Improving Care in a Rural Region with Consolidated Picture Archiving and Communication System (PACS)

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Abstract

Purpose: This project created and evaluated a health information exchange system among three hospitals by developing a shared Picture Archiving and Communications System (PACS).

Scope: This project evaluated implementation of a shared PACS in two rural hospitals (Franklin Memorial Hospital and Miles Memorial Hospital) and an urban tertiary care hospital (Maine Medical Center).

Methods: The evaluation focused on: 1) implementation challenges and their solutions, 2) realized benefits, and 3) the impact of shared PACS on access to and use of relevant priors (RPs.) Pre and post implementation interviews with radiologist, ED staff, management, and others, site visits, and analysis of post implementation data from the PACS were used to examine implementation and impact (e.g. access to and use of relevant prior exams).

Results: Implementation was viewed as successful and beneficial by nearly all three hospital staffs. Although the process presented technical, communication, and human resource challenges, hospital staff realized many benefits from the shared system. Radiologists had improved access to RPs, could provide more efficient evening and weekend radiology coverage, and had greater opportunity to consult with sub-specialty radiologists. The shared system also provided greater security for radiology coverage.

Key Words: Picture Archiving and Communications System, relevant prior exams, shared PACS, health information exchange, consolidated imaging, rural hospitals

Final Report

Purpose

This project created a health information exchange (HIE) system among three hospital radiology departments. Specifically, a large urban tertiary hospital in Maine implemented a shared Picture Archiving and Communications System (PACS) with two rural hospitals. The shared PACS was designed to provide the rural hospitals with access to PACS, to improve the quality and cost of providing radiology services at all three hospitals, and to improve each hospital's ability to share radiology information with the other hospitals. The project goals were:

1. to successfully implement a shared PACS in two rural hospitals and train staff on the effective use of the shared system;

2. to document and understand the implementation of a regional, shared approach to PACs in a network of urban-based and rural health care provider organizations; and

3. to assess the short-term impacts of CI-PACS at the patient, provider, hospital, and health system levels.

This report describes the shared PACS and its implementation so that other hospitals may understand the blue print of this project as they consider developing their own radiology HIE system or incorporating radiology into an HIE system. The report also summarizes the results of the evaluation focusing on the factors that influenced the implementation and success of the project and the impact of radiology information exchange on providing quality radiology services.

Scope

Background

Quality and patient safety initiatives have increasingly focused on the use of health information technology (HIT). In addition to electronic medical records (EMRs), the federal government and others have pushed for health information exchange (HIE).[1] HIE allows electronic sharing of information between health care organizations, facilitating access to and retrieval of clinical data across the continuum of care.[2]

The development of HIE systems, however, have not progressed as well as expected. In a survey of HIE initiatives in 2006, only 9% were fully operational.[3] The challenges associated with establishing these systems likely play a significant role in these slower than expected adoption rates. Financially, the development of these systems includes considerable start up money and maintenance costs, making it difficult to get participants to invest in these systems.

Others face technical issues, including how to determine where the data will be held, who will have control over it, how to make disparate systems interoperable, and how to ensure that each participant organization is using the same standards and protocols. Determining who controls the data can be especially difficult when members are in competition with one another. Finally, the HIE system must address privacy and security issues, including answering questions about who should have access to what data and how to limit access by providers, while reassuring patients that their health information is being adequately protected.

To date, few HIE initiatives have included radiology in their systems. Approximately 10% of HIE initiatives share radiology images compared to 26% who share laboratory data.[4] However, some have argued that radiology could be an ideal first step in exchanging health information. Picture Archiving and Communications Systems (PACS) have already been widely adopted and use a digital format. Incorporating radiology images and reports into the system would improve patient care, address the shortage of radiologists' coverage, and improve efficiency. With patients' increasing mobility across health care organizations, radiologists have difficulty acquiring relevant prior exams (RPs), which improve radiologists' ability to provide the most accurate diagnosis.[5] A "relevant prior" exam is an imaging study from the same patient performed on the same body part as the new exam. Physicians would also have access to radiology reports making it easier for them to coordinate and manage their patients care across providers. While teleradiology, used for years in radiology, represents a potential solution to radiologist shortages, the ability to share images and reports across organizations could make this process more efficient. Lastly, the exchange of radiology images and reports can improve efficiency and reduce costs, by diminishing the need for performing the same exam at multiple facilities.[6]

While there are significant benefits to including radiology in HIE systems, there are also challenges. Not all health care organizations, especially those in rural areas, have adopted PACS due to its high capital and operating costs. These organizations will need to purchase PACS and other new equipment in order to participate. PACS also requires the transfer of large amounts of data that HIE networks may not be ready to handle. Lastly, adding PACS to the system will require additional interfaces to effectively exchange information among disparate systems.[7]

While rural hospitals recognize the need for PACS, they face many challenges in acquiring this technology. They typically have limited financial resources, making it more difficult for them to finance the initial costs for HIT. Salaries are typically lower in rural settings making it harder for hospitals and other providers to attract and retain IT staff to implement and maintain HIT. Compared to urban physicians, rural physicians may be less technologically savvy and more resistant to HIT adoption. Rural providers may also face unique challenges in obtaining the needed network bandwidth and paying for higher transmission costs.[8]

