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Technical Limitations of Electronic Health Records in Community Health Centers: Implications on Ambulatory Care Quality

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Technical Limitations of Electronic Health Records in Community Health Centers: Implications on Ambulatory Care Quality

by

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DISSERTATION

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Abstract

Technical Limitations of Electronic Health Records in Community Health Centers: Implications on Ambulatory Care Quality

Christopher E. West

Research objectives: This dissertation examines the state of development of each of the eight core electronic health record (EHR) functionalities as described by the IOM and describes how the current state of these functionalities limit quality improvement efforts in ambulatory care settings. There is a great deal of literature describing both the potential of the EHR to improve quality of care and showing a lack of improvement associated with EHR use. This study examines the role that the state of development of EHR functionalities plays in the quality improvement.

Study design: A qualitative study of four community health center (CHC) networks that provide EHR services to members and three CHCs from each network. Each network used different, commonly used and CCHIT certified EHRs. Sixty five hours of interviews were transcribed, coded, and analyzed from seventy five semi-structured interviews of leaders/staff. The analysis focused on the eight core EHR functionalities as identified by the IOM.

Principal findings: Out-of-the-box, none of the EHRs studied strongly supported the provision of guideline based care to individual patients or the management of populations of patients. Extensive EHR modification was needed, with some EHRs requiring more work. Challenges were most acutely felt with templates, interfaces, decision support, and reporting functionalities. Limitations were found less often in administrative processes and within practice messaging. Though EHR functionalities greatly improved based on network and CHC

development efforts, focus on quality improvement activities was diminished by the consumption of scarce resources to fix poorly functioning software.

Conclusions: Given that EHR adoption rates will continue to increase it should be emphasized that successful QI efforts are difficult to achieve with the current state of the technology, especially for smaller practices. So far the onus of improving the functionalities for use in QI efforts has primarily been left to the EHR adopters, who generally lack the resources to develop the software. Policy needs to take this into account and fund not only EHR implementation, but also ensure great improvements are made to core functionalities.

Table of Contents

List of Tables

List of Figures

1. Introduction

Health information technology (HIT) in general, and electronic health record (EHR) systems in particular, are seen by many as tools that will enable the transformation of the health care industry. The Institute of Medicine (IOM) has described numerous quality and safety problems present in the United States' health care system and is promoting EHRs as an essential component to improving the quality and safety of care[1-3]. Acting on these concerns, the federal government, with the passage of American Recovery and Reinvestment Act (ARRA), is providing $19.2 billion to support the implementation of EHRs[4, 5]. There is nearly universal acceptance that EHRs have the potential to: improve patient care by reducing errors, providing decision support, and ensuring all patients receive appropriate care; improve access to critical patient care data as it is needed; and better enable communication and collaboration between health care providers and their patients[6, 7].

Despite this potential to improve quality and patient outcomes, implementation of outpatient electronic health records in the United States has proceeded slowly. A 2008 study showed fewer than 5% of physicians had a fully functional EHR and only 13% had at least a basic system[8]. With ARRA funding, these numbers will likely rise, but simply having an EHR does not guarantee improvements in safety or quality [9-11]. While a few studies have shown positive quality impacts due to EHR use, many others reported poor or mixed results [12-14].

There are numerous factors that can influence the quality and safety gains seen when an organization implements an EHR. A recent National Academies Press report highlights the limitations in HIT at a high level and proposes a strategy for HIT development in order to support a 21st century vision of health care[15]. This dissertation complements the work in the NAP report by examining the current state of technological development of core EHR functionalities. I highlight areas in most immediate need of improvement and describe the impact of the current development of EHR functionalities on the ability of health centers to implement chronic and preventive care quality improvement efforts utilizing the EHR.

1.1. Background

1.1.1. Ambulatory care

Ambulatory medical care is responsible for the majority of medical care that happens outside of the hospital setting. The 2006 National Ambulatory Medical Care survey reported over 900 million ambulatory care visits, on average just over 3 visits per person in the United States[16]. Of these, 50.1% of office visits were made by patients with one or more chronic condition. Since 1996, the number of visits by adults 18 years and older with diabetes grew by 40%, with hypertension 28%, and with depression 27% - all faster than the 11% growth of the US population during the same period of time. As the number or patients with chronic conditions continues to increase, new strategies for care need to be adopted. Ultimately, the EHR promises to be part of the solution to meeting the care needs of the patient population with chronic conditions.

Additionally, studies looking at the quality of ambulatory health care delivered to adults in the United States, have consistently found sub-optimal results. For instance, McGlynn found

that only 56% of patients received recommended care chronic care[17] and Ma found "measurable quality deficits" in general care and called, "for greater adherence to evidence-based medicine in US ambulatory settings"[18]. As will be described later, the EHR has a great potential to help ensure that patients are receiving the care that they need.

1.1.2. Community health centers

The nation's 1002 federal qualified health centers (FQHCs) are a major source of ambulatory care, providing primary care to over 15 million poor or underserved Americans. [19]. Of the FQHC patients, 71% have incomes below the poverty-level and 64% are nonwhite[20]. FQHC visits are made up of 40% by the uninsured with the majority of remaining visits covered by Medicaid (35%) and Medicare (8%). Millions more are served in FQHC "look-alikes;" combined, the FQHCs and lookalikes take the label community health centers (CHCs).

Within community health centers (CHCs) and the medical community as a whole, a shift towards the use EHRs is underway. As of 2006, up to 13% of CHCs had adopted full EHRs[21] and with the ARRA funding, many more are considering or planning for EHR implementation. CHC are an interesting setting in which to study the use of EHRs. In many ways they are similar to small and midsized practices in terms of numbers of providers, numbers of patients served, and types of information systems used, but because of their mission they are relatively aggressive in efforts to improve care for the underprivileged. This means that compared to other similarly sized practices they are likely to be further in the use of EHR for QI[10] and thus more likely to have encountered technological limitations, making CHCs an ideal population for this study, while providing results that generalize to a greater population.

Many CHCs are members of CHC networks that provide business, advocacy, or training services. A small but growing number of CHCs networks also provide EHR services, including

training, implementation, help-desk support, application and database hosting, and reporting. These networks aim to help CHCs reap economies of scale in EHR software pricing and information systems staffing and can be better learning organizations than could individual CHCs.

1.1.3. What is an EHR?

The term electronic health record (EHR) is used in one of three ways throughout the course of this dissertation. The first is as a longitudinal electronic repository of a patient's health information[22]. This collection of data typically contains patient demographics, medical history, a record of each medical encounter, orders, referrals, vital signs, and test results. The second is as a system that manages the electronic storage and retrieval of individual electronic health records. Additionally, an EHR system can use data stored in an individual record, in conjunction with tools built into the system, to support care related activities through mechanisms such as evidenced-based decision support, electronic ordering, and outcomes reporting. While all three aspects of the EHR are utilized throughout this dissertation, the third is most often utilized.

Ambulatory EHRs are often used in conjunction other with health information systems. Typically an EHR will have a bi-directional interface with an electronic practice management system (EPMS) which handles office tasks such as appointment scheduling, patient demographics, and billing. For example, the EPMS will send demographics information to the EHR and notify the provider that a patient has been checked in, and the EHR will often send information on services rendered back to the EPMS for billing purposes.

Electronic health records are typically maintained by a health care providers and access is limited to authorized personnel from the health care organization. This is in distinction to a

personal electronic health record (PHR) which summarizes a patient's health and medical history and is maintained by the patient. The PHR falls outside the scope of this dissertation.

The primary role of an EHR within the scope of ambulatory care is to facilitate primary care-related work, including the provision of care, creating a record of the encounter, and billing for services rendered. The Institute of Medicine (IOM) laid out eight core functionalities of an EHR to support this work and to help achieve the goals of improving patient safety, supporting the delivery of effective patient care, facilitating management of chronic conditions, and improving efficiency[23]. This categorization was chosen as the basis for my analysis (described later in this section) based on the breadth and comprehensiveness of the categorization. The functionalities are are:

- *Health information and data:* The electronic documentation, storage, and retrieval of a patient's data necessary to make decisions about care.
- *Electronic communication and connectivity:* Communication amongst health care team members, external care partners (e.g. specialists or pharmacy), and the patient and connectivity to data sources external to the EHR (e.g. lab, radiology) for the purposes of sharing data.
- *Order entry and management:* The computerized entry of orders and the subsequent management of these orders.
- *Results management:* Managing results of all types (e.g. lab, procedures).
- *Decision support:* Reminders, alerts, and other tools to help providers and staff make appropriate clinical decisions and improve patient care.
- *Patient Support:* Tools that can be used to support patient self-care and the management of chronic diseases. Includes educational materials, modules, and patient web portals.

- *Administrative processes:* Includes scheduling, billing, and claims.
- *Reporting and population health management:* The tools and clinical logic/business rules necessary to view and analyze data from the EHR and to manage populations of patients.

These core functionalities form the basis of my analysis which is described later in this section.

1.1.4. Potential for EHR to enhance quality of care

In theory, the quality benefits of ambulatory EHRs are readily apparent. These benefits can be thought of in two categories: those that are "automatic"[1] and those requiring "higher level functions" [2]. In this section, I explain how each functionality described above can contribute to improved quality. Not all functionalities are equally important to QI efforts, so several functionalities (decision support and patient management) form the bulk of the section. Additionally, some quality benefits require the use of multiple functionalities (e.g. checking for drug/drug interactions requires order entry and decisions support).

- *Health information and data:* "Automatic" benefits include increased legibility, organization, and accessibility – charts and lab results are never "lost" and access is not limited to the clinic (e.g. can access from home or the hospital). Higher level benefits include using disease or condition specific templates to document an encounter. These templates help the provider to ensure they are collecting the necessary information about a patient and provide an opportunity for decision support (see "Decision

[1] Automatic means that nothing needs to be done on the user's end to achieve the benefit. For example data viewed in the EHR is legible by the nature of using. The user does not need to activate the functionality or respond to the system in any way.

[2] High level means that in order to achieve the benefit the user must interact with the system. For example, a user must access the health maintenance section of the chart in order to see any recommended services for a patient and then decide how to act upon the alerts. Likewise, when a window appears on the screen alerting a prescriber about a possible medication error, the user must respond to the alert before they can proceed.

support," below). *Electronic communication and connectivity:* Direct communication between health care providers has the potential to improve coordination of care. More important for quality, automatic sharing of data with sources external to the EHR (e.g. lab, radiology) can ensure the provider has access to up to date information.

- *Order entry and management:* Automatic benefits include decreased errors in ordering due to illegible or lost orders. Higher level benefits include the application of decision support while creating orders to help prevent medication errors and the ability to track if orders were filled or referrals were completed.
- *Results management:* The EHR can automatically highlight results that are out of range or need the immediate attention of the provider. Higher level functions include the ability to look at results data for groups of patients to ensure results were followed-up appropriately, thus ensuring no patient with a critical result falls through the cracks.
- *Decision support:* Perhaps one of the most important functionalities for improving care, decision support is inherently a higher level function. Medication errors can be reduced by alerting providers to potentially dangerous situations such drug/allergy interactions like prescribing Amoxicillin to a patient with a penicillin allergy. EHRs can encourage providers to "do the right thing" by providing evidence based patient specific reminders or alerts for chronic and preventive care services. Reminders can be embedded into guideline based documentation templates or flow-sheets that concisely display pertinent information and help structure data collection for a patient with a particular diagnosis (e.g. a diabetes template), be present in a section of the chart that highlights needed services (e.g. a health maintenance tab), or appear elsewhere on the screen (e.g. a pop-up reminder). For example, when a provider sees a diabetic patient and

accesses the health maintenance tab, the provider might see red text on the screen indicating the patient is overdue for a HbA1c test and a lipid panel.

- *Patient Support:* Use of higher level tools such as computerized education modules and materials and web portals to review health data are all ways in which patients can become empowered to better manage their health status by either providing information or education about what to do with the information.
- *Administrative processes:* Many aspects of this functionality do not directly relate to clinical quality, although scheduling is an exception. Scheduling can be used to implement advanced access scheduling, predicting demand for same day appointments and keeping enough visit slots open, thus decreasing missed appointments and ensuring there is room for patients who need to be seen and overall providing a better environment for care.
- *Reporting and population health management:* These are inherently higher level functions. Data on how populations of patients, say diabetics, are cared for can be quantitatively evaluated, both at the level of the health center and by provider or care team. This data can then be used to evaluate strengths and weakness, prioritize improvement efforts, create plans to improve performance, evaluate plan effectiveness, and hold providers and staff responsible for the care they provide. Data from the EHR can be used to track and manage populations of patients, ensuring no patients fall through the cracks. For instance, a report could be run to identify all of the diabetics whose last visit was over six months ago and who had prior HbA1c test greater than 9. This list could then be used by a case manager to recall these patients or be used to automatically generated recall letters, phone calls, or whatever other form of communication a patient prefers.

1.1.5. Prior findings on EHRs and quality of care

Though EHRs clearly have the potential to improve quality of care, the literature reveals mixed results. Numerous studies have reported that EHRs and other forms of health information technology (HIT) can have positive effects on quality of care. One study showed a diabetes registry derived from EHR data helped to improve 9 measures of diabetes care[24]. A systematic review by Garg in 2005 on clinical decision support systems, one feature of many EHRs, found that process measures were improved in 63% of studies [13]. Another review by Dorr in 2007 found that HIT use improved chronic illness care in 67% of experimental studies[12].

Despite these positive findings, there is controversy about the quality improvement value of widespread EHR implementation and the generalizability of these findings to diverse settings. A 2006 systematic review of the effect of health information technology (HIT) on quality, efficiency, and costs of health care found evidence of positive effects, but cautions about the widespread applicability of these findings[25]. The authors found numerous instances where HIT increased the delivery of guideline based care (especially for preventive health), enhanced monitoring and surveillance activities, and improved patient safety though the reduction of medication errors. However, these positive results were primarily from four "benchmark institutions" whose publications comprise 25% of the reviewed studies. These institutions are HIT innovators[26] who have undergone a long iterative development process, internally designing their HIT from the ground up. These studies are difficult to generalize for three reasons: 1) Most current and future adopters of HIT will use commercial software rather than develop their own and 2) The majority of U.S. health care is provided in non-academic medical settings. To further generalize this data, more studies are needed. These studies should investigate "real world" settings, particularly in light of the federal government's push to

increase EHR use. The great majority of these new EHR implementations will occur in non-academic settings using commercial systems.

While the literature on commercial EHRs in outpatient settings is relatively sparse, the predominant finding about EHRs and quality of care in this setting is that general EHR use[3] does not guarantee quality. For example, Linder found that, as implemented, EHRs were not associated with quality improvement in ambulatory clinics[27]; Crosson found that practices using an EHR were less likely to meet diabetes care guidelines for process and treatment[28]; and Zhou found no difference in quality of care measures between EHR-users and non-users and that time of EHR use did not correspond to improvements in quality. Zhou speculated that intensifying usage of EHR features such as decision support may be necessary to improve quality. This corresponds to findings from my prior work on EHRs in solo and small group practices that showed while most practices focused on using the EHR to improve billing, they merely replicated their use of paper charts to provide care, failing to take advantage of EHR functionality to improve quality[9]. Clearly, simply having an EHR in place is not necessarily associated with improved ambulatory quality of care.

In the literature, much of the understanding about why particular EHR adoptions fail to improve quality comes from a sociotechnical perspective which tries to understand the contribution of human and organizational factors to the functioning of sociotechnical systems[29, 30]. In this pursuit, sociotechnical research has tended to emphasize the roles of social factors such as people, culture, and training rather than looking at the shortcomings of the technology itself. I am going to address this missing piece, which is sometimes considered the "sacred informatics ground"[31] of technology. While social factors are important and vital to the understanding of how and why EHRs are used to help improve quality, they alone cannot

[3] as compared to studies with an intervention targeting a specific care area

account for the impact EHR use has on quality. This dissertation, while recognizing the role of social factors, will emphasize the impact that the state of EHR technology development has had on the ability of health centers to use their EHRs to improve quality of care.

1.1.6. Technological limitations of EHRs

In order for an EHR functionality to be able to improve quality of care it must be not just available in the EHR and but also actively used by the providers and staff. While the Certification Commission for Healthcare Information Technology (CCHIT) seeks to help alleviate the availability issues by ensuring that all certified EHRs have a core set of functionality, there is a difference between EHR capabilities that are available and those that are useable. In a detailed analysis of clinical decision support capabilities in CCHIT certified EHRs, Wright et al. found that the availability of decision support elements varied widely between systems even through all EHRs were certified. Another recent study found that more than 1 in 5 outpatient providers do not regularly use each of the available functions and that changes in the availability and use of 9 of these 10 functions over a two year period was "inconsequential"[32]. Given the increasing numbers of practices with EHRs, competition amongst EHR vendors, and more robust standards around EHR functionality stemming from CCHIT, one would expect EHR functionality use to improve; the stagnation in the availability and use of EHR functions is of great concern.

Understanding which features of the EHR are used is important. In one of the few studies that have looked at the use of EHR capabilities, Poon found that the use of specific EHR features (as opposed to simple binary EHR use) was associated with modest improvements in HEDIS measures[33]. This finding makes the typical disuse of EHR functions all the more troubling, in that quality of care is likely impacted as a result of technological disuse.

In prior work Dr. R.H. Miller, Dr. J.W. Adelson and I found several instances where the technology itself clearly limited CHCs' ability to use EHRs in efforts to improve quality of care[34]. A major limiting factor at four CHCs was a lack of documentation templates that incorporated clinical guidelines. One medical director expressed the following frustration:

> Software companies do not invest any significant amount of time or money in developing good templates themselves. They leave it to the individual purchasers to either make their own templates or to buy them from other vendors.

A second CHC in the same study recognized the need for templates following the implementation of an EHR with poor template support and spent three years and hundreds of thousands of dollars developing their own templates. According to the medical director, this effort resulted in “a hodgepodge” of templates developed for specific needs without regard to how they would work together. The resulting provider dissatisfaction led to a *second* extensive template development project to create templates with a uniform look and feel, again with huge monetary costs and extensive investments of time.

Other technical limitations in using the EHR for QI included an inability to easily pull data from the EHR and practice management systems, impacting the ability of CHCs to report on provider performance and to generate lists of patients needing services and a lack of decision support available (such as prompts for needed health maintenance or drug-diagnosis interactions) “out of the box”. Many study CHCs encountered similar EHR limitations and were forced to solve the same problems, essentially having to “reinvent the wheel” when other CHCs and health care organizations had already solved the problem. All of these various challenges served to limit CHCs’ abilities to use the EHR for QI.

Along with the availability of EHR functionalities, observations from prior work also suggest that part of the problem ambulatory care providers and health centers have in using

EHRs for quality improvement is that they underestimate the changes and modifications that the software will have to undergo to fit their particular needs. For example, not only do the providers and organizational leadership lack a full understanding of the impact that that an EHR will have on their workflow and the way medicine is practiced, but they also do not understand the amount of work that will need to go into the system in order to make changes specific to their reimbursement scheme and care environment. These complexities conspired to move functionality from available to unusable, unless enough time, money, and effort were invested.

Instead of focusing on individual functionalities, the National Academies Press's (NAP) recent report, *Computational Technology for Effective Health Care: Immediate Steps and Strategic Directions,* broadly outlines the needs of health information technology in the future and several areas that are applicable to EHRs[15]:

- Automation: when automated systems are deployed in a single environment they must work together harmoniously.
- Data sharing and collaboration: health care data is often stored in different databases, which ought to be searchable with a single click.
- Data management at scale: large bodies of data need to be formatted in such a way to facilitate effective storage and searching.
- Automated capture of patient-provider interactions: mitigate data entry responsibilities and allow providers time for more productive uses by automatically documenting patient-provider interactions.

Data automation, data sharing, data management, and data capture are all expected to be current problems, and will be looked for in the research.

