Building a Health Information Infrastructure to Support the Medication Reconciliation Process*

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Contents

ABSTRACT

The healthcare environment is becoming increasingly dependent on health information technology (HIT), with healthcare providers, patients, and other people engaged in the field producing and sharing information to improve healthcare delivery. This focus has raised the issue of Health Information Infrastructure (HII) to the forefront of policy, design, and law. While several studies have examined each element of HII, little attention has been paid to the overall infrastructure as a collection of technologies, institutions, standards, and practices. In order to fill the gap, this study focuses on medication reconciliation as an example of the wider phenomenon of HII. In particular, the study examines a medication reconciliation process (MRP) as an example to understand the key challenges facing the development of HII, how the challenges are interrelated, and how they can be met as a whole. Following a mixed methodology, involving workflow study, focus group discussions, and in-depth interviews, the study examines “data friction” along technical, institutional, regulatory, and legal dimensions. This study constitutes one of the first efforts to comprehensively investigate health information infrastructure and how technology and other dimensions in infrastructure are interrelated. The study therefore contributes to a better understanding of HII and the practical challenges that hinder the seamless flow of information in the healthcare environment.

Keywords: Health Information, Information Infrastructure, Medication Reconciliation System, Computerized System

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1. Introduction

Health Information Technology (HIT) helps healthcare providers efficiently acquire, handle, and disseminate health information, thereby allowing them to make better decisions for improved healthcare (Wyatt and Sullivan 2005). However, it is widely known that the current healthcare system is inefficient, and healthcare professionals often fail to make optimal decisions regarding patient service (Stead and Lin 2009). The seamless flow of health information has only partly improved by advances in science and technology, with HIT emerging as a central component in the integration, sharing, and management of health information among providers (Wright 2011).

A fundamental requirement for integrating health information is the design and implementation of health information infrastructure (HII). The interoperability of different computerized systems across healthcare networks is a key challenge in the development of HII. The U.S. Health Insurance Portability and Accountability Act (HIPAA) describes pathways for achieving interoperability - e.g., reliable collection, storage, and sharing of health information electronically; transcription of health information according to certain standards; legal considerations in the use and disclosure of health information; and better decision making through information analysis and integration (HHS.gov: Health Information Privacy 2013).

This study examined the implementation of the concept of infrastructure in medication reconciliation, one of the key areas of HII development, the National Patient Safety Goals laid out by the Joint Commission on Accreditation of Healthcare Organizations. The Joint Commission has announced as its third goal in 2007 “to improve the safety of using medications”, naming medication reconciliation as one of its sub-goals (The Joint Commission, 5). The medication reconciliation process, therefore, is an important part of the bigger phenomenon of HII. Medication reconciliation is an interdisciplinary process where professionals from various medical and non-medical fields are engaged, and the process uses health information from multiple sources (e.g., primary care physician, specialists, hospitals, medical records, and pharmacies) to reduce adverse drug events (ADEs) and eliminate unnecessary hospital visits (Fernandes 2012; Kohn, Corrigan and Donaldson 2000). Similar to the Joint Commission’s announcement, the Ministry of Health and Welfare in South Korea also puts effort to reduce the risk of medication errors, and legislated Act 58 included medication reconciliation as one of the certification standards for medical institutions (Korea. Ministry of Health and Welfare 2014). However, the certification standard does not clearly define how medical institutions should proceed medication reconciliation process during medical treatments. Due to the lack of a standard medication reconciliation model, researchers are working

on various ways to find an optimal way to perform the process. The efforts include developing a medication reconciliation program to support the pharmacist's role in confirming the medication history, examining whether multidisciplinary care team or clinical pharmacists has effect on medication reconciliation, and suggesting an expansion on the Drug Utilization Review (DUR) policy for efficient medication reconciliation (Cho et al. 2018; Kim 2015; Jeong 2018; Park et al. 2019). However, each study does not consider the healthcare environment as a whole and only focus on each piece, such as technology, institutional, or legal regulation, of HII. To fill this gap, this study aimed to examine medication reconciliation as an example to understand the challenges that underlie the implementation of HII, how the challenges feed into each other, and how they can be met as a whole.

2. Literature Review

2.1 Health Information Infrastructure

The nature of the healthcare setting is decentralized and health information is created from multiple sources, including hospitals, pharmacies, laboratories (Tsiknakis, Katehakis and Orphanoudakis 2002). None of these sources has the complete information about the patient, and each healthcare provider only pays attention to the information relevant to their needs. Hospitals and providers work in their own silos, and this hinders them from assembling the most updated information. Various healthcare providers within the state county, including hospitals, pharmacies, and health insurance companies, form a health community network to collaborate and share patient information, and it is not easy to collect and disperse the information across community networks. Using disorganized health information, healthcare professionals need to determine what is the most reliable and authorized information, and how they can apply that to their decision making (Corrigan 2005; Detmer 2003; Kohn, Corrigan and Donaldson 2000; Vest and Gamm 2010).

When patient information is incomplete, healthcare providers need to fill in the missing parts in order to build a complete picture for patient care. Decision making based on partial health information is a main source of "clinical errors, misinterpretation, and other life-threatening missteps" (Tsiknakis, Katehakis and Orphanoudakis 2002; Yasnoff 2014, 424). Despite these consequences, efforts to collect health information have faced serious challenges, and healthcare providers need to understand many interlocking factors to meet these challenges. As a minimum, this necessitates

a vast infrastructure to support the flow of health information across systems, to be shared among various key actors, and demands consistency across various settings.

Healthcare providers cope with the challenge of managing fragmented health information by applying technology to healthcare settings. In this regard, the concept of an HII has gained attention as a means to organize small pieces of health information into a whole. The infrastructure connects the key actors, giving them tools to gather and distribute health information promptly and reliably. The key actors - people participating in "clinical, organizational, and managerial activities" - share information and leverage resources across healthcare networks through HII (Tsiknakis, Katehakis and Orphanoudakis 2002, 8-9). The goal of HII is to provide a source for the key actors to access all relevant health information to the greatest possible extent in order to make decisions leading to an improved healthcare environment, reduced hospital visits, and fewer fatalities (Detmer 2003).