Given these challenges many rural hospitals have not yet obtained PACS, while those that have not been able to operate them. This project provides an alternative approach for PACS adoption in rural hospitals by creating a shared PACS. Through the Consolidated Imaging PACS (CI-PACS), a tertiary care hospital (Maine Medical Center) and its health system (MaineHealth) implemented a shared and interoperable PACS in two rural hospitals, Franklin Memorial Hospital and Miles Memorial Hospital. The shared system offers each hospital with potential additional benefits over a stand-alone system. The shared PACS allows these organizations to exchange radiology images and reports among themselves, improving access to RPs, which has been shown to result in better quality of care. Emergency department (ED) staff and surgeons can access images from the rural facilities prior to the arrival of patients at their

hospital, making care more timely. Rural facilities also face significant challenges recruiting and retaining radiologists and may often rely on remote reads and back-up coverage by urban radiologists. The new system allows urban radiologists to remain at their own facility when reading exams taken at other sites, making back-up coverage more efficient and convenient. Lastly, rural radiologists have greater access to sub-specialty radiologists for remote reviews, consultations, and backup coverage when needed.

The results of this project offer HIE system developers important information on the challenges of implementing a shared PACS in rural hospitals, including data access and control, financial sustainability, and interoperability. These would no doubt be similar to those being faced in implementing an HIE initiative in such facilities.

Project Description and Context

In February 2001, MaineHealth, Maine Medical Center (MMC), and other health care providers developed the Consolidated Imaging Initiative (CII) to explore ways to allow multiple organizations to archive radiology images through MMC's PACS and to retrieve and display those images throughout each organization's clinical enterprise. In 2003, they successfully implemented a shared or consolidated PACS at St. Andrew's Hospital. With this success as the foundation, they hoped to implement their shared PACS in other hospitals and organizations. Through funding from the Agency for Healthcare Research and Quality (AHRQ) in 2004, the CII began expanding the shared system by implementing it at Franklin Memorial Hospital (FMH) and Miles Memorial Hospital (MMH).

Under this shared system, MMC's servers store all images taken at MMC, MMH, and FMH, allowing the hospitals to have access to their own and the other hospitals' images through wide area network (WAN) connections to MMC. The shared server eliminates the need for each hospital to maintain its own server. In addition to implementing the PACS at MMH and FMH, MMC maintains the system, provides IT support, and installs upgrades at the two rural hospitals. MMH and FMH pay for new radiology equipment (e.g., Computed Radiography), network connections, and data transmission costs. To maintain the system without further grant funding, MMH and FMH will pay a per exam fee to cover incremental costs incurred by MMC to support the expanded PACS.

Prior to implementation, the participating hospitals expected three major benefits from the shared system: 1) cost savings, 2) improved quality of care, and 3) improved access to radiologists. By eliminating film, the two rural hospitals anticipated saving money on storing and archiving film-based images. All three hospitals expected the shared system to improve the quality of care by providing access to the other hospitals' radiology information, especially relevant prior exams. Previous studies have shown that having access to relevant prior images and reports improves radiologists' ability to interpret radiology exams.[9] Lastly, for many reasons, rural hospitals have difficulty recruiting and retaining radiologists. Since multiple radiology groups can access the shared system, the rural hospitals could choose to use their services if they should lose a radiologist. MMH, which contracts with a Spectrum radiologist for their coverage, expected CI-PACS to help make coverage for nights, weekends, and vacations more efficient as other Spectrum radiologists could easily access cases done at MMH. Prior to the shared PACS, these radiologists would have to travel an hour to MMH, but under the new system they can remain in Portland to review MMH exams.

Settings and Participants

Maine is a large, mostly rural state. The two rural hospitals are separated from MaineHealth, Maine Medical Center and Spectrum Medical Group (all located in Portland) by 60 and 100 miles. MMC is the largest tertiary care system in Maine and routinely receives referrals from the two rural hospitals and others in the state. This section describes each participating organization and its role in implementing the shared PACS.

MaineHealth. MaineHealth is a not for profit integrated health care delivery system that serves approximately 75 percent of the state's population. System members are either owned by MaineHealth, including MMC and MMH, or independently owned but affiliated with the system. Members and affiliates can voluntarily participate in a wide array of benefits and services offered by the health system. MaineHealth contributed to the project by providing the leadership to develop the partnerships needed to implement CI-PACS.

Maine Medical Center (MMC). MMC, the largest hospital in Maine with 600 beds, acts as a level one trauma center and a tertiary referral and teaching hospital. Twenty-five diagnostic Spectrum Medical Group radiologists serve MMC and typically perform over 180,000 exams per year. MMC's radiology informatics team, located within the radiology department, have developed expertise in radiology workflow and the integration of radiology systems. They managed and carried out the implementation of the shared PACS at each hospital.

Miles Memorial Hospital (MMH). MMH, a MaineHealth member, has 46 beds and depends significantly on fundraising and grants to purchase new equipment and systems since approximately 80% of its revenue comes from Medicare and Medicaid. The radiology department has one full-time radiologist, who is contracted from Spectrum Medical Group. They offer CT, ultrasound, mammography, X-ray, and mobile MRI services. The hospital sends the majority of their referrals to MMC.

