of information. The regional nurse leader mentions:

“New procedures are being used by surgeons – e.g. spinal fusion anesthesia – we learn about these in our community and adopt the variable - how it will be collected and recorded.”

The metadata is always kept up to date and is particularly important in establishing interoperability standards. The metadata was published in an online format that allowed the nurses to refer to the “Bible” constantly as they collected, abstracted and recorded patient data. The metadata for each
variable specified examples of values with interpretations, the typical sources of the variable (such as a weekly staff meeting) as well as mechanisms for the validation of the data element.

"The Nurse needs to go back to the “Bible” and try and figure out the intent for each data variable - why they are collecting this variable. We have 140 nurses glued together doing the same thing using the same definitions – regardless of all the changes in their environments”.

National Nurse Executive

An interviewee discussed how the community ensured that conventions to establish common data formats and variable names were rolled out to all sites.

“The system has fields to help us exchange this knowledge. We do that in our region, but these conventions are rolled out nationally to help improve our system.”

Contextual data issues originate from information mismatched to systems, such as cases where the coding required does not match the stored format. The recording nurse collects, interprets and assembles information from multiple systems to transmit a patient case record for the HIS. Information comes from technology based solutions and interactions with clinicians. This extensive review of the patients’ charts often leads to discoveries that can impact the quality of care. The nurse recorders are called upon to do prospective review of the patient charts in order to determine what knowledge they need to share about the patient to clarify the patient variables before and after surgery. As a nurse recorded said:

“Surgeons are poor at charting. They do not care if the Blood glucose is recorded. They do not need it. We go over the patient chart to update values in variables that we submit. Many variables involve abstraction of data from the patient’s case –from M&M [morbidity and mortality] meetings and calling the surgeon or the OR nurses back several times”.

A nurse recorder talks about information conflicts and how they manually resolve these issues through prospective review of the patient charts:

“The physicians tend to copy and paste a lot of stuff from different screens to fill out the patient history screens. This causes information conflicts as a lot of old resolved symptoms come “back to life” in the system.”

Other issues originate from when the interpretability of the information is problematic. One of the nurses gives an example of how they use their training to interpret information:

“I quote my test results. If my score is .97 then I can tell the physician that I am doing it right and you are not in case of documentation “conflicts.”

A nurse explains how manual verification is needed to improve information interoperability related to drug conflicts, which is very important for an effective HIS and patient care:

“There are often conflicts with drugs in the system. Discontinued prescriptions are not marked as “discontinued”, so the same drug could exist with multiple dosages in the system causing conflicts. Which one is correct? Manual verification is needed. Hypertension and diabetic meds are problematic as they can conflict a lot.”

Consequently, the interviews support the second proposition as follows:

**Proposition P2:** Knowledge management practices support knowledge coding practices for interoperability.

**4.3 Knowledge management practices support knowledge sharing**

Knowledge sharing among the clinicians in the healthcare network was found to be a key concept in the understanding of enhancing data interoperability. In the business context, knowledge is defined as any information that is relevant, actionable and is based on a person’s experience (Davenport and
Prusak, 1998). While knowledge stems partly from organizational artifacts like processes, structures and technologies, the dynamic context to knowledge is provided by knowledge workers, their culture and the flow of interactions (Grover and Davenport, 2001). Since patient case knowledge cannot be easily decoupled from the clinical environment in which it is developed, therefore its sharing and understanding must account for the socially situated work practices of clinicians and knowledge workers (Brown and Duguid, 2001). Conferences, frequent training and certification tests enabled the nurses to build agreement in data definitions and meanings. National educational conferences were held annually. The nurse recorders do ongoing training on the descriptions of the information variables being collected and also periodically complete a training module and examination by electronic means. As a nurse recorder said:

“We are doing chart review prospectively, so any knowledge shared to help us interpret the patient charts in a uniform way can help.”

The nurses also attend periodic review session about all the policies, procedures, and information collection methods being advocated. According to one of the nurses:

“We have annual conference to meet and build relationships. We have multiple teleconferences where we discuss questions and concerns. If a nurse has a question, then they can pose that to the regional leaders. The Q&A is made widely available to all the nurses using the Web.”

Through the participation in the community, the nurses support each other by sharing knowledge to more effectively carry on data collection activities, which can span multiple facilities and systems.

“It takes a lot of extra time to get the charts and review information from a completely different system and coding/definitions. We use email and calls. Calls are used more since patient identifying information cannot be emailed.”

Accessibility to information from multiple facilities can be problematic. Different definitions result in a lack of interoperability standards. A nurse explains the effort to access information from facilities associated with universities:

“Some locations farm their surgeries to the university hospitals. It takes a lot of extra time to get the charts and review information from a completely different system and coding/definitions.”

As a Regional Lead mentioned:

“Lots of sites are so small that the nurse may not need to assess a particular variable or face a complicated case in years. This is when community and conference calls help in sharing knowledge.”

Based on the interviews, we found support for the third proposition as follows:

**Proposition P3: Knowledge management practices support knowledge sharing.**

4.4 Knowledge sharing supports knowledge coding practices for interoperability

The interviewees described three types of knowledge that supported their work to enhance data interoperability: (1) how to collect data, (2) what data to collect and (3) establishing data definitions. In order to collect the right set of patient data, the nurses need to understand how to use EHR system better, as a recording nurse said:

“I can adjust. But the (EHR) system I am working in can’t – so we have to accommodate to it by helping each other by sharing knowledge. The system can be setup to help us collect and organize the data. With some practical “thumb-rules”, I am able to avoid duplicating my
data collection activities. This saves me a lot of time in my daily activities.” - Nurse Recorder

A nurse recorder explained how the capture of patient knowledge in the process of building a complete information set. They share knowledge that helps them to better assess the patient chart and stick to the data definition standards that they have:

“Wound infection – sometimes the chief of staff wants to lower the severity of the infection in the documentation. We have to report the correct value otherwise the risk model will not be correct. We usually come to a true assessment of the wound infection, by consulting the full chart, the progress notes. If something like “organ space repair” is noted then the wound is a severe infection”.