To understand the concept of health information infrastructure, we need to invert it to examine it from the bottom, so to speak. In general, infrastructure refers to "the underlying foundation or basic framework as of a system or organization" (Merriam-Webster). Infrastructures are, by character, invisible, making it hard for people to recognize their ubiquitous presence in their daily lives. In particular, people are likely not to pay attention to the more hidden layers of infrastructure (Clarke and Fujimura 1992). Accordingly, Conrads (1946) stressed the importance of turning the infrastructure upside down to emphasize the connectedness of elements in the infrastructure. One can attain a better understanding of infrastructure by identifying its key elements, and their breakdowns and interactions (Conrads 1946). What differentiates a knowledge infrastructure from other technology is that it focuses on forming a framework within which information can flow, while technology is used as a means to streamline information in the infrastructure. Infrastructure provides the foundation over which other elements can operate, thus we need to consider the dimensions that underlies in infrastructure (Larkin 2013).

The seamless flow of health information requires a number of interlocking elements, including technical systems, standards, organizational norms, and legal regulations. According to Lorenzi (2003), HII systems fail due to technological and organizational issues. Institutionally, roles, goals, and resources have to be coordinated effectively. Technologically, rules and standards have to be in place to enable interoperability. This suggests a holistic approach that incorporates all the relevant aspects and dimensions. Previous studies (Balas and Al Sanousi 2009; Ghitza, Sparenborg and Tai 2011) have identified four critical dimensions for interoperability of an HII: technology, standardization, institutions, and legal frameworks.

2.2 Health Information Technology (HIT)

HIT broadly covers the sets of health information technologies used to "collect, manage, and share medical information" (Wright 2011, 344). The U.S. Health Information Technology for Economic and Clinical Health Act encourages healthcare providers to use the electronic health record (EHR) by authorizing incentive payments to healthcare professionals and providers when they use EHRs in a meaningful way (Blumenthal and Tavenner 2010). The ultimate goal of "meaningful use" is not to simply adopt EHRs, but rather to use the EHR and surrounding technologies to gain significant results in the healthcare service, including "better clinical outcomes; improved population health outcomes; increased transparency and efficiency; empowered individuals; and more robust research data on health systems" (Health IT. Gov 2015).

While HIT has proven to be a major contributor to high-quality healthcare service, healthcare is generally a tough environment for technologies to operate in. Healthcare organizations still prefer paper formats and patients are not fully aware of appropriate electronic decision support systems. Limited use of HIT increases medical error, prevents the sharing of patient data across organizations, and deprives patients of medical information they should be aware of (Hillestad et al. 2005). The developmental level of technology in the current healthcare industry is similar to the technical stage that aviation went through in the 1950s, and multiple human and technical issues remain as frictional factors that slow down the development of HIT.

The development of HIT is slow and error-prone due to several reasons. First, healthcare delivery has a real-time and urgent character, leaving healthcare providers with little time to process massive amounts of useful health information. As a result, potentially useful information can be left unnoticed or unused. Second, even well-constructed HIT systems require experts' input to be compatible for meaningful use (Coiera, Aarts and Kulikowski 2012). Most incoming patient data still require interpretation by medical professionals. Lastly, noise in patient data can affect the overall quality of information, and a comprehensive review process is necessary for quality control. This places the burden of data quality control on the shoulders of providers who are already overloaded with their care delivery responsibilities.

2.3 Medication Reconciliation

This study examined a MRP within a community network to understand the technical, standard, organizational, and legal barriers for the successful implementation of an HII. Incomplete health

records are the source of many diagnostic and treatment-related issues. In this study, we focused on one group of issues, having to do with patients' medication history. Using inaccurate medication history as a reference when making medical decisions can lead to inadvertent changes in drug prescriptions. When key actors fail to apply all changes in medication, new medication lists may omit medication that needs to be included and (or) duplicate medications that have already been prescribed. Discrepancies due to omission and duplication cause ADEs, the most frequent drug-related problems during discharge and half of preventable ADEs that happen within 30 days of discharge (Schnipper et al. 2002). To overcome the discrepancies, the Joint Commission proposed that healthcare providers should pursue medication reconciliation as a way to improve patient well-being.

Medication reconciliation is a process of reviewing the patient's medication to determine the discrepancies of the medication lists (Cadwallader et al. 2013). The goal of medication reconciliation is to improve patient safety by preventing hospital and Emergency Department visits due to ADEs. The study applied the definition suggested by the U.S. Centers for Medicare & Medicaid Services:

> ▪ "Medication reconciliation is the process of identifying the most accurate list of all medications that the patient is taking, including name, dosage, frequency, and route, by comparing the medical record to an external list of medications obtained from a patient, hospital, or other providers." (Centers for Medicare & Medicaid Services 2010)

Medication reconciliation poses some challenges that hinder a seamless medication review process. First, medication information exists in multiple types. Formats of medications considered for comprehensive review include "all prescribed medicines, herbals, vitamins, nutritional supplements, over-the-counter drugs, vaccines, diagnostic and contrast agents, radioactive medications, parenteral nutrition, blood derivatives, and intravenous solutions" (The Joint Commission 2017). Healthcare providers obtain this information from multiple sources, including primary care, specialists, admitting hospitals, and local pharmacies (Poon et al. 2006). The person who has the prescription authority is in charge of the MRP and needs to collect all medication records from these sources. In addition, it is not easy to keep track of what all existing medication records are, and the pharmacists often omit medication histories without noticing it (Macaulay et al. 1996; Hobson and Sewell 2002). Second, a patient's medication treatment has a quick turnaround. The MRP depends on patient condition: newly hospitalized, discharged, or in ambulatory care. The hospital collects and verifies the patient's medication history and documents it when patients are newly accepted. The medical professionals also write medication regimens and create medication administration

records. For patients who are discharged from the hospital, post-discharge medication regimens and discharge instructions for home medication are provided, and the medication list is transmitted to the follow-up physician. The process for patients in ambulatory setting includes assembling the list of current medications, which is updated whenever any medication is added or has been changed (Bayley et al. 2005). Lastly, systems in MRP are unorganized. Physicians, pharmacists, nurses, clinicians, and other key actors engaged in the workflow each have their preferred systems and it is not easy to sync information derived from different systems (Poon et al. 2006).