The NAP report suggests that though computerized systems have great potential to improve health care, in reality their impact has been quite limited by their utilization as

substitutes for paper systems. Most process improvements have occurred on the business side, and do not target clinical quality. Furthermore, the software is not typically designed with human-computer interactions in mind, so instead of reducing the cognitive burden on the provider, the computer can add to the provider's load. In this dissertation, I compliment the NAP report's findings by capturing examples of specific limitations in EHR functionalities in commercial systems used in settings outside of elite medical centers in order to better target improvement efforts.

1.2. Research Overview

In summary, prior work has indicated that the current state of commercial EHR technology is a barrier to the use of the EHRs for QI. However, data gathered up until this point has not provided much depth on the limitations present in each of the core EHR software functionalities and amount of work that must be expended in order to make the functionality useable as part of QI efforts. It is not well understood:

- What types of technical limitations are encountered using commercial EHR functionality for QI?
- What the impact of these limitations are on a health center's ability to use the EHR for QI?
- How pervasive these are limitations amongst EHR users and amongst various EHR products?
- What solutions for these problems have already been devised and how transferable these solutions are to other organizations?

This study examines the technological limitations present in each of the core EHR functionalities encountered in the use of four widely used EHRs by four CHC networks and thirteen CHCs, documents efforts to overcome these limitations, and highlights limitations that still need to be addressed. Due to similarities in information systems used and practice sizes, lessons learned in the study population can be applied to similarly sized organizations and similarly targeted EHRs. This study contributes to the field in two main ways: a) documenting the gap between the current state of development of core EHR functionalities in commercial systems and what was needed to utilize the functionalities as part of QI efforts, and b) proposes vendor/policy solutions to help mitigate a number of the functional limitations.

1.3. Methods Overview

For the purposes of this study, the technical limitations of EHRs are addressed through the lens of the IOM's eight core EHR functionalities, examining each of the functionalities at great depth. The population of study is a national sample of four community health center (CHC) networks that provide EHR services to member CHCs and three CHCs from each network. The CHCs have used the EHR for at least 18 months and were purposefully selected for a variety of experiences using the EHR (i.e. high, medium, and low performing health centers).

The research questions above are addressed through a series of four to five semi-structured interviews conducted at each of the CHCs and CHC networks. Interviewees typically included executive directors, medical directors, chief information officers, quality managers, and front-line non-expert EHR users. Semi-structured interview guides were created by adapting questionnaires used on prior projects, reviewing interviews with experts in the use of EHRs for QI, reviewing the literature for commonly encountered EHR limitations, and investigating how

adherence to ADA guidelines for diabetes care could be achieved through the use of EHR functionality.

This project takes place within the context of a larger study looking at factors that affect the pace of implementation EHR-enabled quality improvement activities in CHCs and CHC networks. This study is generously sponsored by the Commonwealth Fund.

2. Methods

This project evolved out of my extensive prior work on EHRs in ambulatory care including studies on the costs and benefits of EHRs[10] and chronic disease management systems in CHCs[35], a case study of the Institute for Urban Family Health, a CHC leader in technology enabled QI[36], and barriers and facilitators of technology enabled QI in CHCs[34] . This study takes place within the context of a larger project funded by the Commonwealth Fund investigating factors that affect the pace at which CHCs within CHC Networks are able to use EHRs as part of quality improvement (QI) efforts. While fully participating in the larger project, my analysis specifically targets the role that limitations and challenges in using EHR functionality play in the ability of CHCs to use the EHR to enhance chronic and preventive care activities. This project utilizes methods similar to and builds upon the instruments and insights from the four prior projects described above and on the materials and observations from an earlier study we conducted on the value of EHRs in solo and small groups [9].

2.1. Sample Selection

Data for this study was collected from five CHC networks providing EHR services and three CHC members per network[4]. Selection criteria for the networks were:

- CHC focus. Primarily provided services to CHCs or CHC look-alikes
- Experience. Provided EHR services to at least three member CHCs for at least 18 months--ensuring the initial learning curve for providing services and using the EHR had been met
- Expansion. Planned to expand provision of EHR services to more CHCs. (necessary to reap economies of scope and scale)
- EHR Software. Used an EHR product that was CCHIT certified and a major contender in the CHC sector
- Commitment. Demonstrated willingness to provide us with requested information

Potential CHC Network participants were identified by reviewing past HRSA grant awards to CHC networks, discussions with HRSA about networks providing EHR services, prior work with CHCs using EHRs, and discussions with persons contacted in the network scan. Ten of twelve networks identified and contacted in the fall of 2007 responded. Three did not meet the established selection criteria and one declined to participate. Of the remaining six we selected the three largest CHC networks providing EHR services along with two other networks with unique service models. Data from four of the five networks in the larger study (the three large networks and one smaller one) have been included in this analysis. CHC members from one network were not able to provide the requested follow-up information and so were excluded. The final analysis included four networks and thirteen CHCs.

[4] For the Alliance of Chicago, we had four CHC cases because one two small CHCs that report to HRSA independently were linked under the same governance board.

Each network utilized a different EHR. All products were widely available, used by numerous mid-sized practices, and CCHIT[5] certified EHR product (see Table 2.1). As of summer of 2009, all CHC Networks had provided EHR services for at least 3 years.

Table 2.1 Characteristics of Four CHC Networks Providing EHR Services

	Alliance of Chicago (AC)	Health Choice Network (HCN)	Our Community Health Information Network (OCHIN)	PTSO of Washington (PTSO)
Founded	1997	1994	2001	2004
Began providing EHR services	2005-06	2004	2005	2006
CHC members	17	65	30	5
CHCs using EHR	17	23	13	5
FTE billing providers using EHR	150	400	387	153
EHR product (vendor)	Centricity EMR (GE)	Medical Manager, converting to Intergy (Sage)	EpicCare (Epic Systems)	NextGen (QSI Inc.)

FTE=Full-time equivalent; CHC=community health center; EHR=electronic health record;
Source: Authors' own data

Alliance of Chicago (AC). Founded in 1997 by a partnership of four CHCs to share resources and knowledge in order to improve quality, AC quickly realized an EHR was needed in order to work on the QI projects they envisioned. A history of close collaboration around QI enabled the four original Chicago members to approach EHR implementation with QI in mind. Additional members of AC are located throughout the United States. The AC used Centricity EMR which is an important player in the markets for small and mid-sized practices.

Health Choice Network (HCN). Founded in 1994, HCN was the largest CHC network, with 65 members. Although centered in Florida, HCN provided services to health centers as far away as Hawaii. HCN began providing billing services for members and expanded to include a variety of other services including contracting with HMOs and information systems services including

[5] Certification Commission for Healthcare Information Technology

EHR and EPMS. HCN used Medical Manager which was recently purchased by Sage and was in the process of transitioning to Sage's Intergy, another large player for mid-sized practices.

Our Community Health Information Network (OCHIN). Founded in 2001 specifically to provide EHR/EPMS services, OCHIN rapidly expanded to over 30 CHC members. OCHIN members were primarily on the west coast, but OCHIN was looking to expand its range nationally. OCHIN enabled CHCs (small to mid-sized organizations) to use EpicCare, which typically was only available to large groups with greater financial and technological resources.

PTSO of Washington (PTSO). Emerged in 2004 from an EHR selection process facilitated by the Community Health Plan of Washington, PTSO consisted of five CHC members in the Seattle/Washington state area. PTSO utilized QSI Inc's NextGen which was widely used in mid-size practices. Initial software glitches slowed down QI efforts and also limited expansion efforts.

2.2. CHC Selection

While gathering data at the network level provided a high level perspective on the technical challenges using the EHR for QI, it was also necessary to talk with CHCs that were the day to day users of the software to learn about their experiences and insights. It was not feasible to do in-depth interviews with all of the CHCs in a network so three CHCs with diverse experiences with EHR use were purposefully sampled from each network. CHC selection was based upon:

- Health center type. Either a federally qualified community health center (FQHC) or a FQHC look-alike[6]
- Experience. Having used the EHR for at least 18 months
- Size. Different numbers of providers and patients
- QI experience. Different levels of experience using the EHR as part of QI efforts

Sample CHCs were chosen based on initial discussions with network leaders and through a brief conversation with leadership at each CHC. CHCs cases were purposefully selected based on variations in size and use of the EHR for QI (i.e. high, middle, and lower performing). CHC characteristics were diverse: for example study CHCs ranged in size from 3.5 to 52.3 providers and 1.8 million in revenues to 81.5 million (see Table 2.2). Overall, most study CHCs were larger than average CHC size and had relatively more available resources.

Table 2.2 Characteristics of Thirteen Community Health Centers using EHRs

Network	**Alliance of Chicago**				**Health Choice Network (HCN)**			
Software Used	Centricity EMR				Medical Manager			
CHC	Erie	HIHC[a]	Heartland Health Outreach[a]	NearNorth	Broward	CHI	Jesse Trice	National Average (2007)
No. Sites (medical)	3	1	2	6	3	9	7	n/a
No. FTE Billing Providers (medical)	35	8.29	9.58	22.93	3.55	37.17	19.37	11.9
MDs	21.31	3.58	2.29	17.66	2.55	22.42	15.4	7.5
Mid-levels	14.01	4.71	7.29	5.27	1	14.75	3.97	4.4
No. Encounters (medical)	110,466	28,163	22,001	90,180	14,383	157,317	71,379	44,083
No. Patients (medical)	23,154	9,279	7,615	31,565	4,539	45,374	23,555	13,085
% uninsured patients (all)	38%	48%	69%	54%	81%	53%	64%	39%

[6] *FQHC "look-alikes"* do not receive the HRSA lump-sum payments, but do receive higher FQHC per-visit rates from Medicare. Both FQHCs and look-alikes must serve the uninsured which account for at least 40% of visits. This manuscript refers to both FQHCs and look-alikes as CHCs.

% Medicaid patients (all)	56%	18%	25%	43%	13%	26%	29%	35%
Patients best served in language not English (all)	69%	13%	5%	16%	20%	30%	8%	27%
Patient Income <=200% of poverty (all)	99%	77%	99%	95%	99%	97%	92%	91%
Cost per encounter (medical)	119	$127	$179	$77	$131	$106	$148	$123
Total revenues (millions)	23.1	4.9	10.4	16.2	1.8	35.3	18.2	8.5
Time since implementation (yrs)	3	3	2.5	3	3	5	5	n/a

Network	**OCHIN**			**PTSO of Washington**			
Software Used	EpicCare			NextGen			
CHC	MCHD	OHSU Richmond[b]	SCCHD[c]	Country Doctor	Health Point	Neighbor Care	National Average (2007)
No. Sites (medical)	6	1	3	2	7	6	n/a
No. FTE Billing Providers (medical)	52.3	11	11.3	12.74	31.97	44.78	11.9
MDs	25.5	5.94	6.9	6.86	25.02	22.33	7.5
Mid-levels	26.8	3.9	4.4	5.88	6.95	22.45	4.4
No. Encounters (medical)	99,164	39,381	31,592	41,466	106,047	107,202	44,083
No. Patients (medical)	40,040	10,691	10,725	14,965	39,374	31,049	13,085
% uninsured patients (all)	49%	14%	20%	51%	44%	42%	39%
% Medicaid patients (all)	47%	40%	52%	21%	37%	33%	35%
Patients best served in language not English (all)	35%	19%	41%	22%	26%	18%	27%
Patient Income <=200% of poverty (all)	97%		74%	88%	79%	88%	91%
Cost per encounter (medical)	$261		$168	$144	$163	$159	$123
Total revenues (millions)	81.5		13.3	9.5	30.2	32.5	8.5
Time since implementation (yrs)	4	3	3	3	3	3	n/a

Sources: 2007 UDS data and author's own data where noted

Notes: HHO=Heartland Health Outreach, HIHC=Heartland International Health Center, CHI=Community Health International, MCHD=Multnomah County Health Department, OHSU=Oregon Health Sciences University, SCCHD=Santa Cruz County Health Department

a) HHO and HIHC are independent health centers, but both are governed by the board of the Heartland Alliance; b) OHSU Richmond is a CHC "look-alike" and so does not report UDS data, self-reported data; c)SCCHD does not report UDS data for all clinical; self-reported data.

2.3. Data Collection

Data was collected using detailed semi-structured interview questionnaires, adapted from previous work[9, 10, 34, 35] (see appendices 1.1, 1.2, and 1.3). Due to the nature of this project being situated within a larger project, a number of the questions asked do not apply to this analysis. Three questionnaires were used: one for CHC networks, one for CHCs, and a matrix detailing CHC use of the EHR for various chronic and preventive care areas. Questions focused on the use and usefulness of the EHR as part of QI efforts in CHCs, ways in which QI efforts were limited by the EHR, modifications made to EHR software, and on network and CHC perspectives on the barriers and facilitators to utilizing the EHR as part of QI efforts, including network provided services. Interviews were conducted either in person or over the phone, audio recorded, and transcribed. Interviewees at the CHC and network level included medical directors and other clinical leaders, other clinicians using the EHR, senior executives and managers, and technical staff. At least three interviews were conducted for each case (both network and CHC). Interviews almost always included the CEO or Executive Director, a clinical leader (almost always the medical director), and one person with technical expertise on the EHR and often included directors of quality and front line providers. Data from over 68 hours of interview data were collected from 75 CHCs. Additional observational data was collected from EHR software demonstrations.

2.4. Data Analysis

The interviews produced a dataset composed of detailed and contextually laden observations, personal experiences, and professional expertise. The richness of information contained in the qualitative data could not be captured by statistics alone. Further, the relatively small sample size and the varying expertise of the individual interviewed did not lend itself to a quantitative analysis of the data. Therefore I used a qualitative approach to analyze my data and complemented it with a mechanistic approach to parsing through the data to ensure that I did not miss any data.

Data collection and analysis for this project was an iterative process that began as data collection started and evolved throughout data acquisition to focus on areas of particular interest. This process allowed new insights to be tested and validated, thus ensuring the data collected was able to answer the most relevant questions. Re-interviews were conducted to follow-up on areas of interest that were not fully explored during initial interviews. These are common techniques within qualitative research.

At the outset of analysis, I developed a preliminary set of codes, used to identify salient features of particular quotations from interview transcripts. The coding allowed for the rapid retrieval and analysis of sets of quotations corresponding to a code or set of codes. The initial codes corresponded to concepts from questions in the questionnaires. Dr. Miller and I then refined and revised these codes. We began by coding a series of interviews together, clarifying the meanings of codes, removing codes that were underutilized, and adding codes for important concepts that were not captured by existing codes. During the coding of the first dozen transcripts, numerous changes and revisions were made to the coding; after this point, the codes changed only slightly. Throughout the coding process, Dr. Miller and I met on a weekly

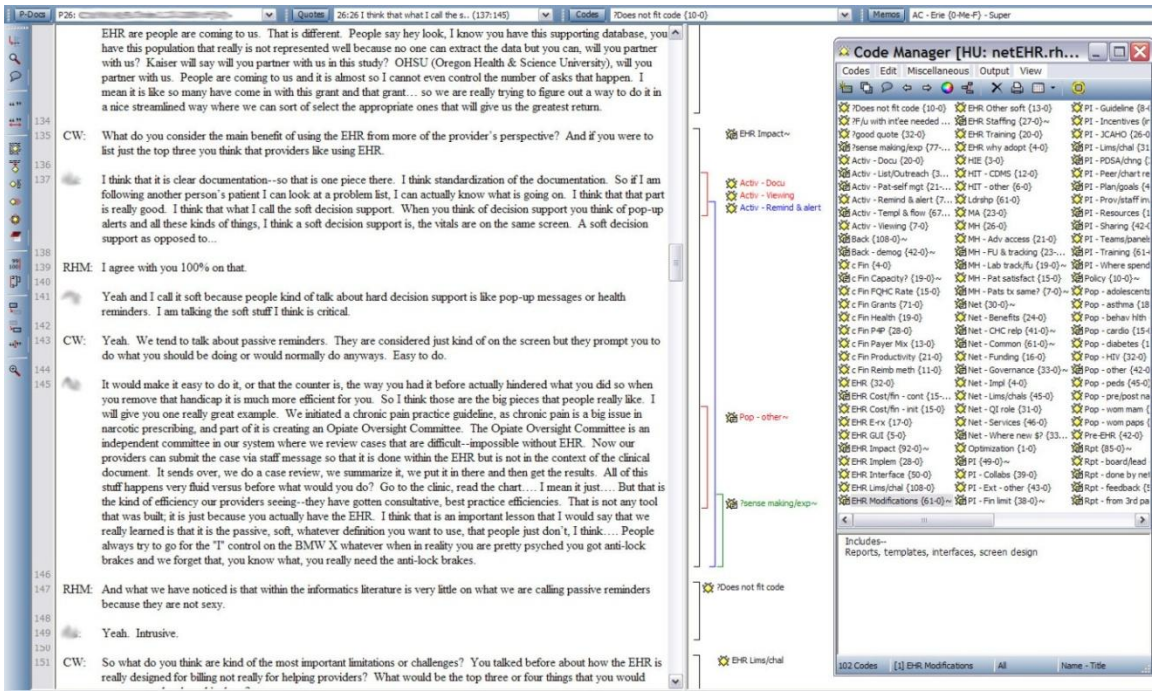
basis to review interviews that we had both coded, discuss insights, ensure we were coding similarly, and to make changes to the coding scheme as needed.

The coding scheme has a hierarchical structure. Most specific codes are grouped into a larger concept category. For example, a code like "limits/challenges" is used for all types of limits and challenges experienced by the key informants. To make this code more searchable, being in the "EHR" concept category as opposed to "Reporting" concept category clarifies the type of challenge captured within the quote. Additionally, the broader concept categories enabled searching on all quotes relevant to the broad category, like "Reporting" or "Performance Improvement."

Coding began by importing interview transcripts into a software program called ATLAS.ti[7] and utilizing the software to manually map codes to quotations from interview transcripts. A screenshot of a coded interview transcript can be seen in Figure 2.1. Please note: a) sections of text can be assigned to multiple codes, b) the list of codes on the right hand side of the screen shows a partial list of available, c) codes are organized by concept category with a short prefix indicating the category (e.g. PI stands for performance improvement activities). We utilized 101 codes, largely falling into 10 concept categories for the larger project. A complete list of concepts and codes are listed in appendix 2.1.

[7] ATLAS.ti Scientific Software Development GmbH. ATLAS.ti is a software program that can assist the researcher with data management, coding, and analysis. It is important to understand that the software is simply a tool and the researcher is responsible for all of the interpretive portions of the analysis.

Figure 2.1. ATLAS.ti Screenshot



To describe how the analysis was done, I present an overview of the steps used for each functionality and then walk through a specific example, Electronic Communication and Connectivity.

Once all of the data was coded, I used the codes to identify portions of the interviews that addressed each of the core EHR functionalities. First, I broke down each of the core EHR functionalities into their underlying components, utilizing the descriptions in the IOM report. For example, Electronic Communication and Connectivity consisted of electronic messaging within the practice, secure messaging to people and patients outside of the practice, and interfaces to data sources external to the EHR. Once I outlined the components of each functionality, I mapped combinations of ATLAS.ti codes and to the components to identify all of the quotations most directly relevant to each component. Table 2.3 lists all of the core EHR functional areas and corresponding codes I used to identify applicable interview quotes.