Franklin Memorial Hospital (FMH). FMH is not a MaineHealth member or affiliate. It is a 70 bed, not for profit hospital that serves approximately 40,000 individuals in 23 rural communities in northwestern Maine. The hospital has a network with a behavioral health provider, a community public health coalition, a multi-specialty group practice, and a physician hospital organization. Two independently employed radiologists (1.5 FTEs) staff the radiology department. On average, they perform 42,000 images a year. Unlike MMH, FMH refers patients to both MMC in Portland and to Central Maine Medical Center in Lewiston.

Spectrum Medical Group. This physician-owned and led multi-specialty group practice is Maine's largest with over 140 Board certified or eligible providers, including radiologists. The radiologists perform over 600,000 diagnostic exams or interventions each year as well as providing sub-specialty expertise. Spectrum Medical Group provided 25% of a radiologist's time to assist in optimizing the clinical and service environment, streamlining radiologist workflow, enhancing the function and usefulness of PACS, and working with the other hospitals' staff. Spectrum also provided MMH $100,000 to purchase a diagnostic work station that allowed the radiologist to perform soft-copy interpretations for CT, MRI, and ultrasound.

Methods

Implementation

Implementation of the Consolidated Imaging Initiative (CII) proceeded in seven phases. They are described below in the approximate order they were accomplished, but some phases overlapped. Each phase description focuses on the high level tasks.

Phase 1: Pre-implementation Preparation. For each site (MMH and FMH), a CI-PACS implementation team was created to develop implementation plans and oversee the implementation process. The implementation team consisted of radiology personnel and radiologists from each respective organization, and the Director of Radiology Informatics from MMC, with administrative, clinical and information systems staff joining the team as needed.

The implementation team conducted a workflow analysis to assess the current and future states of workflow in each radiology department. This analysis was essential in determining how best to implement CI-PACS at each hospital. While the system can typically adjust to differences in workflow, some differences cannot be addressed without changing the workflow process. Therefore, this analysis identified when workflow needed to be changed to fit the system.

The team also assessed DICOM (Digital Imaging and Communications in Medicine) conformance and infrastructure needs. DICOM is an application network protocol that allows for the transmission of radiology images. A DICOM standard was designed to ensure the interoperability of radiology systems. The team evaluated the conformance of each modality (e.g., CT, MRI) to determine the level of interoperability of MMH's and FMH's modalities with MMC's PACS. Non-DICOM compliant systems needed to be upgraded or replaced to conform to the system.

FMH and MMH needed to upgrade their local area networks (LANs) and wide area networks (WANs). During the pre-implementation phase, the team determined the time needed to obtain the network bandwidth, connectivity, and quality of service enhancements. These upgrades have often been difficult for rural communities to acquire. The team also redesigned reading room configurations and determined equipment and lighting requirements.

Lastly, the team created a training plan to encompass functional use of CI-PACS workstations and changes in workflow. Training focused on radiology staff and other clinicians to ensure optimal usage and image review frequency. The team used a train–the-trainer model with MMC's radiology informatics staff training one or two "super users" at each hospital. The super users then trained their own staff. Each hospital used group training sessions, while FMH also used one-on-one training as new components of the CI-PACS were implemented.

Phase 2: Network Connectivity. Establishing adequate network bandwidth between MMC and each hospital represented a key technological challenge during implementation. FMH needed to establish a WAN connection, and MMH needed to increase the bandwidth of their existing connection to MMC. Although the hospitals and management team worked closely with their communities' telecommunication providers to establish these connections, the process still took at least a year. The costs of WAN for MMH and FMH have been $30,000 and $50,000 per year respectively.

Phase 3: Demographics/Radiology Order Flow. The PACS-to-RIS interface provides the shared PACS with patient demographic and radiology order information. A RIS is a computer-based system that allows a radiology department to store and maintain patient radiology data and images. Most systems provide patient registration, appointment scheduling, patient tracking, results entry, and reports. The interface between the PACS and RIS serves a number of functions including:

- Linking PACS imaging information and Hospital Information Systems (HIS)/RIS clinical information;

- Connecting all studies for a given patient;

- Providing the necessary order information to enable automatic retrieval of relevant prior exams;

- Updating patient demographics when the information is updated or changed;

- Associating radiology results in the RIS to the images archived in PACS;

- Providing new and prior reports to clinicians via the PACS and web-based access; and

- Providing the link between the digital dictation system and PACS.

The accession number or exam identifier allows the CI-PACS to associate all images for a particular study to an order and all its associated patient and clinical information in the HIS and RIS. Without a valid accession number, the validation process which ensures that all human data entry errors are corrected before the study is archived cannot occur, and the images unavailable for the radiologist to interpret or for clinical distribution.

Each hospital had to decide how to integrate CI-PACS with their respective Meditech systems. Meditech is a vendor that provides HIS and RIS products. The order information could be manually entered in CI-PACS through the Cerner RIS (MMC's RIS) or an interface could be developed between the MMH and FMH Meditech systems and the MMC RIS. Interfaces also needed to be created to connect result reporting and transcription. Ultimately, both hospitals chose to keep their own HIS and RIS, requiring interfaces to be created.