Poon et al. (2006) pointed out that the confusion patients face about their medication is due to the changes in medication regimens, irregular care and hospitalization, and inadequate medication counseling. These issues can lead to medication discrepancies, errors, and ADEs. Challenges in medication reconciliation include variations and redundancies due to the dynamics of the medical environment. First, there are typically three key actors involved in the process, pharmacists, primary care physicians, and specialists, and they have little agreement on their functions and responsibilities in medication reconciliation (Al-Hashar et al. 2017). Second, there are numerous medication records that the key actors need to gather to complete patient's medication history. Third, each key actor takes the patient's medication history and documents it in their own systems, and the information is not shared across institutions. Lastly, patient conditions influence the MRP. It is difficult to compile a complete medication history from patients in the Emergency Department (ED) (Bayley et al. 2005).

3. Research Method

This study utilizes multiple methods to explore the MRP as a component of HII, and explores the following research questions:

- RQ1: What are the different types of data friction in the medication reconciliation process?;
- RQ2: What are the key dimensions of data friction in medication reconciliation process?;
- RQ3: How has computerization of medication reconciliation affected different dimensions of each type of data friction?

RQ1 explores the situation where data frictions occur in the medication reconciliation process, including frictions arising from technology, standards, institutions, and legal frameworks. Each

of these types of frictions manifest themselves on various “dimensions”, which constitute the topic of investigation in RQ2. RQ3 is designed to figure out the impact of technology in medication reconciliation process so that medication reconciliation could turn into a robust and exemplary part of HII.

3.1 Conceptual Framework

The concept of “data friction” is used as a conceptual framework to explain the obstacles and challenges facing the flow of information in the healthcare environment. This section will briefly introduce the definition of data friction, and explain the types of data friction in HII. Friction is used as a metaphor to explain the constraints that hinder the seamless flow of health information. In physics, friction is understood as the resistance between physical systems, which occurs at “the interfaces between objects or surfaces” (Edwards 2010, 83). Friction requires additional energy to transmute an object from one system to another, and data friction refers to the resistance that occurs on the layout of the physical surfaces. The concept of data friction, suggested by Edwards (2010) is:

> ▪ “the costs in time, energy, and attention required simply to collect, check, store, move, receive, and access data. Whenever data travel, whether from one place on Earth to another, from one machine (computer) to another, or from one medium to another, data friction impedes their movement. Every point at which data are moved or transformed represents an opportunity for data loss or corruption” (Edwards 2010, 84-85).

Data is created by various actors, and is “a material existing in a medium” (Edwards 2010). Data friction occurs at any point from creation to collecting, storing, transmitting, and receiving data. In the healthcare environment, the data include a long string of connected objects, including patient records, clinical notes, lab results, and other structured and unstructured data (Tsiknakis, Katehakis and Orphanoudakis 2002). Getting data from a single organization is easy, but collecting data from multiple places and transferring data across organizations requires additional energy. Converting data from one format to another, for instance, requires the use of time and resources. Every link that joins the chain forms an interface, such as between humans, systems, and organizations, which may cause data friction. The level of friction depends on the reliability and quality of data, as well as the number of access points between humans, systems, or organizations. Highly reliable systems that follow standard formats, therefore, create less friction, while unreliable interfaces

generate vast amounts of data friction. Practices that determine the quality of the data source, how the data is formed, policies about who should hold the data, and who has control and access to it determine the degree of data friction in any given situation. Common examples of data friction include “data recovery, correction, or corruption between humans, system, and organizations, and conflicts or disagreements among humans” (Edwards 2010, 84-85, 106, 108).

The transformation of analog to digital data can also be explained in terms of data friction. Unlike digital data, papers need to physically move from one place to another, which requires human and (or) technological activities. The slow and expensive procedure of transferring information from paper to paper causes frictions, and using methods other than papers are generally believed to reduce these frictions. For many decades now, people have been using digital methods to transform information, and different types of data friction have arisen due to the complexity of digital-based techniques. Examples of data friction in digital-based techniques include data loss, corruption, and (or) misinterpretation on the transmitter and receiver ends. Each digital system uses different codes, and encoding and decoding techniques have to be devised whenever information is transposed across systems. Errors could occur due to misinterpretation and noise during the decoding process. The information also needs to be modified based on who the receiver is, and what system and language the receiver applies. When the sender and receiver are human, there could be errors, conflicts, and arguments. All of the elements that hinder the seamless flow of information cause frictions and slow down the process (Edwards 2010).

Previous studies have applied the concept of data friction to explain the role of data governing institution in reforming the secondary use of health data, to describe research data and online communication data movements, to figure out the social-materials factors affecting the development of an infrastructure for archived historical weather records, and to examine how weather forecasting and climatology developed over the course of the previous century (Aula 2019; Bates 2018; Bates et al. 2019; Edwards 2010). Data friction provided a meaningful framework to articulate the chain of operations in climatology, how data moves across systems and humans, and what happens at the point data is transferred from one human, system, or organization to another. The framework, in particular, made possible a long-term study through the examination of data friction before and after the introduction of computers in meteorology.

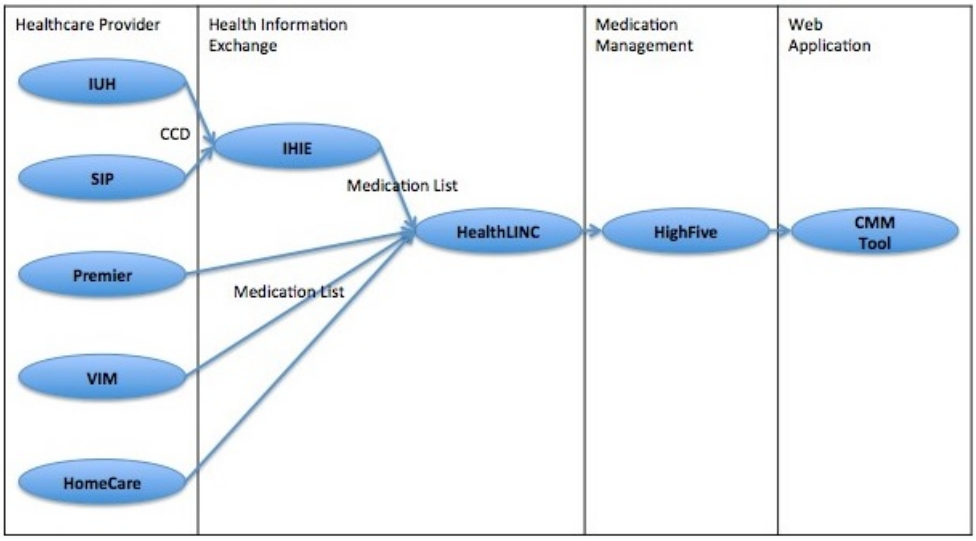
Borrowing the notion of “data friction,” this study similarly identified the various types of friction that might be generated at the interfaces of HII along technological, institutional, legal, and standard dimensions. Different types of data friction arise in infrastructure, each having to do with one of the criteria for a successful interoperability of the HII. The first type of data