Table 2.3 Analysis strategy for each core EHR functionality

Core EHR Functionality	Concept Areas	Codes*	Additional Keyword Searches
Health Information and Data	Activities using the EHR	**Documentation** **Template and flowsheet** Viewing	Template Form Structure Data entry Flow sheet Click Screen
	EHR	Graphical user interface Impact **Limits/Challenges** **Modifications** Training	
	PI Activities	Guidelines Limits/Challenges	
Electronic Connectivity and Communication	Activities using the EHR	Patient self management	Interface LabCorp Quest Lab Pharm Immunization Iz Radiology Imaging Hospital
	EHR	**E-Prescribing** **Interface** Limits/Challenges Modifications	
	PI Activities	Limits/Challenges	
	Reporting	Limits/Challenges	
Order Entry and Management	EHR	**E-prescribing** **Interface** Limits/Challenges	Order Entry Pharm Lab Referral
	PI Activities	Limits/Challenges	
Results Management	Activities using the EHR	**List/Outreach**	Result Referral Lab Test
	EHR	Interface Limits/Challenges	
	Medical Homes	**Follow-up and patient tracking** **Lab tracking**	
	PI Activities	Limits/Challenges	
Decision Support	Activities using the EHR	**Reminder and alert** Template and flowsheet	Reminder Alert Pop-up Red Decision Support Guide
	EHR	Limits/Challenges Modifications	
	PI Activities	Limits/Challenges	
Patient Support	Activities using the EHR	**Patient self management**	Self management Portal Education Ed
	EHR	Other Software	
Administrative Processing	EHR	Interface	Bill Schedule Admin Practice management
	Medical Homes	**Advanced Access**	

Reporting and Population Health Management	Activities using the EHR	**List/Outreach**	Report Valid Feedback Logic Rule
	EHR	Interface Limits/Challenges Modifications **Other Software**	
	Reporting	**Report** **Done by network** **Feedback** **Limits/Challenges** To external organization **Validation**	

* Codes in **bold** are the initial codes used in the analysis of given functional area

Once I had the lists of quotations for each functional area I analyzed the data using pattern-matching[8] and explanation building techniques[9][37, 38]. These techniques have been used successfully in several previously described qualitative studies on clinical information systems – EHRs in various practice sizes, chronic disease management systems[9, 10, 34-36].

I compiled and summarized the results of the pattern-matching and explanation building techniques within each core functional area. These summaries enabled me to spot trends in the data and run additional queries on applicable codes that might have been missed in the original search. I also used the summaries to identify keywords common to the functional area and ran additional keyword searches to ensure I did not miss any relevant data. The analysis technique is thus iterative; the additional data was then incorporated back into the summary of each functional area.

For example, the function of Electronic Communication and Connectivity primarily consists of three components: a) intra-practice messaging, b) messaging with entities outside of

[8] Pattern matching involved looking at the extent to which a prior hypothesis is upheld in each of the study cases. For example, I looked at the data to support or refute my hypothesis that technical limitations encountered by CHCs were acting as a binding constraint on EHR-enabled care management activities and services.

[9] Explanation building involves building and testing a working hypothesis based on the data collected. For example, when data suggested that users of only a single EHR appeared to face a particular limitation (i.e. slow system response time limiting the use of templates that take time to load) I reviewed the data to determine if data showed that these limitations were present in other CHCs, if they could be attributed to a particular EHR or particular CHC network, or if another set of factors were involved.

the practice, and c) interfaces with data sources external to the EHR. To analyze the interfaces component of this functionality, I ran an initial report on all quotations with the code *EHR interface*, producing a list of quotations in which interfaces were discussed. I then summarized this data, organizing the data by the type of interface discussed (e.g. laboratory, pharmacy, radiology/imaging, hospital, state disease or immunization registries, specialists and other providers outside of the CHC, and EPM systems). The summary described the state of development and specific challenges and limitations that existed for each type of interface. Once I had uncovered the types of interfaces that faced barriers, I ran a search on related terms for each interface type. For example, interfaces to the pharmacy repeated arose, so I ran reports on *EHR E-prescribing,* and did a text searches on "pharmacy" and "interface" to fill in all information related to the pharmacy interface. This data was then analyzed and added to the summary for pharmacy.

A similar process was repeated for each of the IOM EHR functionalities and important aspects of each functionality.

3. Results

In this section I go through each of the core EHR functional areas as described by the IOM and delineate the limitations to quality improvement efforts encountered while using the EHR and highlight how problems were either overcome or are still outstanding[23]. Some issues arose with great frequency among the sample, like templates, interfaces, decision support, and reporting so much time will be devoted to understanding these areas in detail. Other difficulties will be mentioned in less detail. I present the results within the framework of Institute of Medicine's list of core EHR functions: health information and data, electronic communication and connectivity, results management, order entry/management, decision support, patient support, administrative processes, reporting and population health management. Some technical limitations underlying the EHR such as interfaces, database designs, and lack of clinical logic, appear as limitations in multiple functional categories.

3.1. Health Information/data

In identifying the core functionalities of an EHR, the IOM report laid out four goals that an EHR should be able to meet: improve patient safety, support the delivery of effective patient care, facilitate management of chronic conditions, and improve efficiency. While health

information and data are not “functions” in and of themselves, in order to achieve any of these goals, the EHR must support the documentation (data entry), storage, and retrieval of health information and data. For the purposes of this analysis, health information and data consists of the collection of patient data necessary to make sound clinical decisions – including diagnosis, notes from prior encounters, demographics, and laboratory study results.

For most EHR users, their primary interaction with the function of health information and data was mainly through data entry and data viewing. The primary mechanisms CHCs used to input discrete data into the EHR were through templates (documentation forms) and interfaces with other electronic data sources (e.g. laboratory, EPMS, or pharmacy). Data were typically viewed through the use of templates. In this section templates and the technological limitations encountered with templates will be discussed at great length. Interfaces will be discussed in detail under the following sections, Electronic Connectivity and Communication.

3.1.1. Templates

Templates provide structure to EHR data input and display. For a given care area (e.g. diabetes, upper respiratory infection, or well-child) templates serve three purposes. First, templates present data that are most likely going to be needed for a given area of care. This is a form of “cognitive support” in which data are presented to assist in the thinking about a problem or issue, but no real world decision is reached (e.g. having vital signs all on the same screen or a summary view of all important lab values). Secondly, templates provide discrete data entry fields for the items most likely to be asked about regarding that care area or that need to be captured as discrete data for performance measurement. By combining the first two along with prompts for particular services needed based on a patient’s data, the third purpose, supporting provider and staff decision making, is also achieved.

At the point of care, the template was the EHR tool CHCs utilized most often to support quality improvement. All CHC Networks engaged in template development for a multitude of chronic and preventive care areas in order to help providers document efficiently, generate more complete notes with reportable data, enable decision support, order tests/services more easily, and delegate tasks to nurses and medical assistants. Templates, not only supported discrete data entry for QI purposes, but also acted as a decision support tool by presenting patient data needed to make decisions in a logically structured manner and providing prompts for needed services. Without the template in place for specific care areas, CHCs found it difficult engage in performance improvement activities.

3.1.2. Purpose of templates

During the visit, templates enabled two major functionalities: documentation and decision support. Documentation consisted of compiling a record of the care that was provided during the visit. Decision support is a separate IOM function that will be discussed in detail shortly; in this section I focus primarily on documentation.

Documentation captured information for billing, reporting, and legal purposes and to establish a continuous medical record. CHCs placed great emphasis on capturing some of this information as discrete data elements codified to have a standard meaning. Without such explicit capture and definition, the data could not be used later for purposes as diverse as filing billing claims, analyzing data for internal purposes, and fulfilling reporting requirements for 3rd party agencies. For instance, funding for a number of CHC HIV programs was contingent upon the CHC providing a federal funding agency with specific data about numbers of visits, laboratory test results, and clinical findings for each patient with HIV. In order to accommodate

these data demands, the HIV template had to be structured in such a way as to capture the necessary data as discrete data elements.

Documenting discrete data in templates was especially important for services such as a diabetic foot exams where without the template, there was no way capture the foot exam as discrete data. Not having a discrete field for this data meant that the data could not be reported on and could not be included in decision support. The ability to collect discrete data during documentation was a prerequisite for many of the more advanced QI functions.

3.1.3. Template availability

As previously described, templates were a key component to QI efforts during the visit. However, only a limited (albeit growing) number of templates were provided by the vendor, which forced networks, CHCs, and providers to create or modify templates, which slowed down QI activities.

Compared to other technological limitations that will be discussed, tremendous differences existed among EHR products in availability of templates and the ease of creating/modifying templates:

- *Medical Manager:* Health Choice Network's (HCN) EHR (Medical Manager, was subsequently purchased by Sage and merged into Sage's existing EHR to create a product called Intergy) included essentially no useful templates with the software. HCN devoted many resources towards improving the software, including extensive template development. After Sage purchased Medical Manger, HCN acted as a co-developer of the new software product (Intergy) integrating many HCN-designed capabilities aimed at addressing software limitations and CHC specific needs. After contributing tens of

thousands of lines of code and hundreds of hours of clinical input and software testing, HCN was in the process of converting to the new product. The HCN developed templates and modifications are being incorporated into the base software package and are available to Sage's other clients.

- *Centricity EMR:* The Alliance of Chicago's (AC) EHR also included only a limited number of templates with the software. AC recognized the importance that templates would have for their QI efforts and invested over a year's worth of developmental effort prior to implementing the software to create templates based on the latest clinical guidelines. This came out to several thousand person hours for the development and hundreds of hours of medical director time, a very sizable investment. The network was satisfied with their initial attempt at creating templates, but was already gearing up to revisit the templates and apply the lessons learned using the templates. Even though GE has been developing a few starter templates, for many care areas, a new Centricity EMR customers would need to go through a similar development process or try to license templates that have already been developed by other users in order to have a library of templates that met their needs.

- *EpicCare:* OCHIN's EHR included no templates with the software, but made available a library of templates developed by other clients and organizations using Epic. The template library worked as a jumping off point, but needed substantial customization to address issues and requirements specific to the CHC sector, incorporate clinical logic into their design, and to match clinic workflows. OCHIN invested heavily in the development of its own "SmartForms" and "SmartSets" to overcome these limitations[10].

[10] SmartSets consisted of a series of expandable checkboxes that allow the user to click through standardized parts of the visit including documentation of a diagnosis, placing an order or set of labs

However, key informants reported the OCHIN-developed SmartForms and Sets were not often used because providers found the premade forms too rigid and preferred using another, more flexible, documentation tool called a dot-phrase[11].This experience demonstrates the challenges that existed in using the multiple documentation tools in EpicCare. OCHIN used up a large amount of their resources that could have been used for QI or other purposes developing tools that were not well utilized because they did fully understand when they began development how providers would choose to use the system.

- *NextGen:* PTSO's EHR, like EpicCare, included no templates with the software but made available a library of templates developed by all clients and organizations using NextGen. Though this large library enabled new clients to access many templates, the templates had not been rigorously verified, so many of them were of poor quality or contained customizations specific to a particular EHR configuration. PTSO used this library to begin their collection of templates, but had to invest a considerable amount of resources debugging the templates, verifying the templates contained the required data fields, and retooling them to meet the needs of their CHCs. Due to pulling templates from a variety of sources, each template functioned slightly differently. As will be discussed later, providers disliked the lack of uniform look and behavior. Also, as with

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relevant to the diagnosis, and ordering prescriptions. SmartForms were designed to be able to document an entire encounter for a specific care area from within the form. The forms consisted of checkbox elements similar to the SmartSet, but also included fields to document clinical findings.

[11] Dot-phrases consisted of short segments of text along with data pulled in from other parts of the patient's record and discrete data fields. Providers documented the patient encounter by pulling in a sequence dot-phrases applicable to the encounter. Like other templates, dot-phrases could be condition-specific and prompt the provider to ask certain questions or perform certain procedures. Dot-phrases could be easily created or modified by providers, allowing providers to create a custom set that suited their personal documentation style. The downside of dot-phrases was that compared to other forms of template, dot-phrases were so customizable that overall documentation was less uniform. This made it harder to ensure particular discrete data was captured during the visit and that decision support embedded into the basic documentation tool was utilized.

Centricity EMR, the vendor was in the process of slowly rolling out improved templates, but the available templates were still were not sufficient to meet the needs of PTSO members.

3.1.4. Template development

CHC networks frequently needed to modify existing templates or create new templates to meet member CHCs' needs. These templates were typically customized only at the Network level meaning that all member CHCs used the same templates except for a few cases when CHC specific development was needed. Individual users or units did not have access to their own customized versions (except in the form of dot-phrases). All networks reported numerous cases where templates required modification based on sub-optimal behavior[12] or usability, changes in clinical guidelines, or changes in data that needed to be reported.

Unfortunately, the template development process was cumbersome, requiring a large amount of resources, both in terms of technical expertise to modify the templates and clinical expertise to guide changes and understand the impact that changes in the software will have on clinicians. The difficulties associated with template updates were a technological limitation of the software.

Template content changes frequently occurred for various reasons:

- Ease of use or usefulness: The initial version of a template was not as easy to use or useful as users desired. All of the networks had to revise and update templates for clinical content and usability in response to user feedback. For successful

[12] Behavior refers to the system's action when an event is triggered, such as clicking on a button or hitting the tab or enter key after entering data.

improvements, the templates needed to be reworked and tested, using both clinical and technological expertise.

- Changing evidence base: The ever shifting clinical evidence base and the need to update decision support embedded into templates. For example, the American College of Obstetricians and Gynecologists pap smear guidelines released in December 2009 changed the recommended age for the initial pap smear and frequency thereafter[39]. A template that prompted the provider to perform a pap smear annually based on the older guideline will need to be updated to include logic to prompt at the recommended interval depending on patient age and history.

- Changes in reporting: Templates needed to be able to capture the data needed for funding, reimbursement, or quality improvement among numerous areas. As new standards came out for reporting of data in order to obtain grant funding or to document services for billing, new discrete data entry fields needed to be added to the record system to capture the information. Similarly as CHCs undertook new QI initiatives they needed to gather data that may not have been present in the EHR to measure their performance and work on strategies for improvement.

- Software upgrades: Despite the effort that went into creating and modifying templates, there was no guarantee that user-created templates would function correctly with software upgrades. The need to repair templates or rework templates to fit with changes implemented by the vendor led to a lot of repeated work, frustration, and stifled innovation. PTSO found this particularly problematic, as they started with a large set of templates customized in-house, but began to move away from their custom templates to the vendor's templates in order to match software upgrades. The effort

required to repair custom templates to work with software upgrades was continuously being weighed against switching to the vendor's templates which may not have had the functionality desired by the CHC's, but had a clear upgrade path.

Template modification and creation was a formidable challenge due to the amount of technical and clinical resources required. While the development process was slightly different depending on software and network, the general approach was similar across platforms. Modification began with user's request. This request was then triaged by the network's technical staff. If the technical staff deemed the request important enough, it was passed on to the clinical committee (typically consisting of clinical leaders representing each community health center). The clinical committee then decided on whether or not to allocate resources toward modifying the template and offered clinical insight on the problem. If approved, the technical staff investigated and solved the problem, creating a modified template. This template was brought back to the committee for review. This whole back and forth process was slow, time and resource intensive, and filled with potential pitfalls, both technical and political. For the purpose of this dissertation, only the technical limitations are covered.

The step described as "the technical staff investigated and solves the problem" was actually quite complex. An OCHIN CHC described the process as follows for attempting to add one class to a list of financial classes of patients.

> Well we asked for a new financial class called indigent care. It didn't sound that complicated. It's a drop down. We just wanted a simple financial class changed. Well it's been 14 months, we still don't have it. Turns out its going to affect more than just us. It turns out its going to affect anybody who has been using the Healthy Kids and Healthy Families programs. To get past data into the same format they would have to go and change all of the previous billing (data in the EHR) and to do this they had to get

(the vendor) involved…. One little change for (our CHC) has far reaching effects and like I said it's been 14 months since we asked for it.

What seemed like a simple issue actually involved changes to the database, changes to the template, discussions with the vendor about the ramifications of the changes because figuring that out was beyond the skill sets of even the highly trained network staff, and a need to back populate data. This scenario was not unique to EpicCare, but typical of template changes.

Because this extensive development work could not be shared beyond a single network a tremendous amount of resources were spent doing very similar work. Template modification was a large use of resources that potentially could have been applied to other QI projects.

3.1.5. Technical factors that reduced template use

Ultimately, templates could only effectively capture data and provide decision support if the providers regularly used them. Managers estimated appropriate template use (i.e. using the applicable template for a given chronic or preventive care area) to be between 30% and 60%. Numerous technical factors played a role in limiting template use and thus limited the impact that templates could have on QI.

Key clinical informants across networks provided examples of how technical factors acted to limit template use. These examples fit into three main categories: usability, efficiency and usefulness.

Usability:

The usability of the templates was a major problem that limited their widespread use. Common usability problems included:

- *Intuitiveness*: Clinical informants regularly described documentation using the EHR as "clunky" and "non-intuitive". The non-intuitiveness of the templates included challenges using the template's interface to find information or to cause the system to produce a desired result. Providers were generally able to adapt and learn a small number of templates quite well. However, a lack of a consistent "look and feel"[13] between templates heightened the non-intuitiveness problem. Users wanted to be able to quickly find the information they were searching for and were "thrown-off" when there was inconsistency in placement of data elements or when interactions with the user interface produced unexpected results. These issues combined to give each separate template s substantial learning curve associated with it that providers had to overcome. Often providers found it simpler to just not use unfamiliar templates rather than expend the time and energy to learn the new, non-intuitive template.

The problem with consistent look and feel was particularly striking with PTSOs NextGen implementation. Numerous templates had been imported from a variety of sources meaning that each had their own distinct layout and set of behaviors. One recurring issue was behavior on closing the template. While most templates would return the user to the "adult office visit" screen where the majority of documentation took place, some did not, disrupting the flow of visit documentation. This is representative of a class of NextGen quirks PTSO reported where interactions with the EHR seemed like they should cause the EHR to have a certain behavior and did not. Users also reported difficulty in finding information and knowing where to enter data due to different layouts in different templates.

[13] Look refers to display elements such as color, shapes, typefaces and the layout of elements on the screen such as data fields, text boxes, menus, and other interface and data elements. Feel refers to the behavior of dynamic elements such as buttons, boxes, and menus.

- *Mouse clicks:* Providers at every network (except those in OCHIN adept at using dot-phrases in Epic) regularly complained to managers about the documentation requiring too many mouse clicks. This slowed data input, reduced compliance with template use, and frequently caused requests for template modifications to be sent to the technical staff.

- *Multiple screens:* Key informants at each network described a frustrating need to shuffle between multiple windows to find the information necessary for a particular patient encounter (again this problem was less severe for those using EpicCare due to more dynamic nature of their documentation tools). This problem became even more acute for patients with multiple conditions. In this case, many providers chose to use only a single template relevant to the patient's chief complaint and ignored the other templates that could apply for the visit. This often meant that patient did not receive all needed services. For instance, if a diabetic with heart disease came in for an upper respiratory infection, then only the URI would be dealt with, even though the patient may have needed several services related to their diabetes and heart disease.

Efficiency

The time it took to document an encounter was another aspect of the templates that hindered their use.

- *Usability:* As described above, when information was difficult to find and templates lacked uniform look and feel, documentation was slowed down. These limitations accounted for some of the extra time key clinical informants reported providers spent documenting.

- *Increased data collection:* When using templates, many providers found they were asked to more thoroughly document aspects of the patient encounter in order to collect more data than was required with a paper chart. While a boon for reporting and decision support, this meant that even if the provider was as fast entering data into the computer as they were on paper, the overall time to document an encounter increased.
- *System lag:* Providers reported lag hindering template use. Lag refers to delays in system response noticeable to the end user. This effect was present at times in every EHR, but was most acutely felt with PTSO's NextGen implementation. It was not uncommon for NextGen to take more than one minute to load a template. In the course of a fifteen minute encounter this meant that providers were hesitant to pull up any templates due to the time the system would spend loading.

Usefulness

Template compliance suffered when providers did not feel a compelling reason to use a particular template. Managers reported that providers did not feel that the advantages for using the template to do documentation outweighed the challenges of learning to use the template and using the template routinely. Providers often found it easier pick a few templates to learn well and to fit whatever they could into those templates instead of choosing the most appropriate template for a particular patient since "most of the fields are the same."

Due to the time it took to learn to use templates and efficiently navigate them, the great majority of providers regularly used only a small subset of the available templates. Providers routinely forced encounter documentation to fit into their favorite templates, even if more appropriate templates were available. The provider then did not receive the full benefits of structured documentation and decision support that were embedded into the condition-specific

templates. As a result, the technological limitations of layout and behavior had the potential to translate into sub-ideal care. Any QI logic that had been embedded into the unused templates was not being utilized.