To automatically match patients' exams from another hospital (i.e., as a relevant prior), the patient identifiers from each organization had to be matched to establish that they are, in fact, the same patient. To accomplish this, all interfaces to or from MMH's or FMH's Meditech systems passed through the MaineHealth Enterprise Master Patient Index (EMPI). This system matched patients from different organizations and established links between them (i.e., the Global Patient Identifier or GPI), enabling the PACS and RIS systems to collate records from each organization, and providing all RPs to the radiologists, regardless of where those exams were acquired.

Phase 4: Computed Radiography Implementation. Both rural hospitals installed a Computed Radiography (CR) unit to enable direct digital capture, storage, and display of images. CR provides physicians and radiologists with images ready almost immediately after the

technician validates that the exam was performed correctly. To provide some redundancy if the CR unit fails, each hospital implemented a high volume and a low volume CR unit.

Phase 5: Modality Connectivity and Digital Archiving. Based on pre-implementation analysis, modality connectivity required upgrading each modality, as needed, to ensure full DICOM compliance. To convert films to digital images, the rural hospitals were provided with diagnostic level digitizers. Once network connectivity was established and patient demographic and radiology information were available in the MMC RIS, images were ready to be archived. By archiving images, the images were stored, routed, pre-fetched, and soft-copy reviewed. Also during this phase, the workflow re-engineering process occurred and training began with radiology and clinical staff.

Due to limited bandwidth between each hospital and the core PACS at MMC, the CI-PACS implementation team installed a local image cache at MMH and FMH. All studies were sent to the local image cache and then forwarded to MMC for permanent archiving. Holding approximately a year's worth of studies, the local cache reduced the number of times exams needed to move across the WAN. With these caches' installed, the performance of the CI-PACS at each remote facility was nearly as good as the performance at MMC.

Phase 6: Diagnostic Soft-Copy Reading. The activation of soft-copy reading on a PACS workstation depended on several steps, including:

- Installation of radiology workstation(s);

- Configuration of the CI-PACS to forward studies to the local image cache and remote archive;

- Creation and customization of each user's account;

- Installation of appropriate digital dictation equipment and interfaces;

- Training all radiologists on the use of CI-PACS workstations;

- Training other radiology staff in new soft-copy reading workflow.

At this point, only radiologists are able to view images. Web access, implemented in the final phase, provided access to other clinicians.

Phase 7: Web Access Rollout. Implementing web-based access to digital images expanded the soft-copy review to additional clinical areas. Before full implementation of web-based access, the implementation team needed to demonstrate high levels of system performance and reliability and that the hospital network implementation was complete. Soft-copy access was provided through Agfa's Web1000 product, using web-based review stations positioned in the ED and other high use clinical areas. These workstations provided clinicians with quality images and image manipulation. In addition, the system allowed remote sites and physicians' offices access to images as long as they had a connection into the hospital's CI-PACS network. With these connections, the implementation team hoped that FMH and MMH could reduce their

reliance on hard-copy films by at least 90%, providing cost savings that could be used to help sustain the CI-PACS.

Under CI-PACS, MMC stores all images taken at MMH and FMH on the MMC servers. Storing images on a single server allows the hospitals to access their own and other organizations' images through wide area network connections to MMC and eliminates the need for each hospital to have its own server. MMC also implements and maintains the PACS at each facility, provides IT support, and installs upgrades. The rural hospitals pay for new radiology equipment (e.g., Computed Radiography), network connections, and data transmission costs. Although the AHRQ implementation grant provided the funding needed to buy equipment and install the system in the hospitals, MaineHealth and MMC have created a way to sustain the system, using a per exam fee schedule to cover MMC's costs.

Evaluation

Overview. Our evaluation focused on answering three key questions:

1. What challenges were encountered during implementation and how were they addressed?

2. What were the realized benefits of the shared PACS?; and

3. How did the shared PACS affect access to and use of RPs?

We used a mixed method approach, relying heavily on qualitative interviews. To address the first two questions, we conducted key informant interviews before and after implementation with hospital leaders, radiologists, ED physicians, and others involved in implementing and using the new system. These interviews were conducted on-site and by telephone. To assess results related to the third question, we used pre and post implementation interview questions and post implementation shared PACS data to assess access to RPs.

Implementation and Realized Benefits. We conducted on-site semi-structured interviews at each hospital with radiology, management and IT staff to assess the implementation process. The interview protocols consisted of four topic areas, including 1) decisions to participate and anticipated impacts of a shared PACS, 2) the planning and implementation process, 3) challenges and lessons learned, and 4) comparisons on the impact of a shared PACS and a stand-alone PACS.[10] We asked specific questions about how the implementation process went at each rural hospital and how it might be improved in the future. To assess anticipated and realized benefits, we conducted pre and post telephone interviews with radiologists and ED physicians at each hospital. To facilitate the interview process, we used tape recorders during the interviews and transcribed and reviewed these tapes to identify key findings and common themes.