friction happens when technology is more focused on the speed of distributed data, and less on its quality and reliability. As a result, a vast amount of data is left behind and the key actors only take the data they can utilize during quick turnarounds. The second type of data friction happens due to human engagement. The data requires interpretations from humans in order to become useful information. The third type of data friction arises because of the noise that occurs when data moves from one human, system, or institution to another. The noise (meaningless data or information) generates errors and slows down the workflow. The last type of data friction is due to the lack of documentation, training, or education that would help institutions smoothly adopt new systems. Technology often focuses on advanced functions, glossing over the importance of the adoption in practice (Edwards 2010).

In its application of this framework to the healthcare environment, the study made adjustments and minor innovations in order to identify the specific types of data friction that emerge in the technical, organizational, standardization, and legal areas. The strong presence of a human element in healthcare, with all its complexity and variability, introduces new aspects that need to be considered in thinking about data and data friction. In particular, it is difficult to come up with a fixed medication reconciliation occurrence rate calculation formula due to the variances in demographic, geographic, and socio-economic specificities of different populations. To highlight these issues, the study examined not only different types but also different dimensions of data friction.

3.2 Data Collection

A Health Information Exchange (HIE) and a community physician group (Southern Indiana Physician [SIP]) participating in a medication reconciliation project called Community Medication Management (CMM) are the research site for this study. Organizations participating in the CMM project include healthcare providers at the Indiana University Hospital, SIP, Premier Healthcare, Volunteers in Medicine (VIM), and HomeCare; Indiana Health Information Exchange and HealthLINC (HL); and the medication management company HighFive. Following the overall pattern of information flow within an HII, the overall flow of data within this system can be described as a linear process of data aggregation, assembly, and analysis. Figure 1 shows this process in a stepwise fashion.



〈Figure 1〉 Information Flow of the Project Setting

To collect data and attain a close understanding of the process, the author participated in bi-weekly CMM project meetings between November 2015 and December 2016, and weekly CMM project developer meetings from November 2015 to July 2016. Based on the meeting observations, three types of data were collected to determine the data frictions in medication reconciliation. The first type of data was gathered from the computerized medication reconciliation system. The author went through a demonstration process with the pharmacist, who is the actual user of the system. This introduced the overall features of the comprehensive risk score and computerized medication reconciliation system in general.

The second set of data was collected through focus group discussions. Focus-group interviews were conducted to determine how the pharmaceutical environment has changed by adopting a computerized medication reconciliation system. Three focus groups discussions were conducted from July 2016 to August 2016. Participants were recruited by nomination from the CMM meeting. The interviews were developed based on the steps in the design and use of the focus group (Stewart, Shamdasani and Rook 1990). The author and the Health Informatics Manager at the HIE conducted a pre-meeting before each focus group to formulate the questions and topics. The author then identified the themes for each focus group, and formed possible research questions. The questions were reviewed and revised by the Health Informatics Manager, and the author prepared follow-up questions or alternative questions to extend the topic as far as possible. Participants read and signed the informed consent approved by the Indiana University. Each focus group

meeting was audio recorded and transcribed. The transcripts were written in natural sentences as uttered by the participants, and the grammar or formality of the sentence was not checked and revised to fully reflect the participants' opinions.

The third data set was collected through in-depth interviews. Three semi-structured interviews with pharmacists and HealthLINC staff went over the MRP using actual patient data, system interfaces were evaluated, and other general aspects relevant to the project were discussed.

3.3 Data Analysis

The workflow was analyzed based on the workflow process mapping template provided by the Office of the National Coordinator for Health Information Technology (HealthIT.gov 2018). The workflow process map helps to clarify workflow, identify bottlenecks, and outline dependencies. For this study, the key actor of the workflow is ‘the user using the computerized medication reconciliation system to proceed the MRP,’ and the workflow models the computerized MRP. The process is mapped at a micro level, including a detailed analysis of the work functions, and the steps are detailed enough for a person to follow and complete the task.

Qualitative data, including meeting notes, focus group discussion and in-depth interview scripts, were analyzed by the five phases introduced in *Qualitative research from start to finish* (Yin 2011): compiling, disassembling, reassembling, and interpreting the data, and concluding. The first phase of qualitative data analysis was to collect all data that had been separately stored and compiled in a certain order (Yin 2011). The meeting notes and scripts were collected and titled by meetings and dates and were listed in chronological order. This data is drawn from ten bi-weekly project meeting notes, eight HIE meeting notes, three tech meeting notes, three focus group discussions, and three in-depth interviews. The second phase was to fragment the compiled data by assigning codes (Yin 2011). For systematic interpretation, Inductive Category Formation was chosen as the interpretation technique (Bradley, Curry and Devers 2007). The third phase was to reassemble the data. The data was fed into a software application (Atlas.ti), and initial and second-round codes were generated by the software. The author conducted an initial interpretation by examining the raw data against the codes. During the interpretation process, excerpts from data that did not match any category were excluded. The parts excluded in the interpretation process consist of system iterations, project administration, interface issues, and other issues that have emerged in the current phase of the research site but that have little or no relevance to the present study. To avoid subjective interpretation, the results were sent to