The issues of usability, efficiency, and usefulness were being worked on by all of the CHC networks as well as the vendors. Most of the networks had finished an initial round of template development and were engaging in a second round to address the issues described above. These efforts were primarily focused on creating templates with a more uniform look and feel that were also more useful and efficient. The vendors, such as GE and NextGen had also begun work to address these issues, but progress was slow and insufficient to meet the needs of CHC users. In fact, Sage did not have the development expertise needed for the Community Health sector and partnered with HCN partnered to develop templates for Sage's CHC clients that were not members of the network.

Even though template development work should help to increase appropriate template use, more rigorous studies are needed to ascertain the extent to which provider use of appropriate templates is a problem, the influence of each factor on providers template use, and to explore other methods other than templates for users to interface with the EHR.

3.1.6. Interfaces

The goal of interfacing with other electronic data sources is to incorporate external data into a patient's electronic record. This route of data acquisition is detailed in the next section.

3.2. Electronic Connectivity and Communication

3.2.1. Electronic connectivity and interfaces

Electronic connectivity and interfaces involve electronically connecting to another system for the purpose of sharing data between systems. Connectivity is essential in order to have a complete heath record and to be able to coordinate care across multiple settings. Interfaces consist of a set of protocols and codes that governed the flow of electronic information between two electronic systems and give meaning to the data that is transferred. Interfaces are either bi-directional with data flowing back and forth between data systems or one-way with data flowing in only one direction. Of note, RHIOs (regional health information organizations that facilitate the sharing of health information between stakeholders in a defined geographic region) were not functioning in areas study CHCs served. There is the potential in the future for RHIOs to play a role in connectivity.

CHCs and networks reported unique problems interfacing with a number electronic data sharing partners. The data sharing partner, type of interface (internal to the CHC or external), and purpose of the interface are highlighted in table 3.1. Detailed descriptions of each data sharing entity and the problems creating interfaces follow below.

Table 3.1 Types of interfaces

Data sharing entity	Interface Type	Purpose
Laboratory	Typically external	Electronic submission of laboratory orders to diagnostic companies such as Quest Diagnostics or LabCorp and electronic return of results.
Pharmacy	Typically external	Electronic submission of prescriptions to pharmacies and return of data on whether or not the prescription was filled

EPMS[14]	Internal	For non integrated EHR/EPMS, a connection to send data between the EHR and EPMS
Radiology/ Imaging	Typically external	Electronic submission of imaging study order and return of the images and readings into the EHR.
Hospital	External	Electronic input of data from hospital encounters including care notes, diagnostic tests, and specimen analysis.
Specialist	External	Electronic submission of referrals and electronic return of referral notes into the EHR.
Childhood Immunization Registries	External	Electronic viewing and update of the EHR with current immunization records and submission of completed immunization records. States or regions typically have requirements to enter childhood immunization data into a designated registry and this is considered the most up-to-date source of immunization data.

Of these types of interfaces, laboratory, pharmacy, and EPMS interfaces were encountered most often. All networks and CHCs had problems obtaining data from radiology/imaging, hospital, specialists and external providers, and state disease or immunization registries.

Laboratory

Almost all CHCs in the study (12 of 13) contracted with laboratory test vendors for diagnostic testing and/or specimen analysis. The responsibility for developing and maintaining the interface varied between networks and even between CHCs depending on size and resources. Two CHC Networks (AC and HCN) acted as the primary contact with the lab companies. In the other two networks, the CHCs and the CHC Network worked together with the lab company around the interface issues. For the purposes of this discussion, networks and CHCs that worked to develop interfaces will be referred to as users. Users encountered relatively few challenges sending lab test ordering information to the laboratory company once the initial interface was developed, however most reported challenges with the way results

[14] Electronic Practice Management System

were returned. These challenges fell into two main categories: results formatting and shifting result codes.

Users reported challenges with the lack of standardization in the format that results were sent back to the EHR. According to the CIO at an OCHIN CHC, "[The lab company] basically took what was on a paper and shoved it into an electronic file." This meant that initially, laboratory companies were sending data without considering how the formatting would impact the usefulness of the data in the EHR.

The issue became particularly problematic when importing test results with non-numeric values into the EHR. Pap smears and mammograms were the examples most often cited, with most CHCs or networks having to work through results formatting. Typically, prior to the EHR, pap smear results were presented as a block of text on a piece of paper explaining the pathologist's findings. However, when the result was returned over an electronic interface, providers wanted and expected a simple flag indicating if the result was normal, abnormal, or questionable, in order to prioritize result handling because according to the same OCHIN CHC CIO, "providers see several hundred results a day and it can be overwhelming…providers don't want to have to read through a couple of hundred words… to figure out what the overall result of the test is." A further problem occurred if flags indicating whether or not a pap smear had been completed were not set in the EHR when the result was returned. This hindered the ability of CHCs to run reports on pap smear data and their ability to trigger decision support based on the test result.

The lack of easy to interpret standardized result format was an issue faced by all users. Users devised a number of solutions for pap smear results including: maintaining pap smears as paper results scanned into the EHR, hiring someone to manually review all results in order to set

flags in the EHR and enter the data, taking a block of electronic text as the lab result and depend on providers to sort through the results, or working with the lab vendor to include standard wording for each type of result (normal, abnormal, or questionable) so that each result could undergo automated text processing to set a flag in the EHR for the result. All of these solutions were worked through on a case by case basis. This meant while the pap smear issue may have been addressed, the issue of correctly flagging results might still be outstanding for mammograms or any other lab test or diagnostic study.

The above problem meant that results of each type of lab test sent across the interface needed to be checked for accuracy. This process entailed looking at a large enough sample of data for each type of lab test sent to verify that the results coming across the interface were accurate and in the expected format. Due to the large amounts of data and the numerous types of lab tests, verify tests result accuracy was extremely resource intensive, even for large resource rich CHCs or CHC Networks, and unfeasible for most small CHCs.

Another common challenge users faced was that the lab companies would frequently change the codes used to refer to a particular test or value without notifying the affected party. This meant that users were, according to the AC, “constantly left playing catch up with the reference labs”. The shifting of codes, if not constantly monitored and corrected, had implication on the integrity of the database and could impact the validity of reports and decision support that utilized the affected data and were a central part of QI efforts.

Pharmacy

Pharmacy interfaces were not well developed in the sample. Only CHI and EOC from HCN had pharmacy interfaces. CHI’s interface was to its own internal pharmacy and EOC had established a one-way interface to enter in prescriptions for a small group of clients but was not

able to receive any information back as to whether or not the order was filled. The PTSO, OCHIN, and AC CHCs studied did not have pharmacy interfaces, but a few were "working on it." CHCs typically handed patients prescription slips or faxed prescriptions, negating some of the benefits of paperless prescribing. Ideally a full pharmacy interface would enable providers to see whether or not patients fill their orders and reduce the number of lost scripts; with the paper system this was completely unfeasible.

Electronic Practice Management System (EPMS)

Three CHC networks used an integrated EPMS and EHR, enabling transparent dataflow between the systems. In the AC, these systems were separated, and the systems did not communicate well, with only a one way interface sending data from the EHR to the EPMS. As a result, the EHR did not have access to information from the EPMS. Therefore there was no record in the EHR of services documented solely through the billing process or entered directly into the EPMS unless the data were also manually entered into the EHR. This meant that that data such as demographics, diagnosis, or services performed outside of the health center such as mammography were not always available for decision support or when reporting from the EHR.

Adding to the challenge of a non-integrated system was that both the EHR and EPMS vendors needed to be involved to solve problems with systems communications. Users reported blame for the systems not working together being passed back and forth between vendors and not being resolved. As a result of only having a one way interface and desiring the simplicity of a single, integrated system by a single vendor, AC was in the process of moving study CHCs to an integrated EHR/EPMS version of Centricity EMR that was already being used by other AC CHCs.

Radiology/imaging

None of the CHCs in the study had working radiology interfaces, though two CHCs reported a strong desire for such an interface. No interviewees were able to describe the challenges to obtaining radiology interfaces.

Hospital

Discharge data from hospital visits was typically scanned into the EHR if it was entered at all. Scanned data was not electronically searchable and so not stored in a useable form for reporting or decision support.

One CHC reported the ability to view hospital data by logging into the hospital's system and none of the CHCs had interfaces with hospital information systems. Likewise no arrangements existed for hospitals to electronically access CHC's data. However, a number of users expressed a strong desire for data sharing. The providers in one CHC's clinical committee stated, "[Our EHR] lacks integration with all of the things that would make all of this agony worth it, specialty and hospital systems." The data collected during hospitalization was rich with information and important for the patient's health and for continuity of care in the primary care setting. However, to input hospital data electronically into the EHR frequently required manual triage, extraction, and input, which the CHCs lacked the resources to perform.

Specialists

No CHCs reported interfaces with specialists or other providers in the community. The lack of interfaces to share data between providers meant that there was a greater potential for duplicate testing and poor care coordination. Managers reported providers would often refer

patients out to specialist and then never receive a report back about the care provided. If a provider did receive a report back, then it would be up to them or their staff to either scan the report into the computer eliminating most of the benefits of electronic data, or to triage the report and manually enter any important data into the EHR, an inefficient and error prone process.

Childhood Immunization Registries

Creating an interface between registries run by governmental entities and the EHRs was fraught with political road blocks no CHCs were able to fully surmount. Two problems resulted from the inability of the EHR to communicate with the registry. For one, when providing immunizations providers had to input the data twice--into both the governmental registry and the local EHR. This double entry increased the chances of data entry errors and was an inefficient use of time. Secondly, the governmental registries contained the child's official immunization records, which could be downloaded into the EHR. Lacking the official record on site interrupted the provider's workflow during the visit as the provider had to log into the registry to access the records and then move back and forth between the registry and the EHR over the course of visit. Additionally, not having the official immunization record in the EHR was a barrier to accurate decision support and reporting.

3.2.2. Electronic communication

Electronic communication consists of tools such as intra-practice messaging through the EHR, e-mail, and patient web portals to facilitate provider, staff, and patient communication. Communication tools had the potential to enhance patient safety and quality of care by ensuring messages rapidly and securely reached their intended target and provided a venue for

patient questions to be answered outside of the visit, potentially avoiding unnecessary visits and increasing efficiency. Two primary forms of messaging existed – internal to the practice between providers and staff and external, primarily between providers and patients.

CHCs reported satisfaction with the messaging tools built into the EHR to send messages between providers and staff within the practice. The CHCs where messaging functionality was not regularly used reported culture as the primary reason. Within practice electronic communication was one of the few areas of the EHR where the technology was not a serious limitation.

While messaging within the practice was common, none of the CHCs in the study reported CHC sanctioned messaging with patients, either via email or secure patient portals. Because of the lack of implementation, the functionality of patient messaging could not be evaluated as part of this study.

Even though providers reported patient demand for messaging services, several non-technical barriers to implementation existed. The primary barriers to implementing patient messaging technologies were the cost of adding messaging modules onto the EHR and concerns about finding expertise to manage the complexity of a secure, HIPPA compliant system. Due to the large expense of setting up secure messaging through modules provided by EHR vendors, CHCs and CHC networks prioritized other uses of their scarce resources. Additionally, concerns about providers being overwhelmed with messages and not having any means to compensate providers for time spent on electronic communications made CHC leaders hesitant to embrace electronic patient communication.

3.3. Order Entry and Management

Order entry and management consist of the ability to electronically order and track the status of prescriptions, laboratory tests, imaging studies, and referrals to specialists or support services. Electronic prescription order entry allows decision support to be applied during the creation of an order which has been show to help prevent medication errors by helping providers choose the most appropriate drug for a given patient, avoid drug-drug or drug-allergy interactions, [40-42]. Electronic ordering can also help eliminate lost orders, ambiguities caused by illegible handwriting or unclear terminology, automate the processing of orders, and allow for providers to see if orders were filled or referrals were completed.

3.3.1. Prescription ordering

Providers in all study CHCs, regardless of EHR, entered prescription orders into the EHR. This enabled providers to receive the benefits of decision support (almost exclusively focusing on drug-drug and drug-allergy interactions) as well as improvements in legibility and ambiguous terminology. However, as described in Electronic Communication and Connectivity, except where CHCs had internal pharmacies, a lack of pharmacy interfaces resulted in prescriptions either being faxed to the pharmacy or printed and handed to the patient. This negated the potential benefits of fewer lost prescriptions and viewing of filled/outstanding orders.

3.3.2. Laboratory ordering

Alls CHCs were able to electronically enter laboratory orders into the EHR and electronically send them to the laboratory. As described in Electronic Communication and Communication, numerous problems were reported with receiving results back.

3.3.3. Referral ordering

Most providers did not have the ability to electronically order referrals or imaging studies due to a lack of interfaces to external entities (e.g. with an oncologist for a woman with an abnormal mammogram). The few interfaces that existed were between an individual CHC and the external entity and were not EHR- or network-dependent. The vast majority of referrals were entered into the EHR and then printed and given to the patient or a care coordinator.

Given the lack of interfaces, handling referrals was a challenging and resource intensive process. Non-EHR processes, such as case management phone calls and compiling separate referral databases, were needed to ensure referrals were completed. The resources necessary for these processes meant CHCs had to either devote extra resources to case management or likely have sub optimal levels of follow-up. Once referrals were completed, it was questionable whether or not the results would be returned to the CHC or how much over the coordination it would take to get the results. Once obtained, results were typically scanned into the EHR. This data was then not searchable and could not be reported on. In order to use this data as part of QI efforts it had to be manually triaged and entered, another resource intensive process that had the potential for errors.

3.4. Result Management

Results management includes both the process—whereby providers view, respond to, and sign-off on results—and the electronic tracking and auditing of results for a given provider or health center. At the provider level, electronic results have the potential to be available immediately (e.g. no need to wait for a results slip or find a paper chart) thus enabling providers to make more informed decisions at the point of care. At the provider or health center level,

results management functionalities in EHRs offer the potential to systematically audit results to ensure no results fell through the cracks as can happen with paper[43] . At the community level, if shared across the health system, electronic results can help decrease the numbers of duplicative lab test and enable better coordination of care between providers.

Types of results include laboratory, radiology, procedures, and referrals. Though multiple types of results exist, this section focuses on the management of lab results because they were the only type of results CHCs were routinely able to obtain in an electronic format and thus highlight the technological limitations of the EHR. Although providers at all study CHCs were able to view most lab results in an electronic format, they were generally unable to achieve the full benefits of electronic results. Lessons learned from laboratory results management can be applied to the management of other referrals as well.

3.4.1. Provider result viewing, response, and signoff

Provider laboratory result management primarily consisted of viewing a result from within the results section of the EHR, responding to the result by interpreting the result, notifying the patient of the implications, and finally signing off in the EHR that they had viewed the result and acted upon it appropriately. The biggest technical obstacle to this process was simply obtaining the data. This issue has been addressed at length in Electronic Connectivity. Lack of a health information exchange infrastructure to obtain data from community sources also contributed to the challenge of obtaining results. Except in one case, electronic linkages did not exist between the CHCs and other community data sources such as hospitals, thus limiting the potential of results viewing to help reduce duplicative testing and enhance continuity of care.

3.4.2. Systematic result auditing

Providers, CHCs, and networks did not systematically audit lab results in order to ensure results were viewed and acted upon within an appropriate amount of time. The exact reasons for this varied from network to network. For example, AC wanted to enable functionality to more rigorously follow provider result management, but the limitations of the EHR stymied their efforts. Centricity EMR featured a flag set to indicate whether or not ordered labs had been processed and the results returned. However, this flag was not automatically switched to completed when the result was sent back from the lab company and so labs remained marked as incomplete until the flag was manually switched in the system (usually by a provider). This meant that there was no way to systematically audit laboratory test results other than to open up every incomplete result in the system to ensure patients went in for their lab test. An accurate report on completed labs could not be run. For users of other EHRs, barriers to ensuring systematic lab result follow-up ranged from similar issues in understanding which labs had been completed to the fact that reports had not been developed to look at provider management of lab results. CHC and Network leadership tended to prioritize the development of other functionality over that of results management. It was interesting to note that key informants from all CHCs partially explained the lack of systematic results tracking as due to the fact that result management was ultimately the responsibility of the provider as a health care professional.

In summary, due to challenges obtaining results through interfaces, under developed EHR functionality to document completed results, and the lack of reports or tools to analyze results handling data, the EHR did not readily support systematically auditing lab results and ensuring each one was viewed in a timely manner and acted upon appropriately.

3.5. Decision Support

There are two main types of decision support: passive and active[44, 45]. Passive or "soft" decision support systems aid with the collection and organization of data, as in the case of using a template with specifically ordered data collection fields to take a patient history. Good template design incorporates many passive elements. On the other hand, active support involves processing data in the system and producing a response specific to the data that is intended to help the user choose between specific courses of action[46]. Active support includes reminders and alerts that stand out: text in red, stop signs, and pop-ups. Some alerts, like drug-drug interactions, concern patient safety, while most others relate to either chronic or preventative care. While there are numerous axes on which decision support functionality can be categorized, the above distinctions are most relevant for this analysis[46, 47].

In order to enable active decision support capabilities, reminders need to be present in the system and backed by solid clinical logic and good data. Further, the reminders need to be structured in such a way that the provider encountered the reminder, trusted the alert, and are able to act upon it.

After briefly describing the types of passive and active decision support encountered, this section will primary focus on active decision support. Limitations to passive support are included within the Health Information and Data section. Throughout the Decision Support section, active support will commonly be referred to as "reminders" and/or "alerts."

3.5.1. Passive decision support

Well designed condition and population specific templates structure the patient encounter by displaying relevant patient data and data entry fields that prompt providers to ask

questions or provide services relevant to the condition or population. Based on the layout of the template, the provider is guided through the actions of the visit in an appropriate order.

CHC networks invested a great deal of resources into embedding best practices into templates, such that a provider fully utilizing a template should have provided "optimal" care as described in the evidenced based guidelines. Providers appreciated the way in which templates helped them ensure they were providing a complete and through visit. One provider raved:

> I appreciate all the prompts. I feel like I'm asking all the questions I should be asking. If it is a routine diabetic I can make sure I am asking all the questions that are appropriate for a diabetic. In the past when I didn't have all these prompts, I forgot to ask things because I was feeling pressure to get on to the next patient and wasn't thinking of them.

Simply having the layout of the template structured with particular data and data entry fields visible provided a logical flow to the visit and supported the provider in making critical decisions. Despite these potential benefits, the fact that much of the decision support logic was locked to the use of a specific data acquisition tool (the template) resulted in an unnecessary linkage between the data collection modality and the provision of decision support. This resulted in missed opportunities for decision support because templates could only impact provider behavior if they were used and many providers chose not to regularly use templates.

3.5.2. Active decision support

Active support can be enacted in one of several ways: pop-ups, on-demand, or embedded into templates. Pop-ups launch new windows on the screen informing the provider of a needed service. On-demand decision support requires the health care worker open up the reminder(s) by selecting a separate tab in the electronic chart (typically referred to as the health

maintenance section (HM)) or clicking on an icon indicating that an alert was waiting. The health maintenance section typically includes a list of services the patient is due for. Pop-ups have been shown to be more effective at changing provider behavior than on-demand alerts[48]. Active decision support can also be embedded into templates. For example, when an appropriate template is used, overdue services for a particular patient can appear in color-coded text to catch the provider's attention.

Active reminders have the potential to be an important part of QI efforts, provided they are presented in an appropriate manner[13]. Ideally, reminders are evidence-based and follow the relevant clinical guidelines. As an example, the American Diabetes Association publishes yearly best practice guidelines for diabetes care[49, 50]. The 2009 edition included over 15 parameters in the guidelines that could be turned into active reminders, ranging from lab tests to retinal screening to performing a foot exam. Other health areas, like heart disease and women's health also have a large list of services, so one could reasonably expect an EHR to include dozens of active reminders.