Access and Use of Relevant Prior Exams. We used both qualitative and quantitative methods to assess providers' access to and use of RPs. First, we conducted semi-structured telephone interviews with radiologists and ED physicians at each hospital before and after implementation. The interviews assessed their views on relevant prior exams and their access to these exams. In the pre-implementation interviews, we asked respondents questions about their prior experiences with PACS, their opinions about participating in a shared PACS, their access to

RPs before PACS, and the impact of RPs on the provision of radiology services. The ED physician interviews also included questions about patient transfers to other participating hospitals. Post-PACS implementation interviews gathered the same information about RPs, but also included questions about realized benefits, perceived change in the access to and use of RPs, and the impact on patient care. After each interview, notes were typed and reviewed to identify key findings and common themes.

CI-PACS data were also used to assess the availability of RPs. Once implemented, the CI-PACS application offered extensive data, providing insight into the effectiveness of the shared PACS. For example, every exam archived in the system was matched with other exams from the same patient using the Global Patient Identifier, providing a clear connection between exams from different organizations. Additional exam data, such as modality or body part, allowed us to correlate the use of RP data with certain exam properties (e.g., is a chest x-ray or a CT scan more likely to have a relevant prior from another organization). The relevant exam data were extracted from the CI-PACS database using standard SQL database queries, then formatted and imported into Microsoft Excel, and analyzed using standard pivot tables. To reduce the size of the dataset to a manageable level, only the exam data from May (22,388 exams) and November (19,974 exams) 2007 were thoroughly analyzed. As expected, exams done in November had more RPs in CI-PACS (53% in November vs. 44% in May) since more patients are likely to have had multiple exams in the shared PACS the longer it is operating.

Limitations. This evaluation has a number of limitations. First, we do not directly measure patient level quality. In the design, we recognized that quality would be unlikely to change in the short time we had to collect data post implementation. Second, assessing the impact of an intervention on quality would have been difficult without a more controlled design, which was infeasible given the evaluation's scope. We also encountered some limitations in our interview protocols. During the pre and post implementation interviews of radiology and ED staff, we asked questions that required respondents to estimate their access to RPs before and after implementation. Many respondents found these questions difficult to answer and often felt that they were just guessing. Given this problem, we decided to drop these questions from the analysis and rely on the PACS data and respondents' perceived access to assess changes in access and use of relevant priors. Finally, we planned to conduct a cost analysis to assess the cost savings for the two rural hospitals. We wanted to assess the cost savings obtained by adopting a shared PACS over a stand-alone, rather than assess the savings associated with acquiring PACS. To do this, we could have either estimated the costs for a stand-alone system for each hospital and compared it to the costs to the shared system or compared participating hospitals with similar hospitals with stand-alone systems. The costs of PACS implementations tend to vary widely depending on application functionality, system robustness, and on-going vendor support. Recruiting comparative hospitals would be difficult since they would have no incentive to participate. In the end, we concluded that any attempt at a "shared vs. stand-alone" PACS analysis would be futile. While such an analysis may have helped in supporting a shared PACS implementation, our results support the hypothesis that the real benefits of a shared system are its ability to provide radiologists with immediate access to RPs, thereby helping to improve the timeliness and quality of care.

Results

Challenges and Solutions

There were several technical challenges encountered during the shared PACS implementation. For the system to be effective, it must be able to share clinical and administrative data from disparate systems. For MMC, developing an Enterprise Master Patient Identifier (EMPI) for the shared PACS was a significant challenge. The EMPI that was developed conducts a behind-the-scenes matching of demographic information to identify whether a patient from MMH is the same as a patient from MMC. However, due to limitations in the EMPI product and its implementation, all potential "first-time" matches had to be reviewed by a human (i.e., the first time the EMPI was asked to match a patient with identifiers from two different organizations, that match was done manually). Furthermore, since people change their names or demographic data were not always captured correctly, this "manual" match may be delayed by hours or days, if the patient or provider must be called to confirm the "oneness" of the two records. Since radiologists are often dictating radiology exams within a few minutes of exam acquisition, these delays are significant. If the patient match did not occur before the radiologist opened the new study, the RPs would not automatically display and would need to be opened manually. However, the radiologist may not know a RP exists, thereby resulting in a RP being missed. Nonetheless, even the delayed matches are generally faster than any solution involving separate PACS since the RPs would need to be moved from one PACS to the other; a cumbersome and costly process.

Both rural hospitals had significant problems with WAN connections and transmission costs. To obtain their WAN connections and adequate bandwidth from their local telecommunication provider each hospital waited at least a year. This problem may lessen in the future with rural hospitals' ability to obtain these connections has improving as the telecommunications infrastructure improves.   FMH and MMH also faced significantly higher transmission costs than would be expected in a more urban area, with FMH paying $50,000 per year and MMH paying $30,000. Staff at both sites was concerned about how they would cover these costs after the grant period ended. Although it is too early to assess results, MMC and the rural hospitals expected that cost-savings obtained from reducing the need for film-based images, and by not having to purchase, upgrade and support their own PACS, would help to cover these transmission costs. Also transmission costs have decreased significantly over the last three years making WAN connectively much less of an issue. Furthermore, other HIE initiatives have begun which share the WAN connections, thereby reducing the costs to one single program.