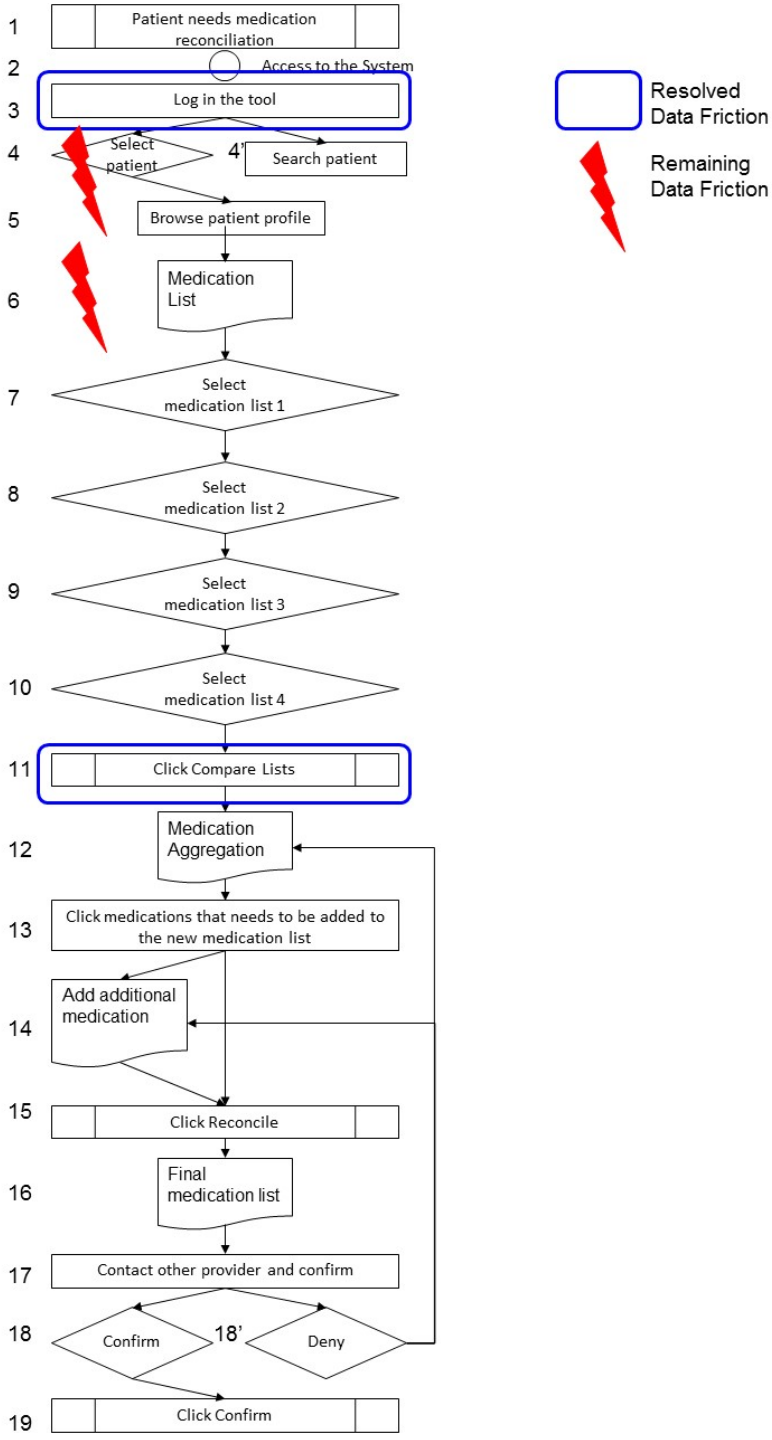
the “member checker for confirmation” (Creswell and Miller 2000). The fourth phase was to interpret the data. This study used “Description” as the major method for interpreting the qualitative data (Yin 2011). The description was used to summarize the routine workflow in MRP. The data, in particular, covered the “nature of institutions” involved in the community level MRP (Yin 2011, 209). The last stage in the process was to draw conclusions from the findings and interpreted data. This consisted of developing the findings into a “higher conceptual level” in order to tease out the conceptual contribution of the study (Yin 2011, 220).

Data collection was completed when the data reached a point of where new data all fit into the existing scheme and no new codes are needed. The notes from HIE staff meeting held on September 27, 2016 and October 13, 2016 showed no new topics where the data had reached the point of data saturation (Fusch and Ness 2015). The author closed the data collection at this point and reviewed the coded data. Based on this initial coding, the author examined the gaps in data and requested in-depth interviews to supplement the data.

4. Findings

This section presents the findings from the data analysis. The first part of the findings focuses on medication reconciliation workflow visualized in Figure 2 and how a computerized medication reconciliation system is incorporated in the workflow. The second section examines data friction on each dimension in HII.

The medication reconciliation process begins when a pharmacist starts working on a specific patient to review his or her medication lists. In order to begin the review process, the pharmacist needs to browse the medication lists. The medication lists are stored in a database and the pharmacist accesses a computerized medication reconciliation system which incorporated the medication list database. The database is composed of health information, including medication history record from primary care providers. When a pharmacist logs in to the system, a list of patients by composite risk score level is shown on the left side of the dashboard. The composite risk score is the overall score, which demonstrates the possibility of a patient being at risk due to medication. A 30-day and 12-month readmission risk score is the possibility that a patient is likely to be re-admitted to the hospital within 30-day or 12-month. In order to select a patient, the pharmacist can either browse through the patient list and select a patient from the list or search for a specific patient in the Search bar. The pharmacist could list the patients by the possibilities of medication reconciliation occurrence.



〈Figure 2〉 Medication Reconciliation Workflow and Data Frictions

When the pharmacist selects a certain patient, a patient home screen opens. The home screen shows a summary of the risk scores of the patient. The risk scores consist of the comprehensive risk score, hospitalization risk score, and drug therapy problem score. The comprehensive risk score represents an overall risk level of a patient; the hospitalization risk score shows the level of possibility that for a patient to be readmitted; and the drug therapy problem score demonstrates the level of possibility that a patient is likely to have some drug therapy issues. There are three tabs per patient. The profile tab shows an overall risk score information, 'Comprehensive Medication Review' tab connects to medication reconciliation, and 'DTPs' tab shows the drug therapy problem of the patient. The pharmacist clicks 'Comprehensive Medication Review' to select and reconcile medication lists. The pharmacist could select and compare up to four medication lists at a time, and the pharmacist views all the relevant medical information at a glance. The pharmacist browses the lists and checks if all the lists are correctly opened, and then clicks 'Compare Lists' to reconcile.