Despite CHCs considering decision support to be an essential component of the EHR, according to one CHC director, "what good is an EMR if it doesn't direct you down the right care path?", active reminders and alerts were minimally used in CHCs beyond drug-drug and drug-allergy alerts. Numerous technical limitations were encountered by CHC Networks and CHCs trying to implement decision support and limited the impact of decision support on quality improvement efforts. The rest of this section explores the technical limitations the limited the use of active decision support tools in study CHCs

3.5.3. Out-of-the-box reminders[15]

Each EHR studied included the capability to create and display reminders from all three forms of active decision support described above. The prescribing modules of all study EHRs included patient safety reminders that were generally viewed as helpful and well-liked. These included drug-drug and drug-allergy alerts. Clearly software vendors were capable of creating useful reminders, though the majority of vendor efforts went towards prescribing. Only one of the EHRs in the study (Centricity EMR) initially came with a limited standard set of decision support tools enabled for chronic and preventative care (called protocols). Because decision support was absent or highly limited out-of-the-box, networks needed to either enable existing decision support capabilities or customize the software to create capabilities.

Enabling and creating reminders and alerts required clinical input to set all of the criteria and double check all of the data to ensure the clinical soundness of the decision support and technical expertise to implement the desired system changes. Creating decision support was neither a simple nor easy process, and was a significant barrier to using the EHR for QI.

3.5.4. Clinical logic development

Developing the clinical logic was time consuming and resource intensive. All CHC networks followed the same basic protocol for creating or modifying decision support tools. This process was also similar to the process for developing reports and templates. First the clinical committee decided upon the clinical logic which would trigger the decision support and mechanism by which the support would be delivered (e.g. prompt, health maintenance tab). Then the technical staff needed to fully understand the clinical logic in order to implement and

[15] Out-of-the-box refers to the base software package from the vendor without any customization by the networks or CHCs.

test the reminder. Finally, the clinicians validated the decision support to make sure it was triggered appropriately and that it meshed well with clinical flow.

The process for implementing reminders from scratch could be exceedingly slow, often taking months or years. As an example, OCHIN had implemented only one active reminder over the four years of EHR use, with two more scheduled to go live. Much of the delay was due to wrangling over the correct implementation of clinical logic for the reminder and then figuring out where to find the data necessary to implement the logic. The later point is discussed in more detail in the sub-section Data Acquisition and Validity.

The rollout of decision support was slowed by the need to ensure clinical logic matched providers' expectations. Due to the complex nature of decisions such as ordering mammograms or pap smears, implementing the clinical logic to support ordering decisions was more complex and any mistakes could produce conflicts between what the provider expected to do for a patient and the recommendation of the tool. In these cases, multiple factors such as patient age, family history, and prior medical history had to be accounted for in a complex set of logical rules.

Managers at a number of CHCs reported great concern about decision support tools producing recommendations that providers did not agree with. Managers feared faulty logic would cause a loss of provider trust and had the potential to create medical errors. When one network began to move forward with a pap smear reminder believed to be faulty by a CHC's medical director, he called his CIO out of a meeting and asked her to, "deal with this now. I want it turned off. Our providers will freak-out and this is a patient safety issue…. We don't want this turned on for all these people because if providers start to rely on this and find it is not

accurate, they will stop using it entirely and we will never get them to adopt it. If this is going to be implemented, implement it correctly so figure out what the business rules are."

Similar to this medical director, clinical leaders across CHCs and networks were consistently cautious in implementing reminders, wanting to double and triple check logic before going live. The common fear was that if a provider encountered a reminder that did not make sense, they would lose buy-in and subsequently doubt all reminders.

3.5.5. Data acquisition and validity

Active reminders, as previously described, process data from the EHR and produce output specific to a patient's data. As such, reminders can only be as successful as the data that supports them. Any technological limitations that adversely impact the acquisition of data and/or data validity also hinder the success of reminders. Technological limitations that impacted data acquisition and validity included interfaces, documentation tools, and database design (database design is discussed in the Reporting section).

Data acquisition and validity was limited by the interface issues previously described. A striking example of interface issues hindering decision support appeared in the OCHIN implementation of EpicCare. Mammography results were typically returned to OCHIN CHCs as free text findings from the pathologist rather than as discrete data elements. However, the algorithm for generating reminders required discrete data. In order to generate accurate mammogram reminders, each health center needed to either collaborate with their lab company to obtain discrete data as part of the returned results or hand-enter all mammogram results into the system, leading to inefficiencies, wasted time, and the potential for data entry errors.

Any time an interface stopped functioning as intended, reminder quality was compromised. For example, AC had to continuously verify data coming over the laboratory interface because it was not uncommon for the code identifying a particular type of result to change without warning by the reference lab. The pap smears codes in particular changed frequently. When the result code changed, values returned to CHCs suddenly stopped satisfying the criteria for a decision support element. Thus reminders for pap smears were triggered even though the pap smear had already been performed. Broken interfaces occurred regularly in at least two networks. These inappropriate reminders had the potential to lead to duplication of services and eventually to a lack of provider response to reminders once they realized the reminders were incorrect.

If data for reminders did not automatically flow into the EHR via interfaces then some form of manual data entry was required to enter discrete data. Services performed in the office, such as a diabetic foot exam, or lab values from outside sources, such as blood draws during a hospital stay had to be manually entered into the appropriate field in the EHR in order to satisfy the reminder criteria. This mode of entry was fraught with challenges based on the need for providers and staff to enter particular data elements into particular discrete data fields. Key informants reported that data was often entered into unexpected places in the EHR it part due differing workflows between providers using the EHR and the multitude of places providers believed a piece of data could go. Data entered into similarly labeled data entry fields on different screens on the front end often linked to separate database fields on the backend. Finding data entered into an unexpected field was typically not part of the logic underlying reminders and so reminders were triggered when the service had been performed but documentation was incorrect or insufficient. The technological interface should be written to either allow the user a single place where it makes sense to enter a piece of data or should link

to a single field in the database. That this did not occur limited the potential impact of decision support.

At all CHCs, providers reported not getting "credit" for services performed because they were documented inappropriately (e.g. they performed the service, but the reminder was still triggered). This problem was compounded by the complexity of the EHR interface and the challenge of either being able to enter data into multiple fields or not being able to find an appropriate field. The net consequences of data entry problems were an incomplete dataset that did not capture all services rendered and provider disappointment in the system. The fundamental limitation in the technology was that the data must be entered into a particular field to satisfy the reminder, and that entry errors can prevent satisfaction. An improved user interface could be part of the solution to aid providers toward entering data in the proper places and receiving "credit" for their care.

The PTSO implementation of NextGen encountered an additional documentation tool related limitation. For reminders to appropriately trigger, the data used to trigger the reminder had to be current. At PTSO, the health maintenance section of the chart was only updated if the provider opened up the appropriate template after performing the needed service. This meant that if a provider did not open the template after ordering a HbA1c for a diabetic who was overdue, the service would continue to show as overdue in the health maintenance section until the diabetes template is updated. This was problematic because providers often ordered the HbA1c without accessing the diabetes template. Consequences to this included provider annoyance at being unable to satisfy reminders, the potential for completing services multiple times for a single patient, and providers ignoring reminders they believe are chronically incorrect.

3.5.6. Encountering reminders

Reminders can only be effective when the provider views them at an appropriate point during the patient encounter. Nearly universally, EHR implementations did not structure decision support in such a way to support reminder viewing at appropriate times. Poor timing of reminders or the need to seek reminders on-demand interrupted workflow and led to reminders that were not viewed. Key informants discussed three separate technological limitations related to providers utilizing reminders: reminder access, reminder visibility, and reminder timing.

Reminder access

Each Network's EHR had a mechanism for providers to access reminders on-demand by either opening a health maintenance (HM) section in the record, thus disrupting their workflow, or opening up a disease-specific template (see "Templates" subsection for details). Each network generated a HM tool in the EHR for providers to visit. This area of the EHR summarized the set of services the patient was due for (at lease those services for which adequate clinical logic had been developed), giving providers a concise view of labs to order or services needed by the patient. The primary limitation to a HM section as way to present reminders was that the providers had to actively seek out the information "on-demand" which, according to key informants, often did not happen during the course of the visit and led to providers not viewing the decision support that was available.

Similarly encountering reminders was also limited due to decision support being embedded into a template. In this case, the success of the support was predicated upon providers choosing to use a particular template, and as was discussed in "Templates", appropriate template usage was far from ideal. For example, in PTSO's NextGen

implementation, if a provider did not use the diabetes template, then the reminders pertaining to the patient's diabetes would not be triggered. With low template compliance rates, template-dependant decision support was underutilized.

To be clear, the limitation was not that templates or HM sections existed as a way to access decision support; rather it was that these were the primary means by which providers were expected to view reminders and providers often did not access the tools that were available.

Reminder visibility

Some reminders that were "so unobtrusive" that providers did not react to them and thus did not view or act upon them. For example, providers using Centricity EMR reported that the "tiny red text" on a tab indicating that there were active reminders waiting in the protocols (HM) section was so unobtrusive that they did not notice the active reminder during the course of the visit. While unobtrusiveness was mentioned numerous times by key informants across systems as a reason for not acting on reminders, it was unclear if the reminders were not noticed or if the reminders were seen, but easy to ignore.

Reminder timing

The timing of decision support was crucial in order for providers to act on the reminder. For instance, AC's implementation of Centricity EMR had a set of protocols that allows a provider to see what was due for patients with select chronic and preventive care needs (e.g. diabetes, HIV, well-child, and well woman). However the way that visit was structured using the "visit navigator" tool that guided the flow of the visit, the protocol appear towards the end of the visit after the provider has done most of her ordering and written up her plan of care, too

late to act upon the reminder. Appropriate timing was a limitation that stretched across EHRs and was frequently coupled with not acting upon.

Combination of factors

As described by a CHC director from PTSO, many of these limitations were present at the same time and interact with one another to hinder the effectiveness of decision support.

> Even if the provider opens the templates, the reminders are still lousy. You need something where you open the screen when you see them for their cold, and it comes up and says, "hello! LDL overdue". Instead, if you happen to be in the right part of the chart and click on the health maintenance it shows, you know that there's a test due .....that one of them is red, in very tiny type, that gives the date--then it should be acted upon. That's not an effective reminder. Additionally the data to drive the reminders was not in place when the EHR went live so reminders were meaningless and now providers ignore them out of habit. It could be useful, but each provider has to take the step to make it useful--you have to press update, you have to open the...you have to take all these steps.

In summary, a fundamental limitation to decision support was that reminders must be encountered by providers and at an appropriate time in order to be effective. In the EHRs studied, the primary EHR related barriers around encountering reminders at the point of care were due reliance upon on-demand reminders, reminders being so unobtrusive they were not viewed, and the timing of when reminders were viewed preventing them from being acted upon .

3.5.7. Acting on reminders

In cases where the reminders were using good clinical logic, the data requirements were met, and the providers encountered the reminder, the final barrier in ensuring the reminders had their intended effect was ensuring the reminders were "actionable". More than just highlighting that a patient was due for a particular service or test, in order for the reminder to have its desired effect of changing provider behavior, the EHR needed to provide a mechanism by which the provider could easily follow the recommendation. For example, given a diabetic patient who hasn't been seen in a year and a half, the HbA1c, lipid panel, liver function tests, albumin, creatinine, and TSH tests could all be ordered and a referral for a retinopathy screening could be easily scheduled with a few mouse clicks, minimizing the interruption to the provider's workflow. Key clinical informants reported that a major reason reminders were not acted upon was that they pulled the provider out of the flow of the visit. With a relatively short amount of time to see a patient, providers were not likely to devote time to the patient's diabetes unless it could be done without taking time away from the patient's primary reason for coming in.

Only the reminders in OCHIN's EpicCare implementation were linked to actionable orders, where if you clicked on the reminder it took you to the appropriate place in the record to satisfy the reminder. All of the other EHRs studied did not have direct links from the reminders to actions. This meant that while a provider might see the reminders for orders and services a diabetic needed, it would be up to the provider to step out of the flow of the visit to complete each one. Key informants reported that by not having easily actionable reminders, providers choose to prioritize other tasks during the visit, thus the decision support was not effective at changing provider behavior. The lack of a strong link between decision support and taking actions based on the support was a major limitation to the decision support technology

used in AC, PTSO, and HCN. All of the networks have recognized this need and are in the early stages of working on solutions.

3.6. Patient Support

Patient support includes a large array of tools that can be used to support patient self-care and the management of chronic diseases like diabetes. These tools include things like printouts, patient web portals, and relatively less commercially developed tools of patient education modules.

3.6.1. Lack of advanced functionality use

While some basic patient support was present in EHRs, the use of more advanced patient support tools was limited both by cost and the general availability of tools that integrated with the EHR. All CHCs in the study reported the ability to print out patient education materials; however the technology used did not include other aspects of patient support. Study EHRs did not have functionality enabled to allow patients to access and record their own data through web portals, or provide patient education through computer based learning modules and thus these more advanced functionalities could not be evaluated.

As was described in for patient messaging, cost was reported as the main factor limiting patient web portal implementation. Reasons for a lack of educational tool usage were not discussed.

3.7. Administrative Processes

Administrative processes include scheduling, billing, and claims. Efficient administrative processes have the potential to increase the efficiency of health care organizations allowing them to provide more timely services to patients and allowing them to rapidly receive authorization for service, decreasing delays in providing services. While, EHRs are generally not used specifically for administrative processes they do interface with Electronic Practice Management Systems which are central to scheduling, billing, and claims. EHRs provide necessary data for EPMS tasks such as scheduling, billing, and authorizing services.

3.7.1. Integrated EHR/EPMS

Three of four networks in the study used an integrated EHR/EPMS and AC was in the process of transitioning its CHCs to an integrated system. Nonintegrated system users reported challenges with administrative processes due to poor interfaces as described in Electronic Connectivity (uni-directional data flow, challenges working with multiple vendors) while those with integrated EHRs did not report challenges with administrative processes related to their EHR.

3.8. Reporting and Population Health Management

Reporting and population health management consists of the tools and clinical logic/business rules necessary to view and analyze data from the EHR. Reporting is necessary in order to analyze and manage patient populations. Reports facilitate the analysis of data for patient populations and enable the targeting of these populations by making possible the creation of lists of patients that meet specific criteria (e.g. diabetics who have not had a HbA1c

in over a year). Additionally, reporting enables centers to objectively evaluate provider and staff performance. Compared to reports using data from EPMS alone, reports utilizing EHR data can be more robust and comprehensive because they rely not just on billing and procedure codes, but on patient health information.

CHCs and Networks considered reporting to be crucial for quality improvement efforts. In order to make changes to improve quality of care, there had to be a way to turn the data in the EHR into information. Only then could the prioritization of particular areas that needed improvement and the objective evaluation quality improvement program outcomes occur.

Reporting from the EHR was challenging primarily due to a lack of EHR based reporting tools, a challenges developing reports, and issues with finding the desired data and ensuring its validity. These issues were severe enough to prompt workaround efforts from all of the networks and a number of the larger CHCs.

3.8.1. Out-of-the-box reporting tools

Frustration with the built in EHR reporting tools was voiced across CHCs. According to one medical director:

> To me it is unbelievable that you can spend this amount of money on a system and not be able to get reporting off of it. It should come out of it… I mean, to me it is like the mammogram of one breast or it is like getting your car and they tell you, by the way, there is no gas tank and they are like good luck. It just does not make sense to me. Or you get in your car and there is no steering wheel. It is a serious component that is missing and they have to find a way to build reporting within it and reporting I mean at every level.

> It is maddening to think that you are in the 21st century. Can you imagine a major corporation buying an information system, spending millions on it and then not having any reporting that they want? I mean health care… we should be demanding this.

Across the sample, key informants considered reporting to be an essential EHR functionality and found the implementation in their EHRs to be lacking, as represented by the quote above.

All EHRs except for Medical Manager shipped with built in reporting tools. CHCs universally found these tools to be insufficient for their needs. While these tools allowed users to submit queries to the EHR database and generate limited reports, key informants considered the tools insufficient for their needs or the needs of their organization. The basic users I interviewed found the tools to be confusing and were frustrated when they were unable to obtain desired data. Successfully using the query interface required understanding how data was stored in EHR databases, knowledge of the correct operation produce the desired output, and then being able to correctly interpret the output that had been generated. For these reasons, EHR based reporting tools were not made available to basic users at OCHIN and PTSO.

Advanced users were also frustrated by the tools which they found to be highly limiting, not giving them the fine grained control of reporting output they needed. For example, Centricity EMR limited the number of parameters and operations that could be used to combine them in a report. Several CHCs had technical personnel with enough expertise to write queries to the EHR database using the provided reporting tools. However, all of these report writers chose to acquire 3rd party business intelligence tools such as SAP's Crystal Reports or develop their own data warehouses instead of using the built-in reporting tools. As evidenced by the exclusive use of 3rd party tools, the built-in reporting capabilities were severely lacking. CHCs all

had unique data needs and in order to report on the specific items they needed, CHCs either used 3rd party solutions or worked with the network to produce custom reports.

In addition to the reporting tools, three EHRs included a small number of pre-written reports. These reports were universally considered unhelpful due to their extremely limited nature. These reports typically did not present data in a way the user found useful and offered little flexibility for customization, either in the contents or display of data. After using these reports for a brief time, even basic users wanted the systems to do more than they did. Further, different types of users had different reporting demands, which the canned reports did not address. That is, a medical director's or administrator's needs were very different from those of a general provider, but the canned reports did not address the need for different reports for different audience "levels."

3.8.2. Data acquisition and validity

Data needed to exist in sufficient quantity and quality in order for meaningful reports to be produced. If data were not collected or the meaning of the data could not be verified, then accurate reports could not be generated for use as part of quality improvement efforts. As stated by the director of quality and performance excellence of one network, "There is a three stage process in trying to improve quality. The first is to turn data into information. The second is to turn information into good decisions and change. The third is to evaluate the change." High quality data was necessary in order to create the information upon which quality improvement efforts were built. If the data were not correct or information was missing, reports were inaccurate and thus could not be used as a lever to motivate change. All of the same data acquisition and validity issues described in the Decision Support section were applicable to

reporting, especially the need for providers to use certain data entry tools in order to capture discrete data and for functional interfaces to gather data from outside of the visit.

3.8.3. Report development

CHCs and CHC networks encountered two main challenges when writing reports for EHR data, difficulty accessing the necessary data and creating the clinical logic underlying the report. For one, the databases were poorly designed and documented. Secondly, the clinical logic for generating good reports was complex and continued to evolve as the medical evidence base changed

3.8.4. Database design and documentation

Poor database design and scant documentation combined to make it difficult to produce meaningful reports from the EHR. For example, NextGen merged two formerly separate products—their EPMS and EHR into a single unified product. This resulted in difficult to decipher data structures/table formats within the merged databases. CHC report writers had a hard time determining where needed data were stored. According to one CHC's report writer, "NextGen, from the back end, looking at the table structure, is one of the most God awful messes I've ever seen in my life. Trying to pull data, there isn't a searchable data dictionary." Data fields with similar names were repeated in multiple tables within the database and ambiguous documentation left unclear the mapping between fields on the screen and the underlying fields into which data were stored. That is, the mapping between the field on the screen and the underlying database was scanty and inadequate.

OCHIN experienced similar frustrations with the database design and reporting tools. One CIO explained the challenges inherent to reporting on data in Epic.

> Epic is a non-relational database. The difficulty with that is that when Epic writes out the data to the database it does it in an old fashioned flat file. So when you are trying to find the segment you want within that flat file, our IT group just pulls their hair out trying to unbury this data. … The reporting tables you get from Epic are so horrendous, they are horrible. I couldn't believe some of the things I was seeing. It was like I was back in the early 1980s. We had to do a lot of reverse engineering, a lot of QA testing, a lot a validating on assumptions because there was not a lot of documentation provided by Epic.

In addition to the challenges of finding data, assumptions about what data meant needed to be tested and validated to ensure the accuracy of reports.