Knowledge management practices, such as nurses in the CoP, manually verify and correct the data, sharing patient knowledge with each other in the community. Often organizational politics can place pressure on the nurse to compromise on the level of severity to record for a given complication – e.g. a wound infection. Quoting a nurse recorder:

“There is often political pressure at the facility level to lower complication count as the performance reports depend on it. The bible helps us show the physicians what the meaning of a complication is and how the severity is judged.”

The nurse needs to be unbiased about referencing the data standards to improve the interoperability of the data. A nurse recorder mentioned:

“Variables like “Cardiac Arrest” require further investigation. We stick to the definition that says for our system, to be considered as cardiac arrest, it must have a loss of consciousness.”

A nurse explains how knowledge sharing is needed, when new equipment is introduced into the healthcare network:

“Lab names change with new equipment and the data created in one facility is visible to other nurses outside that facility. The nurses share their training and knowledge.”

Knowledge sharing also supported efforts to reduce variability in charting that resulted from the constant turnover in residents. A nurse explained the problem:

“New residents come in every 2 weeks. Hence charting can vary a great deal. The resident needs to do a good job in charting and that is not the case always; language and conventions can vary. The attending signs off on the charting but usually does not spend too much time. Given the turnover in residents, the interoperability of charts and what is in the system varies a great deal.”

Consequently, the interviews support the fourth proposition as follows:

**Proposition P4: Knowledge sharing supports knowledge coding practices for interoperability.**

In summary, our grounded study discovered that knowledge coding practices for interoperability were affected by the technology-enabled knowledge acquisition, knowledge management practices and knowledge sharing.

5 **DISCUSSION**

Silos are typical in healthcare organizations. In this study, staff turnover, varying processes and diversity in their work systems resulted in data entry that was non-uniform and that could not be aggregated or compared. As a result, typical problems ranged from misunderstanding data definitions, errors in data entry, incomplete data sets, conflicts between multiple data sources, and inaccessibility of data from remote facilities. The study found that by increasing knowledge sharing among nurse recorders in the healthcare network the threats to data interoperability from the silos of medical practice were mitigated. A high standard of data interoperability was essential for the reliability of the
dashboards and reports from the HIS, which the healthcare policy makers and hospital administrators used routinely for decision making. Key findings in this case include:

- The need to focus on addressing data interoperability for large scale distributed health information system is essential and must be planned from the beginning of any HIS project.

- While the judicious use of technology, such as enforcing formats and completeness in data entry mitigate some data interoperability issues, complementary knowledge management practices are needed to bridge silos and achieve true “semantic” interoperability in the healthcare setting. Building a CoP for the nurses alleviated problems with the interoperability of information collected from multiple systems and medical documents. Through participation in the community, the nurses supported each other to more effectively collect, process and transmit data.

- The stakeholders in the HIS – the people who will be using the models generated from the data – need to be involved in each stage of the HIS data lifecycle. The importance of the knowledge management practices need to be enforced by surgery program chiefs (such as requiring residents to complete charting responsibilities), by hospital administrators (e.g. taking the politics out of variable definitions), and by the policy makers (such as providing adequate budget and resources to support data interoperability activities).

- In the healthcare environment, multiple sources of patient data (such as administrative and benefits data, insurance claims data, staff meeting minutes) are available and each must be judiciously leveraged for improving data interoperability so that the data can be used in the HIS.

- HIS reports and measures for the data interoperability attributes need to be tracked and compared period by period. Suitable robust and easy to understand data interoperability measures include items such as completeness, number of exceptions requiring rework, number of conflicts among multiple data sources and the timeliness of the data transmission for a case.

This study meets the criteria of applicability in grounded theory. It fits the substantive area of study, it is understandable to the practitioner and it provides potential items for the action and conditions to which it applies. Moreover, it has generalizability to other healthcare systems and other industries that collect information from multiple sources.

5.1 Implications for Research and Practice

Silos of information in organization wide systems are a problem in several industries. Bridging the silos is especially important for information systems that support distributed healthcare networks. This research contributes by addressing data interoperability concerns in such a diverse environment. This study deepens our understanding of enhancing data collection processes by a team of nurses supported by a set of organizational practices. Our study also advances the existing body of IS research on facilitating electronic healthcare delivery systems. Moreover, researchers can use the grounded theory generated model for further empirical research on improving the interoperability of patient information in a HIS.

There are two important implications from this study for practitioners. First, the study illustrated the importance of several knowledge management practices, such as a CoP and how it facilitated knowledge sharing among users and data collectors. It showed how a CoP can bridge the diversity inherent in a large organization. Second, the study highlighted a potential way to support critical knowledge sharing. Furthermore, adequate training and support helped ensure that the data was suitable for aggregation and comparison across a distributed organization. A nurse explained how better data interoperability provided the input for more reliable results from the HIS risk model used by the surgeons. “A better risk model results from the better data interoperability.”
5.2 Future Research

This study was conducted in a large national healthcare network of providers and care facilities that was under a single administrative infrastructure. While the network had a very large number of patients and was geographically dispersed with a wide variety of care facilities that ranged from acute-care hospitals to outpatient clinics, there were established channels of administration, coordination and management in place across the healthcare network. The study should be replicated in an inter-organizational (inter-network) environment, where clinical data needs to be shared and aggregated across multiple healthcare networks. The challenges are likely to be more severe in such a setting.

References