The medication reconciliation results are classified into four categories: 'Identical Medications,' 'Similar Medications/Similar by Drug Subclass,' 'Unique Medications,' and 'Undetermined.' The categories are listed in the order of their priority, and the medications that are highly likely to reconcile show up in the top and those that are less likely in the bottom. Medications listed under 'Identical Medications', 'Similar Medications/Similar by Drug Subclass' are groups that need close attention. 'Identical Medications' are same medications with same strength and same form. 'Similar Medications' are same medications with different strength and different form, or different strength in same form. The system increases accuracy by dividing similar medications into 'Similar Medications' and 'Similar Medications by Drug Subclass'. The medications listed under these categories are medications used for the same medical purposes and are hence interchangeable. The criterion to decide whether a medication should be defined as 'Similar Medications' or 'Similar Medications by Drug Subclass' is the active ingredients. Medications grouped in 'Similar Medications' have same active ingredients and 'Similar Medications by Drug Subclass' have different active ingredients. Different active ingredients affect patients in various ways, and the system categorizes 'Similar Medications by Drug Subclass' to highlight similar medications with different active ingredients so that the pharmacist can pay attention to these medications. To emphasize 'Similar Medications by Drug Subclass', medications listed under this category are labeled with a red A icon at the top right-hand corner of each medication. This is to alert pharmacists so that they are aware that there is one or more similar medications having different active ingredients. Medications listed under 'Identical Medications', 'Similar Medications/Similar Medications by Drug Subclass' are considered for reconciliation, meaning

that identical or similar medications have been prescribed more than once causing duplications in medication.

After the pharmacist reviews the initial result, he or she moves to an initial decision making process by selecting medications that will stay in the list and the ones that will be deleted. The second decision making step involves the addition of new medication(s) to the list. A drug database tab opens when the pharmacist clicks '+Drug' icon, and he or she can search the database or manually enter the medication. Adding a new medication step ends when a pharmacist finishes and clicks 'Reconcile'. The pharmacist then contacts other healthcare providers to confirm that this would be the new medication list. The providers agree or disagree with the result, and the medication list is finalized if other providers show their approval. The whole process comes to an end when the pharmacist clicks 'Confirm,' and medication reconciliation is done. The updated list is automatically saved in the system and shows up when system users log in and pull up the medication list.

Based on this workflow, the following subsection focuses on data friction on the four dimensions of the process - technology, standards, institutions, and legal frameworks.

4.1 Data Friction and Technology

The first key change driven by computerization is the creation of a central repository of medication information. The algorithmic analysis of the medical records used in medication reconciliation integrates and crosschecks information from different sources in order to establish their accuracy. Before the computerized medication reconciliation system was implemented in the research site, pharmacists relied on paper-based medication lists for medication reconciliation. The pharmacists obtained medication lists by using a landline phone and fax, and received medication records from healthcare providers through fax documents. The computerized system, on the other hand, provides a mechanism to carry out medication reconciliation by utilizing various data sources directly involved in patient care. The objective of the computational medication reconciliation system is to have all the medication lists on one platform where software can support the process through integration and automation. The goal is to be able to pull relevant medication information from one central source instead of having it all fragmented at each location. The computerized system utilizes various data sources from healthcare providers directly involved in patient care. Such providers include physicians, health practitioners, pharmacists, dentists, retail pharmacists, and so on.

4.2 Data Friction and Standards

The second key impact of computerization is the application of a fixed medication reconciliation occurrence rate calculation formula. In addition to the above technical functions, the computerized medication reconciliation system provides patient profiles to help pharmacists decide which patients should be given priority for the MRP. To that end, the system calculates a patient's risk score based on a built-in formula. The risk score formula utilizes the pharmacy fill data and the risk level indicates where the patient's current risk lies relative to the general population in the community. The composite risk score is a single number that represents the relative opportunity to reduce a patient's risk of poor outcomes related to suboptimal medication use. The score is made up of weighted contributions from hospital admission information. This score is presented as a value ranging from 1 to 100 representing the risk relative to the peer population, and is set to a default configuration based on the opportunity for pharmacy intervention. The composite risk score formula includes the probability of five different events:

- A hospital admission within the next 30 days;
- A hospital admission within the next 12 months;
- Having a medication list discrepancy drug therapy problem;
- Having an adherence drug therapy problem;
- Having a therapeutic consideration drug therapy problem

While the composite risk score is the total risk level of the different events, the formula also calculates the individual probability of each event. The 30-day and 12-month readmission risk scores state the likelihood of a patient being readmitted to the hospital within the next 30 days and the next 12 months, respectively.

The objective of the risk score in the computerized medication reconciliation system is to stratify patients so that the pharmacists know who to target first. Patients having a high-risk score are highlighted to alert the pharmacists that they need to focus on those patients more than others. A color coding scheme is used to label patients based on their level of risk. Patients with high risk are color coded by red, moderate patients in orange, and low risk in yellow.

4.3 Data Friction and Institutions

The third key change driven by computerization is the improvements in communication among stakeholders, and an expansion of the boundary of relevant stakeholders in the process. Improvements in communication among stakeholders after the implementation of the computerized system are apparent in the exchange and sharing of information with other providers in the network. Pharmacists, to begin with, no longer call or fax other providers to request medication lists. The lists are already stored in the system, allowing pharmacists to pull them up, and send tasking messages if they want to look for medical information that is not stored in the system. Second, the burden on patients has been reduced. Pharmacists used to fax recommendation letters to other providers and had to give the patient a hard copy to carry to the visit with the provider as a means of verification. Using the computerized system, the pharmacist can send the letter by using tasking messages, which has a 100% response rate, providing feedback as to whether the recipient has read the message. Lastly, pharmacists do not need to share the medication lists to relevant providers after they have completed the process. The system automatically updates the list when the pharmacist confirms and saves the reconciled list. In sum, the frequency of interactions with providers in the network has decreased, and using tasking messages saves time and reduces the burden on the patient.

On the other hand, the introduction of the computerized medication reconciliation system expands the boundary of relevant stakeholders in the process. While previous interactions were either inside or across healthcare networks, pharmacists now have to communicate with stakeholders working in non-healthcare settings. The stakeholders in non-healthcare settings include the HIE staff, as well as technicians and designers at the Medication Management Company. Pharmacists, as the primary users of the system, find themselves participating in meetings with these new stakeholders in order to provide ideas, feedback, and suggestions on design iterations. The interests and priorities of these stakeholders, however, do not always align with those of the pharmacists, who tend to focus more on actual records representing patient symptoms, risk level, and others, as compared to the focus of the new stakeholders on cost reduction due to unexpected hospitalization driven by medication discrepancies.

4.4 Data Friction and Legal Frameworks

The last key impact of computerization is the breakdowns due to the legal regulations. Medication

reconciliation needs to follow the legal regulations legislated by state and federal governments. These include privacy protection laws and regulations that govern the sharing of medication information. According to 42 CFR Part 2, healthcare providers need to obtain a written consent whenever they share information about psychiatric and substance abuse medications. Information on medication lists passes through multiple organizations, and regulations such as the above create breakdowns whenever a patient record is sent from one organization to another.