The implementation process also illustrated differences between urban and rural hospitals. While urban hospital staff are highly specialized, rural hospital staff tend to be generalists. Even after conducting a work flow analysis, some rural staff felt the implementation team did not understand how *their* radiology department worked. Unexpected differences in workflow that could not be changed also resulted in challenges for the team. Prior to PACS, the transcription process at FMH identified and placed urgent or emergency cases at the top of the list. For these cases, transcriptionists were provided information on whom to call immediately after the report was completed. The transcription system that MMC uses places urgent or emergency cases at the top of the list, but does not identify them as urgent. Therefore, they appear just as the next report to transcribe and transcriptionists do not know to rush a particular case. The system also

does not include information about who to contact when the report is completed. At MMC, urgent cases were communicated by the radiologists, not the transcriptionists. Initially, FMH tried MMC's transcription system, but decided that they could not change this portion of their workflow. To resolve this problem, MMC's IT staff created new interfaces to ensure that the different transcription system would work at FMH under CI-PACS.

Other differences in knowledge also affected the process. The rural hospitals had a strong understanding of how their hospital and radiology department worked, but they lacked expertise in PACS. On the other hand, MMC had significant experience in implementing PACS and the workflow at a large organization, but knew little about how rural hospitals work. These differences in knowledge led to some difficulty for rural staff in communicating what they wanted in a system and MMC implementation staff fully comprehending the needs of the rural hospital. Furthermore, the PACS implementation at MMC had been finely tuned for the desired workflow at MMC. The needs of the other organizations could not always be met either due to the limitations of the software to support disparate workflows, or because a change in workflow would impact all sites participating the CI-PACS.

The rural hospitals also identified human resource challenges. One hospital chose not to hire its own IT support staff or a PACS project manager. The Director of Radiology at this hospital took on the responsibility of managing the radiology department and the implementation process. In retrospect, the director felt that having these staff available would have made the implementation process run more smoothly. The other hospital had an IT support person on-site which they felt helped them to look out for their hospital's interests, assisted in project management, and addressed day to day issues. While the shared PACS model certainly removes the need for the rural hospital to hire staff to support the core PACS infrastructure, it does not eliminate the need to provide adequate local staff to support the implementation. The lesson learned was that the central PACS team could not completely mitigate the need for dedicated staff to support a PACS implementation, even at a relatively small organization.

Many providers find changing how they do things difficult, making it important to obtain clinician buy-in early in the process. One hospital involved their radiologists, physicians, and others in the planning phase. By involving physicians early, they were able to identify physician champions making it easier to get buy-in from other clinicians. The other hospital brought physicians into the project later and found it harder to get physicians to acclimate to the new system. Again, while the experience of the remote "central PACS staff" can help reduce the burden on the local staff, it cannot replace the involvement of the local team.

Realized Benefits of a Shared PACS

The hospitals involved in CI-PACS anticipated that the shared PACS would bring additional benefits over a stand-alone PACS, including greater access to RPs, cost savings, and assistance with radiology coverage. As part of the evaluation of CI-PACS, we wanted to know whether hospital staff actually felt that they had achieved these benefits. Through interviews with management, radiology and IT staff, we found that overall, the staff at all three hospitals felt that the shared PACS had lived up to their expectations. Radiologists found that they had improved access to RPs, allowing them to base their diagnosis on better information. A few staff, however, thought the drawbacks of a shared system did not outweigh the benefits. They felt the shared PACS was slower than having a stand-alone PACS because they needed to transmit images over long distances, while they only had a small percent of cases where they needed a RP image from

another organization. One staff member suggested that being able to make hospitals' different stand alone systems interoperable would be more effective and efficient.

An important reason for one hospital to participate in the shared PACS was to ensure radiology coverage. They felt more secure knowing that if they lost a radiologist they could rely on other radiologists to at least temporarily provide coverage. The other hospital already uses a radiologist from Spectrum, which may offer them other benefits. The radiologist at this hospital found that if he got too busy or could not come to work, other Spectrum radiologists could provide the hospital coverage by reading exams remotely. The ability to read exams remotely also benefited Spectrum radiologists by eliminating the wasted time to drive to the other hospital, often in inclement weather. Although not used to its full potential, both hospitals found consultation from other radiologists, especially sub-specialty radiologists, to be an important benefit from CI-PACS. With these consultations, they could determine whether a patient needed to be transferred to another facility and confer with another radiologist in difficult cases.

Access to and Use of Relevant Priors

Our interviews indicated that radiologists perceived a change in their access and use of relevant priors before and after implementation. The radiologists all stated that they had improved access to relevant priors, especially in situations where they were not aware that there was a relevant prior. Before the shared system, radiologists only knew there was a relevant prior if it was within their own institution or if a patient said they had a prior exam at another facility.