3.8.5. Clinical logic development

Finding the data was only half of the challenge in creating reports. The other half was creating the clinical logic that underlay the report. The challenges in creating clinical logic for reports were very similar to those described in developing the logic for decision support. Also, as with decision support, there was also a continual need to update the clinical logic to reflect the current evidence base. Users across all networks were frustrated with the lack of existing reports and the effort required developing new reports. One CHC report writer expressed frustration about Epic's lack of an existing mammogram report.

> We have been doing reports since the very beginning … EMR is going on 3 years and we feel like sometimes when we ask the question, we can't be the first one to want to know this information, and wish there were better ability to share these reports. It surprises us that these questions haven't been asked before - the questions we are trying to

answer in our reporting…. We can't be the first ones to want to know about mammograms. It's surprising that there isn't some other, better way.

These questions were asked again and again across study CHCs and vast amounts of resources were invested in essentially solving the same problems.

3.8.6. Workarounds for reporting

As described above, built-in reporting tools did not meet CHC needs. Faced with this difficulty, all study networks completed or were in the process of developing data warehouses and reporting tools to access and analyze data from the EHR[16]. A data warehouse was essentially a copy of the live EHR database, processed and formatted to make data extraction easier, and used for analysis[17]. Reporting tools allowed users to access the data from the data warehouse in a more user friendly way than writing queries directly to the database, often in the form of pre-written reports. This sub-section will go through the efforts of each network to address reporting needs.

Alliance of Chicago

AC, who had made the most progress in creating reports for CHCs, worked closely with GE to co-develop a data warehouse. AC supplied many of the requirements and clinical logic specific to the CHC sector, developed reporting tools, and validated data while GE programmed many of the reports, maintained the hardware, and set up the data warehouse environment.

[16] Three large CHCs also developed their own data warehouses independently of the networks due to a need to utilize EHR data.

[17] This had two benefits. It minimized the impact of running large queries on the live database, thus overburdening the live servers and slowing response time and the data were stored in a format that could be more efficiently searched than the live EHR databases. This was because while the live EHRs had been developed to support high volumes of transactions involving small amounts of data, they were not designed for sorting and processing large amounts of data at once.

Data for the warehouse was pulled from AC's servers by GE over an interface, processed, and imported into the warehouse. AC users were then able to access a library of reports via a web interface. Overall AC was happy with the quality of reports produced, but believed the way that data was presented needed to be improved to meet the needs of CHC end users. GE was in the processes of migrating the warehouse to a new set of business intelligence tools with improved presentation functionality. Of note, the reports that were developed for the GE data warehouse were available to other CHCs using GE's data warehouse for Centricity EMR.

OCHIN

OCHIN chose to implement a data warehouse and reporting tools developed by a not-for-profit medical group also using Epic. It took over two years of work for data warehouse and the reporting tools to go live. Part of the challenge was modifying the clinical logic to meet the needs of CHCs and part was creating a display and report request layer on top of the warehouse that was simple to use and yet allowed enough flexibility for users to get the data they need and be confident in the data. Due to the time it took to develop this warehouse and specific reporting needs, one of the large OCHIN CHCs went ahead and developed its own data warehouse. It was unclear how this tool and the network's solution would co-exist.

Health Choice Network

Over the course of the study period, HCN developed a data warehouse and an accompanying set of reporting tools for CHCs to use. Prior to this there were no reporting capabilities in the EHR and 3rd party software was necessary to access any data for reporting. Their reporting tools, named QUICK, were rolled out over the summer of 2009 with only a

handful reports developed and validated, but with many more reports in the process of being written.

PTSO

Recognizing the need to report on EHR data, the two largest CHCs in the PTSO independently developed reporting environments and accompanying sets of reports to meet their own business and performance improvement needs. For other smaller, less resource rich CHCs in the PTSO, developing an independent reporting environment was not a feasible option. Due to this unmet need, PTSO was in conversation with the two larger CHCs about a strategy to expand one of their reporting environments to the network level.

3.9. Summary

In summary, technology does indeed limit the CHCs ability to provide quality care. The main components of the EHR where CHCs and Networks invested substantial resources were the templates, interfaces, and reporting tools. These components are necessary for multiple parts of the IOM's functionalities, particularly health information and data, decision support, electronic connectivity and communication, and reporting. I will discuss the recurring problems and potential solutions in the "Discussion and Conclusion" chapter.

4. Discussion and Conclusion

At the outset of this dissertation I described the great potential of EHRs to help improve quality of care and how each of the core EHR functionalities can contribute to enhancing clinical quality. In particular, reporting and decision support hold great promise as tools to help improve quality of care. However, as documented in the literature and based on my prior work, use of commercial EHRs often has not been associated with the promised improvements in quality of care, in part due to the lack of features that could improve quality and lack of use of those features.

It was suggested in the NAP report on *Computational Technology for Effective Health Care* that the main problem with EHRs is that they are designed to mimic paper processes, thus shortcutting the potential of the EHR[15]. My data do support the claim that the EHR is currently being used for little other than paper replacement. The potential of the EHR to offer decision support or lighten the provider's cognitive burden is not being realized. I have identified particular technological limitations in core EHR functionalities that are constraining the impact of current generation EHRs on quality. Whether improving these limiting factors alone will be enough to improve QI efforts is unknown. It is possible substantial technological improvement within the current EHR paradigm can realize much of the EHR's potential, but it is

also quite possible that the EHR needs to be more dramatically reconceptualized; however that is beyond the scope of this dissertation. This work describes the limitations in EHR functionality as currently conceptualized and offers suggestions on how to move forwards.

In this work, I have shown four examples of implementations of commonly used commercial EHR software for medium sized practices, each requiring extensive software development work by the CHC networks and their members to engage in modest QI efforts. Upon initial implementation none of the EHRs did a good job of supporting the provision of guideline based care to individual patients during visits or the management of populations of patients because the EHRs lacked the required templates, decision support, reporting, functionalities as delivered out-of-the-box. These limitations meant that clinical leaders and staff at both the CHC networks and CHCs devoted a great deal of time and resources towards enhancing the software and improving the ease-of-use and usefulness of the EHR, especially the templates/documentation forms, interfaces, and reporting. These software issues limited the development of quality improvement activities by consuming scarce CHC and network resources to fix poorly functioning software and to develop the infrastructure necessary to support quality improvement activities.

Many EHR users were disappointed with the maturity and capabilities of their EHRs. As described by one provider champion, “EHRs are in their infancy. They have the potential to get a lot better. You would not accept this level of wrongness from your bank. You know, getting your bank statement and oops we messed up your checking account or oh sorry we said that that worked but it doesn’t. You wouldn’t accept this from the banking world, but EMRs, I’m sorry, they are really not there yet.” At this point, EHR technology is causing problems that constrain QI efforts.

4.1. Some core EHR functionalities were more limiting than others

Some areas of EHR functionality were viewed by study participants as better than others. EHR technology itself was not viewed as a major barrier for one and a half of the eight core EHR functions: Administrative Processes and Electronic Communication (messaging within the practice). Most Patient Support capabilities were not implemented, primarily due to cost, and thus could not be evaluated. The remaining functions all suffered from technological limitations to different extents.

4.1.1. Functionalities with few technological limitations encountered

Administrative processes, including scheduling and billing, were well supported in EHRs that were integrated with their EPMS by the same vendor. The three CHCs that did not have an integrated EHR/EPMS were all transitioning to an integrated system. Based on the experiences of study CHCs, an integrated EHR/EPMS should be encouraged in order to minimize data integration challenges between systems.

Electronic Communication (messaging) within the practices was determined primarily by a CHC's culture rather than issues with the technology. All of the EHRs supposed intra-practice messaging and where the technology was utilized, it was generally well liked. Secure messaging outside of the practice, one function of patient portals, was not used by any CHCs and thus could not be evaluated.

4.1.2. Numerous limitations in core EHR functionality limited QI efforts

Functional limitations that hindered QI efforts were present in a number of core EHR functional areas.

Health information and data limitations, primarily in the form of templates or documentation tools, restricted the amount of discrete data that could be collected during the visit, thus limiting the availability of data both during and subsequent to the visit. Data collection limitations also impacted other core functional areas. Without the necessary data, subsequent QI processes such as decision support and reporting that relied upon this data could not take place.

Despite the number of limitations that still exist in capturing data at the point of care, the ability to capture discrete data in all of the EHRs studied was far superior to using a paper based record system. Of the EHRs studied Epic had the fewest limitations in entering discrete data due to the flexible nature of their documentation tools. However, the ability to enter data into the other three EHR's dramatically improved from initial implementation due to the efforts of the network staff, clinical committees, and to a lesser extent the vendors to improve the templates. Of these, template use in NextGen progressed the least and remained fairly challenging. It is interesting to note that EHR vendors from three of the four networks repackaged portions of network-developed templates for distribution with the EHR. Investigation of models of more flexible documentation similar to Epic's may be an area worth considering by other vendors.

Vendors have begun to recognize the need to create disease and condition specific templates and documentation tools. These tools are slowly being rolled out as they are developed, however at present the pace is quite slow. Three factors might help improve the

pace of development efforts. For one, as federal definitions of meaningful EHR use are clarified, vendors should be able to react to more specific development targets. Secondly, more vendors should consider collaboration with high level users to create templates that can then be distributed to other users, decreasing development costs for the vendor and compensating users for the investment made in creating templates. The effort of HCN and Sage is an example of the potential for this type of collaboration. Thirdly, more sophisticated template design tools could be created which would allow users or organizations to drag and drop modular components to easily modify existing templates and more rapidly create custom templates.

While the development of disease and condition specific documentation tools is part of the solution, other problems still exist in terms of the usability, usefulness, and efficiency of these tools. Providers in the study did not consistently use appropriate documentation tools, instead mostly preferring to use a small sub-set of templates with which they were familiar. This was problematic because much of the decision support logic was depended on the use of particular templates which made decision support unnecessarily linked to the use of a specific data acquisition tool. Without addressing the issues of usability, usefulness, and efficiency it will be challenging to increase template use.

The Agency for Healthcare Research and Quality's (AHRQ) Research Center on Health Information Technology and other researchers are working on improving documentation tools for the EHRs, but it is currently unclear what impact this research will have and how it can be translated to commercial products[51]. In the near future, templates will remain the modality of choice for most EHR systems to collect discrete data at the point of care. Improvements to templates are needed in two areas. Requiring the smallest paradigm change, templates need improvement in their usability, usefulness, and efficiency. Secondly, templates would benefit from a significant redesign, including a modular drag and drop interface that would enhance the

quality of provider data entry while decreasing the burden of template development and allowing for more rapid template development. However, long-term, more funding is needed to sponsor work on alternate methods of capturing the care process such as speech recognition, linked devices, and other embedded approaches that minimize the provider's data entry burden.

Electronic connectivity (interface) limitations, like those in health information and data, hindered quality improvement efforts. Lack of electronic data from third party sources limited providers' ability to make decisions at the point of care based on this information, limited the ability of providers to ensure continuity of care with other providers(e.g. referrals to specialists), and limited the QI processes that could take place, due to limited data. These same limitations would have been encountered with paper record use, so are not unique to the EHR. While all CHCs had lab interfaces, these interfaces often did not work correctly or were modified by the lab company with little to no notification of the CHCs. Recent efforts at the federal level by the Office of the National Coordinator for Health Information Technology (ONC) to help standardize laboratory interfaces by choosing use of the LOINC vocabulary as one of the criteria for meaningful use should help with this problem[52]. However there are numerous other third party data sources such as prescription, referral, hospital, and state registry that need standardization as well. RHIOs [18] and other forms of health information exchange hold the potential to be part of the solution, but their development has been slow. There are efforts underway to create a standard for EHR data exchange with the development of the Continuity of Care Document (CCD) and Continuity of Care Record (CCR) formats. Both of these standards appear to be gaining traction in the market, providing the "envelope" for data to be exchanged

[18] A RHIO is an organization that brings together health care stakeholders within a defined geographic region and governs (and often facilitates) the sharing of data among these organizations with the goal of improving health care in that region.

and a high level format for the data. However, both standards lack a rigorous definition of the "semantics" of the codes or terminology to ensure that messages exchanged in these formats are meaningful. What is needed is for these standards to continue to improve and be adopted, to enforce the use of rigorous data exchange standards, and to provide incentives to encourage the sharing of data between organizations (e.g. hospital and health center) because presently there is not a business case for exchanging data[53]. **Decision support** limitations meant that few reminders and alerts beyond drug-drug and drug-allergy were utilized in the study EHRs. More often, passive decision support was available in the form of templates or documentation tools to help structure the visit, but even this depended on utilization of the appropriate documentation form. A lack of available reminders, combined with the need for providers to "pull" reminders from the system in order to see them, decreased the ability of decision support tools to influence provider behavior at the point of care. The major technical limitations to utilizing EHR based decision support were threefold: the lack of pre-existing reminders, alerts, and templates which meant that clinical logic underlying the decision support had to be developed independently for each network; the way in which reminders were displayed which made it easy to miss or ignore the reminder; and the challenge of acting upon a reminder once it was viewed.

Due to the relatively flexible, unstructured nature of documentation in Epic, there was a greater chance of missing passive reminders that were typically embedded into more structured templates. However, with the inconsistent use of disease and condition specific templates, passive reminders in the other EHRs were also missed. Template use was particularly challenging for the NextGen based implementation due to the lag encountered when opening templates. Having viewed just one NextGen implementation, it is not possible to determine if the lag problem was specific to the implementation or to the software; regardless, it does

demonstrate how overall system functioning can impact the use of specific EHR features. All of these issues demonstrate the dearth of human-computer interaction (HCI) principles in the development of current generation EHR systems and, as described in the NAP report, highlight the necessity of integrating HCI principles into future EHR design[15].

The development of clinical logic was one aspect of decision support and reporting that was resource intensive and needed to be continuously addressed. Due to the similarities in developing logic for decision support and reports, related issues are addressed in more detail in reporting section below.

This research also uncovered several questions about reminder delivery that need more research: What are the most effective ways to deliver reminders in commercial systems? To what extent does reminder fatigue exist and what are the resulting limits on reminder effectiveness? How does inaccurate data impact a provider's "trust" in a reminder? Key informants were hesitant to implement reminders and alerts due to these concerns, but research has not yet shown whether or not the concerns outweigh the benefits of the reminders.

Reporting limitations were so severe that three of the four CHC networks completely sidestepped the EHR technology itself by developing or co-developing data warehouses and reporting tools; the fourth network was looking at ways to better implement reporting. The inability to extract meaningful data on patient populations and provider performance was such a huge limitation that networks and large CHCs made it a priority to develop these reporting tools. Data from these reports was an essential component of quality improvement efforts. The network-developed warehouses were still limited in the reports that they could produce, but will continue to become more and more useful as their as development continues.

While the larger, more resource-rich CHCs, could afford the skilled personnel necessary to develop their own reporting tools in the absence of network development efforts, small CHCs with fewer resources were limited in their reporting capabilities without the help of their network. These limitations are likely to carry over to small group practices as well, which are unlikely to have connections to a larger body the way CHCs are connected to networks. Given the poor reporting tools found in study EHRs, vendors need to improve the very basic reporting capabilities, including partnering with third parties to develop better reporting tools. For more complex reporting needs, most of the reporting solutions were limited to the networks or large CHCs that had developed the warehouses. The only exception was the warehouse co-developed by AC and GE that was an option available to other GE customers.

Meaningful EHR use guidelines for reporting can help give vendors direction to target report development efforts, but they must be based on a well defined set of clinical logic. One of the most challenging aspects of report development (and decision support) was crafting the clinical logic for a report from a clinical guideline. In the short term, if the federal government in partnership with professional organizations and standards bodies such as HL7 were to come up with a rigorous set of standardized representations for common reports, the creation of reports would be much easier for vendors and those using third party reporting solutions such as the network's data warehouses. As a longer term solution, companies such as Isabel HealthCare and Thompson Reuters are working on developing clinical logic libraries that can then be plugged into an "execution engine". This clinical logic can then be easily updated as clinical guidelines and reporting standards change and automatically distributed to end users. This will reduce the burden on users to be continuously up to date on all clinical guidelines and to manually update their system's clinical logic.

A more enduring problem going forwards is likely to be obtaining data that is useable for reports (and decision support as well). This issue is addressed in the subsequent section "Populating the EHR" and will require extensive work on data capture and interfaces with external data sources.

Order entry management and **results management** limitations meant that no systematic electronic processes could be used to ensure patient orders were filled or that patient results were viewed in a timely manner and appropriate follow-up action was taken. Both functionalities were limited by a lack of interfaced data and tools built into the EHR to support the systematic management processes. While interface standards discussed above should help ensure data is returned to the EHR in a format that allows management, vendor development or co-development efforts are need to create tools within the EHR to enable the systematic tracking of orders and results.

4.2. Across all the areas of limitations there were several underlying problems

Across all core EHR functional areas there emerged several underlying limitations that cut across multiple functionalities, these included lack of pre-build functionality and challenges populating data into the EHR.

4.2.1. Lack of pre-built functionality

All CHCs and networks in the study invested heavily in the creating and refining templates and other documentation tools, reports, and reminders due to a lack of functionality that was available at implementation. Across networks and CHCs there was much "re-inventing

the wheel" where the same functionality or logic was independently developed multiple times. Examples include all networks building diabetes documentation tools or templates, two CHCs at PTSO developing their own separate data warehouses, and three networks developed their own reminders for mammograms. This led to large amounts of duplicative work and investment of resources that could have been otherwise utilized to expand QI efforts into new areas. The fundamental challenge in all of these areas is that creating each of these functionalities takes a great deal of clinical input and expertise and smaller organizations do not have the resources to devote to this task, even if they did have staff with the technical skills necessary.

4.2.2. Populating the EHR

Having all of the necessary data in the EHR was essential to be able to report on data and to support provider decision making. There were two main problems with getting discrete data into the EHR. The first was that manual data entry (templates, dot phrases) were often found to be non-intuitive, inefficient, and did not necessarily capture all of the data needed for reporting and decision support. This led to data being entered into unexpected places, entered in a non-codified manner because it was "easier", and providers not using the most appropriate forms or templates to capture discrete data. The second challenge was populating EHR data with data from outside the visit with interfaces to data sources external to the EHR. The interfaces that did exist (e.g. lab) suffered from non standardized set of codes and formats used to send results to a health center. Many other areas such as childhood immunization registries, hospitals, or specialists did not have interfaces available to share data. As described above, work is needed on alternate and automated methods of capturing the care process to minimize the provider's data entry burden. Work is also needed to improve interface standards for all types of EHR data.

4.3. Conclusion

Given that EHR adoption rates will continue to increase it needs to be emphasized that successful QI efforts are difficult to achieve with the current state of EHR technology. Efforts to increase EHR adoption are unlikely to deliver the expected quality improvement gains without a substantial focus on standards to measure quality and structures in place to enhance EHR functionalities. Though the ONC has been given two billion dollars to help address EHR issues, only sixty million dollars (3%) have been allocated for strategic research projects to improve key aspects of HIT[53]. This amount of funding is disproportionate to the need and further substantial funding is needed[54]. The proposed meaningful use guidelines will help begin standardization, but may initially be overly ambitious given state of the technology. Several specific places policy could help create the needed structure to improve the technology are noted above. The onus of improving the technology cannot fall solely on the backs of EHR adopters, who generally lack the resources to develop the documentation, decision support, and reporting tools required for quality improvement efforts to succeed. Instead of giving financial incentives to providers solely for adopting an EHR, funding must be put in place to give financial incentives to measure quality (this recommendation is similar to those made in the NAP report) and to improve the EHR functionalities. Functional improvement efforts need to focus in the short term on improving the EHR technology using computer science methods that are currently available such as HCI principles, but also need to focus on future oriented efforts to develop new technologies that will enhance the collection of data and give patients and providers the cognitive and decision support needed to improve healthcare.