Regulations dealing with the confidentiality of sharing medication lists containing alcohol and drug abuse records have added an extra requirement for a written consent from the patient every time the medication list is shared. As medication lists moved to an electronic format, the actors involved in the process have become numerous. Healthcare providers who have the records send the medication lists to the HIEs, who then in turn send the lists to technology vendors to be stored in a repository. Any healthcare providers who have a mutual agreement to participate in this collaboration can access the repository and view the medication lists. In sum, a medication list passes through multiple organizations and numerous healthcare providers have the right to use the medication list. This means that numerous written consents are required to include medication lists containing alcohol and drug abuse in the computerized MRP - a major issue that has been the subject of a publication by the Department of Health and Human Services as recently as January 18th, 2017 (Federal Register 2017).

5. Discussion

The findings of this study showed that the adoption of computer technology into MRP has brought about partial improvements, by reducing some of the workload and errors of the paper-based workflow, while failing to alleviate some problems associated with data friction. These findings have some important implications for the implementation of HII in general. First, as in the case of other healthcare settings, medication reconciliation also applied technology to cope with the challenges of managing the complexity of health information. The introduction of a computerized system to medication reconciliation was driven by a desire to overcome limitations paper-based medication reconciliation process had (Small 2013). However, the findings demonstrate that although the computerized system has improved MRP in general, some sources of data friction remain intact and, moreover, additional types of data friction have been introduced into the workflow.

Secondly, medication lists including drug and alcohol abuse treatments are not included in

the medical record repository, leading to a kind of data friction due to data omission that impacts the quality of medication reconciliation results. Medication reconciliation integrate and crosscheck information from different sources in order to establish their accuracy. These include patient reports of adherence along with pharmacy data on adherence (Cadwallader et al. 2013), community drug lists along with hospital lists (Tamblyn et al. 2012), intake list along with hospital list (Plaisant et al. 2013), and current inpatient medication orders with outpatient medications from the Outpatient Medication Profile (Vawdrey et al. 2010). With any of these omissions, the reconciled list does not fully reflect the patient's current medication status, which forces the pharmacist to take additional steps to compare the final list for any discrepancies in the drug and alcohol abuse treatments.

Third, applying technology into the workflow has changed the medication reconciliation workflow, as well as the stakeholders participating in the workflow. Pharmacists now interact with stakeholders who are non-healthcare providers (e.g., staffs, technicians, and developers in HIEs and medication management company). With each stakeholder pursuing a different objective, they need to engage in a negotiation process to present their goals, discuss possible solutions, and come up with an agreed compromise. Moreover, applying computerized system into the MRP has great potential to lead to conflicts in roles and responsibilities. Before the introduction of the system, the medication reconciliation occurrence rate calculation formula was the domain of pharmacists. Taking this role away from them can potentially generate conflicts and some degree of resistance (Moore 1996).

Lastly, applying the risk score to MRP faces three practical challenges. First, pharmacists are unaware of the formula that calculates the risk score; it is not clear to them what the score meant for each area (e.g., comprehensive history, hospitalization history, and drug therapy problem). Second, differences of geography and locality may undermine the generic application of a risk score across populations. The pharmacists wonder if a trend in that state's population may not be reflective of the situation in another state. Lastly, the computerized medication reconciliation system is designed to operate for specific healthcare providers. There is no single standard medication reconciliation and risk score formula that can be implemented across providers, who might have adopted data formats of their own, making it difficult to share the same medication data across the board (Kramer et al. 2007; Lesselroth et al. 2012; Pronovost et al. 2004). Medication lists exist in various formats - patient's oral description, composition-based clinicians' notes, and electronic formats. Furthermore, electronic formats imported from EHR systems do not possess a standard format, creating issues of interoperability at different scales and levels (Beckett, Crank and Wehmeyer 2012; Cornish et al. 2005; Ketchum, Grass and Padwojski 2005; Tam et al. 2005; Weeks, Stanley and Vinson 2005).

In summary, the introduction of computing technology into the MRP has brought about changes in other key dimensions of infrastructure. Applying a computerized medication reconciliation system has reduced data frictions due to data loss, frequency of data exchange, and communication among various stakeholders. These data frictions arose when pharmacists could not capture all the relevant medication information, had to contact multiple providers to request the information, and needed to manually review medical records and reconcile medications. Despite its impact, some areas of the workflow cannot be resolved by technology alone: information in the workflow needs standard formats for better compatibility, collaboration among key actors should face minimal conflict and resistance in adopting the computerized system in practice, and legal regulations need to support seamless HIE. These are the key components of HII, without which a robust HII cannot be successfully implemented. While the key focus in the design and development of HII has been on technology and on improving technical systems, the present study findings clearly demonstrate that technology is one of several components that need to be considered to attain the goal of a nationwide HII.

6. Conclusion

The research undertaken here seeks to provide a comprehensive examination of MRP using the concept of “data friction” as a conceptual framework to explore the challenges faced in the computerization of MRP. This is the first study of its kind on the computerization of MRP from an infrastructural perspective. To obtain a first-hand understanding of these problems, the study reported findings from the empirical study of a research site, with a focus on the underlying relationships between technology and other dimensions of infrastructure. As expected, these findings demonstrate that the computerized system has improved MRP in general, but has left some data frictions intact and in place. Moreover, it has brought additional types of data friction into the workflow. Perhaps the most significant manifestation of data friction is generated by disagreements over the fixed medication reconciliation occurrence rate calculation formula. The pharmacists, in particular, raise questions about the risk score formula and how it assigns scores to patients. Having taken over some of the tasks and responsibilities that previously belonged to pharmacists, the system needs their trust and support for successful implementation - elements that are still missing in the current environment.

Its conceptual and empirical contributions notwithstanding, the current study carries several

limitations. First, only one research site was examined. Medication reconciliation is a nation-wide healthcare service and each state has its own community level medication reconciliation sites. Thus, other than in its broad conclusions, the findings of this study may not directly apply to all of them. Second, medication reconciliation targets patients with a high risk of hospital readmission, as well as those who suffer from complex diseases and take numerous medications. The study shows what pharmacists need to consider when dealing with elderly complex patients. Other patients with different demographic and medical histories may require other considerations. Third, the participants in qualitative data collection were mostly pharmacists. The qualitative data did not fully reveal various stakeholders' perspectives in the medication reconciliation practice.