Both radiologists and ED physicians also commented on how access to and use of RPs improved the quality and efficiency of providing care. Prior to the shared PACS, patient transfers between the rural hospitals and MMC required that film based exams be copied and sent along with the patients, sometimes delaying care. Even with a stand-alone PACS the rural hospitals would have to copy images to a CD, which depending on the number of images can take a considerable amount of time. However, under the shared system, images are available in the system for staff even before the patient arrives, improving their ability to diagnose the problem and plan potential treatments. ED physicians also felt that having these images readily available reduced the need to perform the same exam again once the patient arrived at MMC. Lastly, ED physicians at all three hospitals found that they used the RPs more often under the shared system since the RPs automatically appeared on the screen with the new images. Prior to the shared PACS, RPs were not readily available and the physicians did not have the time to track them down.

The analytical data provided by the CI-PACS database provided significant evidence to support the assertion that relevant prior exams are often available from another facility. For example, the Table 1 below shows that on average 49% of exams that contained at least one RP done at the same site as the original exam, and that about 7% of exams done had a RP at a different site. Thus, in November 2007 alone, nearly 1,000 of 13,340 exams done at MMC, MMH, or FMH had at least one RP done at another site. Without a shared PACS system, these relevant prior exams would need to have been moved from one PACS to another – a cumbersome, costly, and error-prone process. Table 2 shows RPs broken down by exam type. While all exam types had at least some RPs at another site, body, neurological, and spine exams had RPs at another site about 11% of the time. Chest exams, the most common type of radiology procedures, had a relevant prior at another site in about 8% of the cases.

Table 1. November 2007 relevant priors by site

Exam Location	Total # Exams	# With Priors at Same Site	% With Priors at Same Site	# With Priors at Another Site	% With Priors at Another Site
MMC	9,851	5,161	52%	725	7%
Franklin	2,167	824	38%	112	5%
Miles	1,322	518	39%	162	12%
Total	13,340	6,503	49%	999	7%

Table 2. November 2007 relevant priors by exam type

Exam Type	Total # Exams	# With Priors at Same Site	% With Priors at Same Site	# With Priors at Another Site	% With Priors at Another Site
CHEST	3,911	2,557	65%	314	8%
BODY	2,769	1,584	57%	310	11%
NEURO	1,115	505	45%	125	11%
SPINE	981	367	37%	106	11%
BREAST	705	470	67%	10	1%
VASC	549	270	49%	10	2%
FOOT/ANKLE	513	123	24%	8	2%
HAND/WRIST	509	117	23%	15	3%
HEAD/NECK	474	107	23%	7	1%
KNEE	449	100	22%	26	6%
HIP	337	104	31%	18	5%
SHOULDER	319	59	18%	19	6%
LOWER EXT	195	35	18%	2	1%
BONE	195	60	31%	20	10%
UPPER EXT	193	34	18%	4	2%
CARDIAC	123	11	9%	5	4%
OTHER	3		0%		0%
Total	13,340	6,503	49%	999	7%

Conclusions and Implications

This project demonstrated that a shared PACS is not only feasible, but can offer additional benefits over stand-alone systems. While there were challenges to implementing the shared system, most staff at the participating hospitals felt that overall the process went smoothly. Having improved access to RPs from other hospitals increased radiologists' access to and use of RPs, providing them with more information to make diagnoses and to assist other physicians in clinical decision making. Access to RPs across organizations also improved the quality and efficiency in providing care for patients transferred from the rural hospitals the rural hospitals to MMC. Lastly, the shared system made back up radiology coverage more available to the participating rural hospitals and improved the efficiency of such coverage for Spectrum radiologists.

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The implementation of this shared system also has several lessons and implications for other health information exchange efforts. To assure that patients could be identified across all three hospitals, the implementation team needed to develop a master patient identifier. HIE projects can take away important lessons from this process by further examining the technical aspects of how it was developed and learning from challenges. For example, before implementing HIE projects, developers may want to focus more time on ensuring that patient demographic data are completed with the same level of accuracy across organizations. By doing this, they may save time spent on manually verifying whether two patients are actually the same patient.

Although more challenging, this project also illustrates that disparate systems can be made interoperable. While the hospitals all shared the same PACS, the rural hospitals had different RIS and HIS than MMC, requiring the implementation team to connect these disparate systems. The project also demonstrates that sharing or exchanging information across organizations needs to address differences in work flow and organizations willingness to alter their workflow. During implementation, FMH discovered that the transcription system within the shared PACS would not allow them to identify urgent cases or note who to contact when these cases had been transcribed. Ultimately, they decided they could not change their transcription process and purchased their own system, which needed to be made interoperable with the shared PACS.

Lastly, this project provides HIE developers with an alternative model, which may offer potential benefits over current HIE efforts. Under the shared PACS, participating organizations purchased the same PACS and used their current RIS and HIS. The urban tertiary hospital archived all data on a central server, allowing information to be accessed by all participating providers. With many rural and small providers facing significant barriers to adopting HIT, the shared system model improves these providers' access to HIT. In addition, sharing a system limits the duplication of costly hardware used for storing data, allows more rapid implementation, and reduces the ongoing costs of upgrading and supporting the system. The shared system approach to HIE supports a cost sharing model that could fund HIE efforts. A shared system may be more likely to receive financial support since it reduces the burden on each organization.