References

1. Kohn KT, Corrigan JM, Donaldson MS, *To Err Is Human: Building a Safer Health System.* 1999, Washington, DC: National Academy Press.
2. Institute of Medicine, *Crossing the Quality Chasm: A New Health System for the Twenty-first Century*. 2001, Washington, DC: National Academy Press.
3. Committee on Quality of Health Care in America and Institute of Medicine, *Preventing Medication Errors*, in *Quality Chasm series*. 2007, National Academies Press Washington DC.
4. *Conference Report on H R.1, American Recovery and Reinvestment Act of 2009. 111th Congress, First Session, Congressional Record—House, 155:H1307–1516.* 2009 February 12 Last Accessed March 08, 2010]; Available from: http://www.conferencereport.gpoaccess.gov/.
5. *The American Recovery and Reinvestment Act of 2009. H.R.1*. 2009; Available from: http://thomas.loc.gov/cgi-bin/bdquery/z?d111:h.r.00001.
6. Bates, DW, et al., *A Proposal for Electronic Medical Records in U.S. Primary Care.* J Am Med Inform Assoc, 2003. **10**(1): p. 1-10.
7. Hillestad, R, et al., *Can Electronic Medical Record Systems Transform Health Care? Potential Health Benefits, Savings, And Costs.* Health Affairs, 2005. **24**(5): p. 1103-1117.
8. DesRoches, CM, et al., *Electronic Health Records in Ambulatory Care -- A National Survey of Physicians.* N Engl J Med, 2008. **359**(1): p. 50-60.
9. Miller, RH, et al., *The value of electronic health records in solo or small group practices.* Health Affairs, 2005. **24**(5): p. 1127-37.
10. Miller, RH and West, CE, *The value of electronic health records in community health centers: policy implications.* Health Affairs, 2007. **26**(1): p. 206-14.
11. Zhou, L, et al., *The Relationship between Electronic Health Record Use and Quality of Care over Time.* J Am Med Inform Assoc, 2009: p. M3128.
12. Dorr, D, et al., *Informatics Systems to Promote Improved Care for Chronic Illness: A Literature Review.* J Am Med Inform Assoc, 2007. **14**(2): p. 156-163.
13. Garg, AX, et al., *Effects of Computerized Clinical Decision Support Systems on Practitioner Performance and Patient Outcomes: A Systematic Review.* JAMA, 2005. **293**(10): p. 1223-1238.
14. Wolfstadt, JI, et al., *The effect of computerized physician order entry with clinical decision support on the rates of adverse drug events: a systematic review.* J Gen Intern Med, 2008. **23**(4): p. 451-8.

15. Stead, W and Lin, H, eds. *Computational Technology for Effective Health Care: Immediate Steps and Strategic Directions.* Committee on Engaging the Computer Science Research Community in Health Care Informatics; National Research Council. 2009, National Academies Press: Washington, DC.
16. Schappert SM, Rechtsteiner EA., *Ambulatory medical care utilization estimates for 2006. National health statistics report; no 8.* 2008: Hyattsville, MD.
17. McGlynn, EA, et al., *The Quality of Health Care Delivered to Adults in the United States.* N Engl J Med, 2003. **348**(26): p. 2635-2645.
18. Ma, J, and Stafford, RS, Stafford, *Quality of US Outpatient Care: Temporal Changes and Racial/Ethnic Disparities.* Arch Intern Med, 2005. **165**(12): p. 1354-1361.
19. FQHCs receive annual lump-sum payments from the Health Resources and Services Administration and have per-visit Medicaid reimbursement rates higher than other Medicaid providers. FQHC "look-alikes" only receive the higher per-visit rates. For the purposes of this proposal FQHCs and FQHC "look-alikes" will be referred to together as community health centers.
20. Bureau of Primary Health Care, *Section 330 Grantees Uniform Data System (UDS), Calendar Year 2006 Data, National Rollup Report* 2007, Bureau of Primary Health Care: Washington, DC.
21. Shields, AE, et al., *Adoption Of Health Information Technology In Community Health Centers: Results Of A National Survey.* Health Affairs, 2007. **26**(5): p. 1373-1383.
22. HIMSS. *Electronic Health Record*. 2010 March 9, 2010]; Available from: http://www.himss.org/ASP/topics_ehr.asp.
23. Institute of Medicine, I. *Key Capabilities of an Electronic Health Record System*. 2003 2/27/2010; Available from: http://books.nap.edu/catalog.php?record_id=10781.
24. Weber, V, et al., *Employing the electronic health record to improve diabetes care: a multifaceted intervention in an integrated delivery system.* J Gen Intern Med, 2008. **23**(4): p. 379-82.
25. Chaudhry, B, et al., *Systematic Review: Impact of Health Information Technology on Quality, Efficiency, and Costs of Medical Care.* Ann Int Med, 2006. **144**(10): p. 742-752.
26. Rogers, EM, *Diffusion of Innovations*. 2003, New York, NY: Free Press.
27. Linder, JA, et al., *Electronic Health Record Use and the Quality of Ambulatory Care in the United States.* Arch Int Med, 2007. **167**(13): p. 1400-1405.
28. Crosson, JC, et al., *Electronic Medical Records and Diabetes Quality of Care: Results From a Sample of Family Medicine Practices.* Ann Fam Med, 2007. **5**(3): p. 209-215.
29. Ash, JS, et al., *Categorizing the unintended sociotechnical consequences of computerized provider order entry.* International Journal of Medical Informatics, 2007. **76**(Supplement 1): p. S21-S27.
30. Ludwick, DA and Doucette, J, *Adopting electronic medical records in primary care: Lessons learned from health information systems implementation experience in seven countries.* International Journal of Medical Informatics, 2009. **78**(1): p. 22-31.
31. Coiera, E, *Putting the technical back into socio-technical systems research.* I J Med Inform, 2007. **76**(Supplement 1): p. S98-S103.
32. Simon, SR, et al., *Physicians' Usage of Key Functions in Electronic Health Records from 2005 to 2007: A Statewide Survey.* J Am Med Inform Assoc, 2009: p. M3081.
33. Poon, EG, et al., *Relationship Between Use of Electronic Health Record Features and Health Care Quality: Results of a Statewide Survey.* Medical Care, 2010. **48**(3): p. 203-209.

34. Miller, RH, West, CE, and Adelson, JW, *Factors Affecting EHR Use for Quality Improvement in Community Health Centers.* Under Revision, 2009.
35. Miller, RH and West, CE, *Chronic Disease Management System-Enabled Quality Improvement in Six Community Health Centers.* Under Revision, 2009.
36. Miller, RH and West, CE, *Rapid EHR Use for Quality Improvement: Community Health Center Case Study.* Author's Unpublished Work, 2007.
37. Mason, J, *Qualitative Researching*. Second Edition ed. 2002, Thousand Oaks, CA: Sage Publications, Inc.
38. Yin, R, *Case Study Research: Design and Methods*. Third Edition ed. Vol. Voume 5. 2003, Thousand Oaks, CA: Sage Publications.
39. *ACOG Practice Bulletin No. 109: Cervical Cytology Screening.* Obstetrics & Gynecology, 2009. **114**(6): p. 1409-1420 10.1097/AOG.0b013e3181c6f8a4.
40. Ammenwerth, E, et al., *The Effect of Electronic Prescribing on Medication Errors and Adverse Drug Events: A Systematic Review.* Journal of the American Medical Informatics Association, 2008. **15**(5): p. 585-600.
41. Devine, EB, et al., *The impact of computerized provider order entry on medication errors in a multispecialty group practice.* Journal of the American Medical Informatics Association. **17**(1): p. 78-84.
42. Eslami, S, A. Abu-Hanna, and N.F. de Keizer, *Evaluation of Outpatient Computerized Physician Medication Order Entry Systems: A Systematic Review.* Journal of the American Medical Informatics Association, 2007. **14**(4): p. 400-406.
43. Casalino, LP, et al., *Frequency of Failure to Inform Patients of Clinically Significant Outpatient Test Results.* Arch Intern Med, 2009. **169**(12): p. 1123-1129.
44. *Computer-Assisted Medical Decision Making*, ed. A.R. James and S. Tuhrim. 1985: Springer-Verlag New York, Inc. 296.
45. Shortliffe, EH, *Computer Programs to Support Clinical Decision Making.* Jama, 1987. **258**(1): p. 61-66.
46. Sim, I, et al., *Clinical Decision Support Systems for the Practice of Evidence-based Medicine.* Journal of the American Medical Informatics Association, 2001. **8**(6): p. 527-534.
47. Mussen, M, Shahar, Y, Shortliffe, EH, *Clinical Decision-Support Systems*, in *Biomedical Informatics*, Shortliffe, EH and Cimino, JJ, Editors. 2006, Springer: New York. p. 698-736.
48. Tamblyn, R, et al., *A Randomized Trial of the Effectiveness of On-demand versus Computer-triggered Drug Decision Support in Primary Care.* Journal of the American Medical Informatics Association.2008. **15**(4): p. 430-438.
49. *Executive Summary: Standards of Medical Care in Diabetesâ€"2009.* Diabetes Care, 2009. **32**(Supplement 1): p. S6-S12.
50. American Diabetes, *Standards of Medical Care in Diabetes--2007.* Diabetes Care, 2007. **30**(suppl_1): p. S4-41.
51. *AHRQ Research Center on Health Information Technology*. 2010 [cited 2010 March 15, 2010]; Available from: http://healthit.ahrq.gov/.
52. Office of the National Coordinator for Health Information Technology, O., *Health Information Technology: Initial Set of Standards, Implementation Specifications, and Certification Criteria for Electronic Health Record Technology; Interim Final Rule*. 2010, Department of Health and Human Services: Washington D.C. p. 2013-2047.
53. Miller, RH and Miller, BS, *The Santa Barbara County Care Data Exchange: What Happened?* Health Aff, 2007. **26**(5): p. w568-580.

54. U.S. Department of Health and Human Services, H. *Fiscal Year 2010 Budget in Brief*. 2010 March 22, 2010; Available from: http://www.hhs.gov/asrt/ob/docbudget/2010budgetinbriefw.html.

Appendix 1 Semistructured Interview Questionnaires

Appendix 1.1 CHC Questionnaire

CHC Survey: Rapid EHR Use for Quality Improvement in Community Health Center Networks Providing EHR Services

Background information on your organization

- Please confirm your title, how long you've been in your position, and your duties and responsibilities?
- Is the following information correct? (if we do not have this information already)
    - # of sites
    - # of billing providers (MDs/NPs/PAs)
    - Ratio of support staff to billing providers
    - # of patients
    - # of yearly patient encounters
    - Breakdown of % Medicaid, Medicare, self-pay, and uninsured
    - EHR and practice management system (name)
- When did you become a FQHC?

Leadership

- Who are the main leaders at the health center?
    - Titles
    - How long in current positions?
    - How stable has leadership been?

Financial

- How would you describe the overall financial state of your organization?

- How has it changed in the last three years or so?

- What is your FQHC rate?
- How are you typically paid for services (e.g., per visit rate, primary care capitation)?
- Are you at capacity or can you provide more patient visits?
- List grant funding or special program reimbursement you get for chronic preventive care? (e.g., cancer screening for uninsured women, Ryan White…)
  - From whom?
  - For what?
  - How central is special funding for QI to having those activities?
  - What activities would be cut without the program specific grants
- What pay for performance or other incentives do you receive?
  - From whom?
  - For what measures?
  - How much are incentive payments?
  - What effect on changing QI activities?
- Do you receive any measures or reports from health plans?
  - How are these used?

EHR finances

- How much did you pay for initial EHR costs?
  - How did you pay for it? (e.g., grants, loans, operating funds)
- How much do you pay for on-going fees/technical support?
  - How do you pay for them?
- What have been the most important financial impacts of the EHR?
  - Productivity changes?
  - Efficiency benefits?
  - Other increases/decreases in revenues due to the EHR?

Electronic Health Record

- When did you implement the EHR (time period)?
  - For all sites?
- What EHR services does the network provide to you?
  - Full ASP EHR hosting
  - Implementation
  - Training
  - Database management
  - Reporting
  - Help desk support
  - Template / interface development
- Does the network provide any services you do not use?
- Do you obtain interfaced electronic data from:

    - Practice management system?
    - Labs?
    - Pharmacy?
    - Other electronic data sources?

- Do you use electronic prescribing? How are prescriptions sent to the pharmacy?
    - Does electronic prescribing have clinical decision support (e.g., drug-drug, drug-allergy,…)?
    - Formulary checks?

- Please walk us through your/the network's implementation and training process:
    - How well did that work? (How satisfied were you?)
    - What could have been better?
    - How do you train new providers on the EHR?

- Who maintains EHR hardware, software and databases—network or CHC staff?
    - What do you do and what does the network do?
    - Is there a separate instance of database for your CHC?

- What technical staff does the CHC have?
    - What do they do that network staff doesn't do?
    - How much of their time is related to EHR work?

- Do you run reports or does the network run reports for you?
    - How customizable are these reports?
    - How difficult is it to run reports?
    - What staff do you need to run reports?
    - How satisfied have you been with reporting?

- How much software customization have you/the network done?
    - How much template development was done?
    - How much report development was done?
    - Who did it?
    - What were the other main software changes made? (BPAs, HM)
    - How flexible/easy is it to modify is the EHR? (how much effort did it take?)
    - Do all CHCs use common templates/reports?
    - How many of the templates follow evidence based guidelines?
    - Do you use 3rd party software for reporting (e.g., Crystal Reports)?

- What are the main benefits of using the EHR?
    - Have they changed over time?
    - How has the EHR changed the way that providers care for patients?
    - How does the EHR affect the speed of the visit?

- What are the most important limitations/challenges using the EHR?
    - Challenges, in order of importance
    - Potential challenges include interfaces, template dev, reminder dev, reporting dev, finding IT staff, usability issues

- What would you like to do with the EHR, but:
  - The vendor software does not support it?
  - You don't have the technical support/resources necessary to alter it?
- How satisfied are you with the EHR (scale of 1 to 10) (Explain)

Chronic disease management system pre-EHR

- What chronic disease management system did you have? (Name)
  - What did you do with it? (what activities did it enable?)
- Did you maintain the CDMS yourself?
- Did you obtain interfaced electronic data from:
  - Practice management system?
  - Labs?
  - Pharmacy?
  - Other electronic data sources?
- What technical staff did you have (pre-EHR)? For what?

Medical Home

- Where do most new patients come from?
  - ER, referral from other PCPs, referrals by specialists, walk-ins to your acute care clinics?
- How do you try to establish on-going relationships with new patients?
  - Can you afford to take in more uninsured patients?
  - Is there any difference in how patients are cared for based on insurance status or other criteria?
- Do providers have patient panels?
  - If providers have panels:
    - How are panels determined?
    - How do you try to ensure that patients see their provider?
    - How often do patients see "on-duty" providers and not their regular provider?
- Are you able are you to schedule same-day appointments for providers?
- How do you schedule follow-up visits for patients?
  - Who do you ask come back?
    - How do you remind them to do so?
  - Do you schedule regular periodic preventative care visits?
  - Do you follow-up on no-shows?
    - If yes, how and under what circumstances?
- What services does the CHC provide to help patients manage chronic conditions?
  - E.g., group classes, education, printed materials, written care plans?
- Do you routinely survey patients on their care experiences?

- What do you do with the results?

- Do you have processes in place to track lab results and ensure all lab results are acted upon appropriately?
- Do you have processes in place to track referrals, to ensure that patients act upon their referrals and that the results come back to the health center?
- What were "medical home" activities BEFORE the EHR?
    - Did the EHR enable any changes "medical home" activities or facilitate the instantiation of new ones

QI and CQI leadership, training, experience

- What is your role in QI efforts?
- What major QI programs has your organization implemented?
    - What QI programs/efforts were in place before you had the EHR?
    - What QI efforts were been put in place after the EHR?
    - What projects are you currently developing?
- Who are key QI leaders in your organization?
    - What are their roles?
    - Who champions QI? (E.g., Admin, QI coordinator?)
    - How much admin time is allocated for QI?
    - Are administrators "on the same page" as clinical leaders about QI?
- How were organization leaders (including you) trained in quality improvement?
    - Participated in any health disparities or other collaboratives?
        - Which collaboratives?
        - When did participation start in each one?
        - Was participation before or after EHR implementation?
        - Which leaders were trained? [lower level or upper level leaders]
        - How helpful was the collaborative participation?
        - How much spread of collaborative concepts?
    - Participated in business process reengineering collaboratives?
    - Participated in other special QI training programs (IHI, Intermountain)?
    - JCAHO or other certification process?
        - How important?
    - CQI training courses (e.g., at Intermountain?)
    - How do you train providers/staff in QI?
- Do you routinely use PDSA cycles/other change management strategies?
- Does your organization have a formal QI plan?
    - What does it consist of?
    - Do you have a formal planning process in place to determine QI goals?

    - How important is the EHR to QI planning?
    - How important is the QI plan relative to other (business) plans?

- How important is reporting to your QI efforts?
    - When (what year) did you start reviewing performance data?
    - What areas/measures do you report on?
    - Who does the reporting—network or CHC or both?
    - What reports does management/leadership routinely review?
    - What reports does the Board routinely review?
    - Does the practice set goals based on performance reports?
    - What is the path of a report through the organization (e.g. first to QI committee then management)?
    - How do you provide feedback on reported data?
        - Provider meetings
        - Reports on individual performance v average?
        - Blinded or unblended reports?
    - How much data cleaning have you undertaken to create valid reports?
    - How important are performance comparisons among CHCs to your QI efforts?
- Do you offer incentives to providers/teams for achieving QI results?
- How do you try to change behavior of repeat under-performers?
- How involved is the typical physician/NP in current CQI efforts?
    - What do they do?
    - What are key challenges to getting providers involved with QI?
- How involved are staff in CQI efforts?
- How has the delegation of tasks changed since the introduction of the EHR?
    - Have any tasks moved from higher to lower skilled workers (i.e. from providers to nurses or MAs)?
- If you were to implement a new chronic/preventive care program,– i.e. for patients with HIV--how would you go about setting it up and implementing it?
    - How would new decisions progress through the leadership chain?
    - How would you make sure the program works well—feedback loop to and from providers?
- If you had more grant money, how would you spend it to improve quality the most?

CHC relationship with network

- When did you start working with/developing the network?
- Why did you join the network?
- In your role within the CHC, how do you interact with the network?

- How much does your CHC pay the network for EHR services
    - That is, what's the financial arrangement with the network?
- What are the network leadership bodies (committees, board of directors)?
    - How much control over decision-making do CHCs have?
- BEFORE the EHR, what services (QI, training, technical support, billing) did the network provide your organization?
- What services does the network provide your organization, besides EHR services?

The network's role in QI

- What is the main role the network has in improving patient quality of care?
- What are the primary services the network provides that help improve quality of care? For example:
    - Change management, workflow redesign help?
    - Template design, reminder creation/activation?
    - Reports on performance
    - Lists of patients needing services?
- How much do health centers control QI priorities at the network level?
- Overall, who is the primary motivating force behind QI – clinics, network, or both?
- Does the network or other CHCs apply pressure on members to participate in QI programs or projects?
    - If yes: do they make sense for your health center?
- Do clinics share CHC performance reports with each other?
- How do clinics to share best practices with one another?
- What are the main benefits from the network's role in QI?
- What are the main limitations in the network's role in QI?
- What's your vision for what the network should do in QI?
- What new resources would you want the network to get for QI—if there was a million dollars in grant money for QI, how would you want the money divided up between the network and the CHC?
- On a scale of 1 to 10, how satisfied are you with the network's role in QI.

Appendix 1.2 Network Questionnaire

Network Survey: Rapid EHR Use for Quality Improvement in Community Health Center Networks providing EHR Services

Background

- Can you confirm your title, how long you've been in your position, and your duties?

First we'd like to get a better understanding of your organization

- Can you please confirm the basic details of the network (if we do not have this information already)
  - # of CHCs—how many in each state? (confused by the number of states mentioned)
  - # of billing providers
  - # of yearly patient encounters
  - # of yearly encounters in EHR
  - # of CHCs you provide EHR services to
- How was the network formed?
  - Why was it formed?
- Does the network provide more than EHR/practice management system services? (e.g., claims processing, advocacy….)
  - When did the network start providing EHR services, why, and how evolved?
    - How large was the initial network?
  - Which services were available prior to the EHR? (if applicable)
- How has the network grown? Are their further plans for expansion?
- What does the overall governance structure of the network look like?
  - Who are the main leaders in the network?
    - Title
    - How long have they been in their current position?
  - Has the leadership composition of the network been stable?