Despite its limitations, however, the research site of this study is a government funded project, and can provide valuable insights for generalization to other communities. Since medication reconciliation is a nation-wide process, the findings in this study can indirectly be applied to other healthcare settings. Moreover, the findings could also be incorporated in other healthcare workflows to examine the challenges of implementing a robust infrastructure in healthcare environments. This study constitutes one of the first efforts to comprehensively investigate health information infrastructure and how technology and other dimensions in infrastructure are interrelated. Future research could examine data frictions of the infrastructure in different healthcare environment. The context of this study is focused on the U.S. which does not have a centralized healthcare insurance system. South Korea, on the other hand, have a national healthcare system and poses some different challenges and issues in HII (Cho et al. 2018; Kim 2015; Jeong 2018; Park et al. 2019). Since previous research on medication reconciliation conducted in South Korea did not integrate critical four dimensions affecting the seamless implementation of HII, future research could apply the framework and findings from this study to examine the underlying data frictions South Korea healthcare environment carries.

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• **국문 참고자료의 영어 표기**
(English translation / romanization of references originally written in Korean)

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Appendices

[Appendix 1] Data collection listed in chronological order

Date	Title	Participants	Topic
11/10/15	Bi-weekly meeting 01	Pharmacists HIE staffs	• Demo medication list functionality • New MRP page and matching activity • Tasking discussion • Workflow and requirements
11/23/15	Bi-weekly meeting 02	Pharmacists HIE staffs	• Drug related problems
12/01/15	Wednesday meeting 01	HIE staffs	• Problem in current situation
12/08/15	Bi-weekly meeting 03	Pharmacists HIE staffs	• Single identifier • HL7
12/09/15	Wednesday meeting 02	HIE staffs	• Introduction to RXL
12/15/15	Wednesday meeting 03	HIE staffs	• Workflow and breakdown
01/05/16	Bi-weekly meeting 04	Pharmacists HIE staffs	• Interface
01/21/16	Tech meeting 01	HIE staffs Tech developers	• Data source
02/02/16	Bi-weekly meeting 05	Pharmacists HIE staffs	• MRP task
02/04/16	Tech meeting 02	HIE staffs Tech developers	• Data format • Risk score formula
03/02/16	HIE meeting 01	HIE staffs	• Breakdowns
03/21/16	HIE meeting 02	HIE staffs	• Standardization issues
03/21/16	HIE meeting 03	HIE staffs	• Database
03/22/16	HIE meeting 04	HIE staffs	• Indiana law • Breakdowns
04/07/16	In-depth interview 01	Pharmacists	• Workflow demonstration
04/29/16	Bi-weekly meeting 06	Pharmacists HIE staffs	• Tasking function • Risk score
06/03/16	HIE meeting 05	HIE staffs	• Law friction • Breakdowns
06/23/16	Tech meeting 03	HIE staffs Tech developers	• RxNorm
07/04/16	Bi-weekly meeting 07	Pharmacists HIE staffs	• Phase1 • Phase2

Date	Title	Participants	Topic
07/12/16	Focus group 01	Pharmacists HIE staffs	• General Introduction • Phase1 • Phase2
08/02/16	Bi-weekly meeting 08	Pharmacists HIE staffs	• Herbal • Risk score status
08/02/16	Focus group 02	Pharmacists HIE staffs	• Before using RXL
08/16/16	Focus group 03	Pharmacists HIE staffs	• Risk score
09/13/16	HIE meeting 06	HIE staffs	• Risk score
09/26/16	Bi-weekly meeting 09	Pharmacists HIE staffs	• Platform
09/27/16	HIE meeting 07	HIE staffs	• Risk score • New functions • Workflow
10/13/16	HIE meeting 08	HIE staffs	• Fill history
11/07/16	In-depth interview 02	Pharmacists	• New functions
11/21/16	In-depth interview 03	Pharmacists	• Workflow demonstration
12/05/16	Bi-weekly meeting 10	Pharmacists HIE staffs	• New interface

[Appendix 2] Focus Group Discussion Questions

■ Focus Group Discussion 01

- Opening question
  "How have you been involved in the CMM project?"
- Introductory question
  "Think back over the past months/years of the things that CMM did. What would be the biggest difference between before and after adapting/applying the tool?"
- Transition question
  "Who, and how did you communicate outside the organization when we didn't have the tool?"
- Key questions
  "What were you communicating?"
  "Explain how you gather and disperse that information now. How much time did you spend gathering information, and how was that time spent? Immediately without any delays?"
- Ending question
  "Have we missed anything?"

■ Focus Group Discussion 02

- Opening question
  "How is your task in the project going on?" or "What particular task did you work on over the last two weeks?"
- Introductory question
  "Compared to the days when you used fax and phone to communicate with people outside the organization, what went particularly well (in terms of communication) after adapting/applying the tool?"
- Transition question
  "After the tool has launched, to whom and how do you communicate outside the organization?"
- Key questions
  "What are you communicating?"
  "What are the barriers in communication?"
  "How can technology be of help to those barriers?"
- Ending question
  "Of all the things we discussed, what to you is the most important?"

■ Focus Group Discussion 03

- Opening question
  "Today, we will discuss about 'Care Triage'. What was your overall impression and experience of Care Triage at PHARMACeHome?"
- Introductory question
  "What do you think is the significance of Care Triage, and how it will add value?"
- Transition question
  "After the tool has launched, to whom and how do you communicate outside the organization?"
- Key questions
  "CCNC has introduced the purpose of using Care Triage as 'use 30 day admission risk to identify which patients should have home visits scheduled first, use drug therapy problem or high priority discrepancy risk to identify which patients may need to have their high level overview/cursory review, use intervention guidance to determine which patients need pharmacist medication review, determine medication management needs for patients in light care status, use overall risk profile and hospitalization risks to determine which patients need additional outreach before deferral due to inability to contact, and identify patients with specific medication management needs'. Out of these factors, what would most fit to CMM's target patients? Which function do you expect to use the most in Care Triage at CMM?"
  "Would any of these functions be redundant? Or would you recommend to include any additional functions to the new model?"
  "How can Care Triage change your pharmacy workflow?"
- Ending question
  "What do you think is the most important part in Care Triage, and which part would you make Care Triage useful for you?"