Financial

Finances: What are the network's revenue/expenditures—for CIS services?

- How would you describe the overall financial health of your organization? (stressful over past couple of years—does it look grim going forward)
- What's the network's financial model?
  - Revenues v costs?
  - How much do CHCs pay for EHR/practice management system services?
  - How much do they depend on grants?
- How much grant money do you get? For what/from whom?
- Shortfall?
- Do you have past debts to repay?
  - Is there a business case for the EHR in member CHCs? (Does it pay for itself or not)—depend on grants?
  - Has this business case changed over time?
- What's the overall financial health of the CHCs?
  - How does that affect services the network can provide?

- How are CHCs paid
  - Fee for service, capitation, combination?
  - Is there any P4P?
- Does the network want to expand providing EHR services beyond its current members? (Question of expandability)
  - Why?
  - What are your overall network ambitions/goals?

Electronic Health Record

More detail about the electronic health record system

- Are all CHCs on the same EHR and PMS? If not, how many on each?
  - Which EHR?
  - Which PMS?
  - How well integrated are the systems?

What is the network's role in creating CHC resource/policy "readiness" for implementation and use for QI for chronic preventive care.

- Can you please walk us through the implementation process if a new CHC wanted to become a member and implement an EHR?
  - Needs assessment?
  - Workflow assessment/redesign?
  - Training in the EHR? Training in change management?
    - Who is trained? Hours?

How do the CHC and the network divide up responsibilities for the EHR?

- CHC versus network responsibilities:
  - Who's responsible for routine maintenance of EHR software and databases?
  - All have same software (Do CHCs customize the software)?
  - Common database architecture?
  - Do CHCs have separate instances of the database?
  - What EHR support responsibilities do the individual CHCs have?
    - E.g., help desk, hardware maintenance
  - How key is the network in changing templates?
  - Can CHCs easily report on their own EHR data or does it have to go through the network?
    - Do CHCs have expertise needed to run queries?
- What EHR services do you provide:
  - Full EHR capabilities implemented? (For how many FTE providers, CHCs)
    - Documenting
    - Ordering
      - Prescription -- electronic, printed, faxed? Decision support?
      - Labs – electronic, printed, faxed? Matching?
        - Can all lab results be tracked? (abnormal flags? Alerts for follow-up?)
      - Referrals
        - Can these referrals be tracked?
    - Viewing (electronic reporting of lab results through interfaces)

        - Messaging – within practice, with patients
        - Patient self management – educational materials, viewing own data
        - Reporting – who can report? How difficult?
            - Data cleaning/validation processes?
            - Can patients be assigned to providers (i.e. assigning patient panels)? How widely is this used?
                - Does network reporting take this into account?
    - Implementation
    - Training
- How much customization did/does the EHR need?
    - What did you do? How much effort did it take? Was this expected or an additional burden?
    - Are there things you would like to do but are limited by the system?
- Were there any unexpected results from the EHR implementation or the use of EHR features?

The network's provision of services

How are QI policies set and what is the influence of the convening function of the network as compared to the services that the network provides?

- What are the primary services the network provides that help improve quality of care? For example:
    - Change management, workflow redesign help?
    - Template design, reminder creation/activation?
    - Reports on performance
        - What data does the network provide data to the clinics?
            - On clinic performance?
            - On provider performances?
        - What does the network do with the data other than report it to the clinics?
        - Do you provide performance comparisons among CHCs in the network
            - Is the data comparable enough to permit comparisons?
        - How does the network try to standardize the data?
        - Does the network provide feedback to clinics on the data?
            - Is there some enforcement or follow-up?
            - Who is responsible (network or individual CHC)?
    - Lists of patients needing services?
    - Self management support?
    - Network staff directly provide QI-related services?
    - Does the network provide uniform services to all CHCs or individualized services for each CHC?
    - CQI
        - Does the network provide continuous quality improvement (CQI) training for network personnel?
        - Does the network provide CQI training for CHC personnel?
- How do CHCs differ in focus on QI?
    - How does that affect network provision of QI services?

- What were network efforts to improve quality BEFORE the EHR? (see above)

Governance, culture of quality, leadership

- What minimum obligations do you place on the centers, in addition to paying their fees?
- What are the key committees that CHC members serve on?
  - Do all CHCs have members on all committees?
  - How continually active are these committees?
  - Are most/all CHCs active in the committees?
- Medical Director Meetings
  - How often do the medical directors meet?
  - What do they discuss?
  - What do you want them to discuss?
  - Do they share best practices?
  - How consistent is participation – does everyone participate
- Beyond the medical directors meetings, is there other:
  - Leadership?
  - Governance?

What policies do network leadership/staff set versus policies that members set?

- How much does the network influence QI priorities at the CHC level?

What are the main benefits from the network's role in QI?

- What are the primary obstacles to QI in the network?
  - Money at the network level?
  - Are CHCs interested enough—how much emphasis place on culture of quality?
  - Other?
- What new resources help QI efforts?
  - Where would the resources do the most good QI? —if there was a million dollars in grant money for QI, how would you want the money divided up between the network and the CHC?
    - Medical director?
    - Additional QI staff?
    - What would both do?
- What's your vision for where the network is heading with QI?

Relationships among CHCs

- Overall, how actively do CHCs collaborate with each other?
- What are key conflicts among CHCs in the network? Why?
- Do any non-CHC members participate in the network? If yes, how does that affect the work of the network?

Medical Home Facilitation

- How important is medical homes measurement and improvement
- Does the network facilitate/require CHC use of advanced access scheduling?
- Does the network facilitate/require CHC surveys of patients on their care experiences?
- Does the network facilitate/require CHCs to set yearly performance goals? For what?
  - How are these set? By whom?
  - Network wide performance goals? For what?

Appendix 1.3 Quality Improvement Program Matrix

CHRONIC CARE PROGRAM	Diabetes	Asthma	CAD
Current			
o Is this program for all patients with this diagnosis or a specific subset? Describe			
Put an X for each feature of the program where you do the following			
o Outreach/follow-up			
▪ Lists of patients needing services			
▪ phone calls (automated or human?)			
▪ letters			
▪ Who does it? o FTE, team/site, #pts responsible for			
▪ other			
o Case-management			
o Point of care reminders/alerts?			
o Condition-specific templates (and use)			
o Health education (1-on-1, group visits)			
o Visit summaries for patients			
o Feedback to providers(measures, *how*) ?			
- At all sites? (if not, how many)			
Program Background			
- When did the program start? (year)			
- *How do you pay for program?* o *More paid visits, grant funding, pay-for-performance, other*			
- *Are there incentives for providers/teams?* o *If so, for what and how much?*			
	Diabetes	Asthma	CAD
Immediately pre-EHR: *What were you doing just before you started using the EHR?*			
Please give a simple description of the program.			
Put an X for each feature of the program			
o Outreach/follow-up			
▪ lists of patients needing services			
▪ phone calls			
▪ letters			
▪ Who does it? o FTE, team/site, #pts responsible for			
▪ other			
o Case-management			
o Point of care reminders/alerts?			
o Templates			
o Health education (1-on-1, group visits)			
o Visit summaries?			
o Feedback to providers(what measures, how) ?			
- At all sites? (if not, how many)			

CHRONIC CARE PROGRAM	Depression	HIV	Hep C/Other
Current			
o Is this program for all patients with this diagnosis or a specific subset? Describe			
Put an X for each feature of the program where you do the following			
o Outreach/follow-up			
▪ Lists of patients needing services			
▪ phone calls (automated or human?)			
▪ letters			
▪ Who does it? o FTE, team/site, #pts responsible for			
▪ other			
o Case-management			
o Point of care reminders/alerts?			
o Condition-specific templates (and use)			
o Health education (1-on-1, group visits)			
o Visit summaries for patients			
o Feedback to providers(measures, *how*) ?			
- At all sites? (if not, how many)			
Program Background			
- When did the program start? (year)			
- *How do you pay for program?* o *More paid visits, grant funding, pay-for-performance, other*			
- *Are there incentives for providers/teams?* o *If so, for what and how much?*			
	Depression	HIV	HepC/Other
Immediately pre-EHR: *What were you doing just before you started using the EHR?*			
Please give a simple description of the program.			
Put an X for each feature of the program			
o Outreach/follow-up			
▪ lists of patients needing services			
▪ phone calls			
▪ letters			
▪ Who does it? o FTE, team/site, #pts responsible for			
▪ other			
o Case-management			
o Point of care reminders/alerts?			
o Templates			
o Health education (1-on-1, group visits)			
o Visit summaries?			
o Feedback to providers(what measures, how) ?			
- At all sites? (if not, how many)			

PREVENTIVE CARE AREA	Pap Smears	Mammogram	Prenatal	Primary Care Visit	Other
Current					
o Is this program for all patients with this diagnosis or a specific subset? Describe					

Put an X for each feature of the program where you do the following					
○ Outreach/follow-up					
▪ Lists of patients needing services					
▪ phone calls (automated or human?)					
▪ letters					
▪ other					
○ Case-management					
○ Point of care reminders/alerts?					
○ Condition-specific templates					
○ Health education (1-on-1, group visits)					
○ Visit summaries for patients					
○ Feedback to providers(what measures, how) ?					
- At all sites? (if not, how many)					
Program Background					
- When did the program start? (year)					
- *How do you pay for program?* ○ *More paid visits, grant funding, pay-for-performance, other*					
- *Are there incentives for providers/teams?* ○ *If so, for what and how much?*					
Was there a rollout of specific EHR functionality for this program					
	Pap Smears	Mammogram	Prenatal	Primary Care Visit	Other
Immediately pre-EHR: *What were you doing just before you started using the EHR?*					
Put an X for each feature of the program					
○ Outreach/follow-up					
▪ lists of patients needing services					
▪ phone calls					
▪ letters					
▪ other					
○ Case-management					
○ Point of care reminders/alerts?					
○ Templates					
○ Health education (1-on-1, group visits)					
○ Visit summaries?					
○ Feedback to providers (measures, how) ?					
- At all sites? (if not, how many)					

PREVENTIVE CARE AREA	Well-child Visits	Childhood IZ	Flu Shot	Obesity	Smoking
Current					
○ Is this program for all patients with this diagnosis or a specific subset? Describe					
Put an X for each feature of the program where you do the following					
○ Outreach/follow-up					
▪ Lists of patients needing services					

▪ phone calls (automated or human?)					
▪ letters					
▪ other					
o Case-management					
o Point of care reminders/alerts?					
o Condition-specific templates					
o Health education (1-on-1, group visits)					
o Visit summaries for patients					
o Feedback to providers(what measures, how) ?					
- At all sites? (if not, how many)					
Program Background					
- When did the program start? (year)					
- *How do you pay for program?* o *More paid visits, grant funding, pay-for-performance, other*					
- *Are there incentives for providers/teams?* o *If so, for what and how much?*					
Was there a rollout of specific EHR functionality for this program					
	Well-child Visits	Childhood IZ	Flu Shot	Obesity	Smoking
Immediately pre-EHR: *What were you doing just before you started using the EHR?*					
Put an X for each feature of the program					
o Outreach/follow-up					
▪ lists of patients needing services					
▪ phone calls					
▪ letters					
▪ other					
o Case-management					
o Point of care reminders/alerts?					
o Templates					
o Health education (1-on-1, group visits)					
o Visit summaries?					
o Feedback to providers (measures, how) ?					
- At all sites? (if not, how many)					

Appendix 2 Interview Codes

Appendix 2.1 Complete list of interview codes by category, with descriptions

Category	Category Description	Code	Code Description
Activities using the EHR	How was the EHR used for various activities[8].	Activ – Docu	Using the EHR for documentation
		Activ - List/Outreach	Production of lists of patients from the EHR and the conduct of outreach activities. Does include lab tracking and follow-up
		Activ - Pat-self mgt	Activities to enhance patient self management. Includes case-management, patient education, group visits, educational materials
		Activ - Remind & alert	Generation of reminders and alerts by the EHR. Also includes soft or passive reminders
		Activ - Templ & flow	Includes discussion of templates or flowsheets
		Activ - Viewing	Use of the EHR to view data
Background	Included CHC and Network history, patient populations served, demographics	Back	Background that does not include: -number of providers -number of specialists, NP, PA -Turnover - recruitment and retention -number and type of patients - Number of sites and types - Types of patients at a particular site
		Back - demo	Demographic background information. Includes: -numbers of providers, patients, and sites - types of providers, patients, and sites - recruitment and retention of providers and patients
Electronic Health Record	Outside of the actives described	EHR	EHR related quotations that don't fit in other EHR codes

	above, how the EHR was used, what were the limitations, and how did the EHR impact QI.	EHR Cost/fin - con	Continuous or on-going costs related to the EHR. Includes in-house technical support, contracting for external technical support, payments to the network
		EHR Cost/fin - init	Initial costs for the EHR
		EHR E-rx	Electronic prescribing through the EHR
		EHR GUI	Anything related to the graphical user interface of the EHR
		EHR Impact	Impacts of the EHR. Includes changes in efficiency, productivity, finances, or quality due to the EHR.
		EHR Implem	EHR implementation
		EHR Interface	Connecting the EHR to an external (to the EHR) data source. Includes laboratory, radiology, EPMS
		EHR Lims/Chal	Challenges and limitations related to using the EHR
		EHR Modifications	Changes that have been made to the out-of-the-box EHR system. Includes reports, templates, screen design, decision support
		EHR Other Soft	Other software beyond the EHR that was needed to complement the EHR's functionality
		EHR Staffing	CHC staffing for the EHR and reporting
		EHR Training	Training on the EHR
		EHR why adopt?	Why did the CHC adopt an EHR?
Finances	Looked at the financial health of the CHCs and the networks and the impact that grants had on QI activities	Fin	Financial information that does not fit under any of the other financial codes
		Fin Capacity?	Includes text about: -- the ability for a CHC to see new patients -- recent expansion -- their desire for to grow and expand access to care
		Fin FQHC Rate	Reimbursement rate for the FQHC
		Fin Grants	Grants received or applied for
		Fin Health	Financial health of the CHC or the network
		Fin p4p	Information about pay for performance
		Fin Payer Mix	% payers that are medicare, medicaid, insured, and uninsured/self-pay
		Fin Productivity	Provider productivity and any changes that may have occurred due to the EHR.

		Fin Reimbursement Methods	How are CHC's reimbursed for services rendered --capitation, grants, per-visit payments?
Health Information Technology	What forms of HIT were used prior to the EHR (e.g. disease registries, practice management systems)	HIT - CDMS	Chronic Disease Management and Registry System use
		HIT - Other	Other forms of HIT besides CDMS
Medical Homes	What medical homes activities were being done and how well did the EHR support these activities	MH	Medical homes activities that do not fit under other medical homes codes
		MH - Adv Access	Advanced Access. Includes flexible scheduling, same day appointments, 24x7 phone access.
		MH - FU & Tracking	General processes to track patient populations and conduct outreach to those who need services. Does not include lab tracking or follow-up.
		MH - Lab track/FU	Processes in place to ensure all lab values are looked at in a timely manner and followed-up with as appropriate
		MH - Pat satisfaction	Patient satisfaction. Is it measured and how often? What is done with the results of the measurement?
		MH - Pats tx same?	Are all patients treated the same regardless of payer class, race, language, or other demographic factors
Network	Anything relating to the function and functioning of the network including services provided by the network to member CHCs, the benefits and challenges of participating in a network, governance, and ways to improve the network.	Net	Information about the network that does not fit under finances or under the other network codes.
		Net- Benefits	CHC benefits related to participation in the network
		Net - CHC relp	Relationship between the CHC and their network. Shared resources.
		Net - Common	Common policies and software between network members
		Net - funding	How is the network funded?
		Net - governance	How much control of priorities do the CHCs have at the network level? What governing bodies are involved at the network, who is on each body, and how are decisions made?
		Net - Impl	Role of the network in EHR implementation

		Net - Lims/challs	Limits and challenges related to participation in the network and/or challenges at the network level
		Net - QI role	The network's role in QI at member CHCs
		Net - Services	What services does the network provide to member CHCs excluding QI.
		Net - Where new $?	If the network were to be give a multimillion dollar grant, how would they choose to spend the money to improve quality of care?
Performance Improvement	The performance improvement activities that were occurring at CHCs and Networks, factors that impacted these activities, and the role the EHR played	PI	Performance improvement. Includes culture of quality and anything else that doesn't fit under another PI code
		PI - learning	How a CHC or network learned about PI and PI strategies and tools.
		PI - Collabs	Experience in BPHC's Collaboratives
		PI - Ext - other	Participation in collaboratives other than those sponsored by BPHC
		PI - Fin limit	The impact of financial limitations on PI efforts
		PI - Guideline	How much of PI activities are PI based?
		PI - Incentives	CHC use of internal incentives as part of PI programs
		PI - JCAHO	JCAHO accreditation and impact on PI
		PI - Lims/chal	Limits and challenges on PI efforts not directly tied to finances
		PI - PDSA/chng	Use of PDSA or other change management techniques
		PI - Peer/chart rev	Peer review or chart auditing effort to assess quality of care or documentation
		PI - Plan/goals	Performance improvement plans and goals, including: - planning processes and goal setting -actual goals - important initiatives that are not captured elsewhere - how are PI areas prioritized
		PI - Prov/staff invol	Involvement of providers and staff in PI efforts
		PI - resources	Resources allocated for PI, includes % time for PI staff and PI committees
		PI - Sharing	How CHCs share best practices between sites and how CHCs share best practices with other CHCs

		PI - Teams/panels	Are providers and staff grouped into teams? Do providers or teams have panels of patients they are responsible for?
		PI - Training	Training in PI aside from collaboratives
		PI - Where spend $ CHC	How could new money best be spent at a CHC to improve PI efforts?
Population	Population of patient served with a particular QI program or EHR modification	Pop - adolescents	Anything related to adolescents
		Pop - asthma	Anything related to asthma
		Pop - behav hlth	Anything related to behavioral health
		Pop - cardio	Anything related to cardiovascular disease
		Pop - diabetes	Anything related to diabetes
		Pop - HIV	Anything related to HIV
		Pop - other	Anything related to other patient populations (e.g. coumadin, hep C, TB)
		Pop - peds	Anything related to pediatrics
		Pop - pre/post natal	Anything related to pre or post natal care
		Pop - wom mam	Anything related to mammography
		Pop - wom paps	Anything related to pap smears
Reporting	Quotations describing reporting form EHR data, how it was done, and challenges and limitations in the process.	Rpt	Performance reports, not lists of patients needing services. General statement about reporting
		Rpt - board/lead	Reports targeting the board or leadership
		Rpt - done by net	Reports produced by the network
		Rpt - feedback	Reports with the purpose of giving feedback on performance. Does not include provider specific reports
		Rpt - from 3rd party	Reports produced by third parties such as health pans (not CHC or network)
		Rpt - Lims/chals	Limitations and Challenges in generating reports
		Rpt - prvdr spec	Reports specific to individual providers or care teams
		Rpt - to ext org	Reports produced for the purpose of providing data to an external organization (e.g UDS, grant requirements)
		Rpt - validation?	Includes provider buyin and provider specific reporting as it relates to ensuring data quality
Miscellaneous	Codes that did not fit into any of the	?Does not fit code	Important quotations that did not easily fit into another code.

	designated concept categories	?F/u with int'ee needed	Unclear statements by interviewees that need clarification
		?good quote	Quotations of importance with the potential to be included as part of a manuscript.
		?sense making/exp	Broader ideas and sense making - crucial for understanding
		HIE	Health information exchange
		Ldrshp	Anything dealing with the impact of leadership on EHR use or QI efforts
		MA	The specific role of medical assistants
		Policy	Direct implications for public policy, what policy should be.
		Workflow	Changes in workflow

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