Next Steps and Future Projects

Before ubiquitous PACS, images obtained at other organizations and needed as RPs were sent via film or not sent at all. While CI-PACS removed the need to transfer images between participating organizations, the system does not provide a solution for sharing information with sites having "stand-alone" systems. Today, images are generally transferred between those organizations via CDs. While these CDs have significant benefits over traditional film (e.g., images can be manipulated electronically when they are viewed, they can be imported into our local PACS, etc.) there are also problems with this approach. CDs are much easier to lose than a jacket of film. They are small enough to fit into a lab coat pocket, or they are often inadvertently left in a computer CD drive. Also, the data on CDs are sometimes corrupt when it arrives at its destination, unbeknownst to all until the image review is attempted.

The current CD import process is very labor intensive, and the personnel required to perform the import are not available during off hours. Most organizations implementing PACS reduced their film library staff as the need to manage films declined. Tertiary referral hospitals such as MMC which are recipients of many incoming referrals did not anticipate the need to manage a complex and labor intensive process of importing CDs and digitizing film based images sent from referring organizations. As PACS become more prevalent in smaller hospitals and out-

patient imaging centers, this image importing work has grown significantly. More importantly, we ultimately want all exams sent to us via a CD to be imported into our PACS so those images can be reviewed using our system (by all users needing access, not just the user who happens to be in possession of the CD), and so those images can be easily compared to new exams acquired at MMC and other sites participating in the CI-PACS.

Currently, we are investigating a solution to the problem, which would allow images to be transferred electronically between disparate PACS systems using private or encrypted public (i.e. virtually private) network connections between organizations. Being done in conjunction with the One Maine Health Collaborative project (MaineHealth, Maine General Health, and Eastern Maine Health), this project will ultimately enable organizations to transfer relevant imaging exams (i.e., imaging studies for patients being or having been treated at both organizations) between one another such that those exams are available when and where needed. Although driven by the One Maine Health Collaborative, the project's ultimate application will include all hospitals or imaging centers that wish to participate. The approach has several components:

- Secure Network Connections: In order to transfer images electronically, a secure network connection must be established between the sender and receiver. While not without some work, VPN connections are generally straight-forward to establish, and, in fact, often already in place.

- DICOM Connections: Digital Imaging and Communications in Medicine (aka DICOM) is relatively universal in the radiology imaging world. Most PACS systems support DICOM, at least to the extent required to transmit a basic image from one PACS to another. While idiosyncrasies in DICOM do exist, they are not much different, probably less so, than is experienced when attempting to import a CD created on a "foreign" PACS. While we do anticipate some challenges with the DICOM transfers between organizations, we suspect most can be overcome.

- Image Transfer Registry: One of the challenges associated with electronic image transfer – and the prevalent reason we have not previously pursued it – is that once images arrive at the remote PACS, they must generally be "processed" (requiring human intervention) to successfully import them into the remote system. This step effectively "moves" the study from the "foreign" patient and exam identifiers (i.e. the identifiers used where the exam was first acquired) into the local system, thereby aligning the imported exam with new (or previous) exams obtained at the local site. If not done properly, the transferred exam will effectively be "lost" as it will not connect to other exams for that patient. In addition, there have always been numerous other concerns impeding the electronic transfer of exams. For example, how does the receiving site know an exam has been transferred – or how does it know why the exam was sent? How does the receiving site verify it has received all exams and images that were sent? In order to ensure clear communication between the sender and receiver, we have developed an Image Transfer Registry which fully captures all necessary communication between the sending and receiving sites. This web-based application ensures the transferred exam(s) can be properly handled by the receiving organization.

- Image Transfer Protocol: Lastly, in order to ensure image transfer is both safe and efficient, we have developed an Image Transfer Protocol. This protocol clearly defines the expectations between two organizations aspiring to enable electronic image transfer between them. This document clearly identifies the protocol to be followed when transferring images between sites. Questions like "who do I call if the image transfer fails" or "which exams do I transfer" are clearly defined in the protocol. It is this document, along with the aforementioned Image Transfer Registry, that will enable us to extend the electronic transfer of images to organizations outside the One Maine Health Collaborative. Any organization agreeing to follow the established protocol (which specifies, among other things, the use of secure network connections, DICOM transfers, and required use of the Image Transfer Registry) could replace the cumbersome process of sending CDs to MMC with an approach utilizing electronic transfer to MMC.

We hope to begin our first testing of electronic image transfer in the next few months. The network connections are currently being established (or enhanced) between the three organizations participating in the collaborative. Once network connections are established, initial DICOM transfers will be tested. The initial version of the Image Transfer Registry has been built and will be tested and improved during the initial image transfers. Finally, the draft of the Image Transfer Protocol has been written (see attached) that will define clearly how the image transfer will occur. Once the testing of electronic image transfer is complete among the organizations participation in the collaborative, we will quickly offer its use to other organizations local to MMC.

Statewide Central Archive. Once we have established electronic image transfer between disparate PACS, we hope to go one step further. Image transfer between sites will still be relatively labor intensive and not very efficient. For example, if a patient were to have a CT study at MidCoast Hospital, that CT would likely be stored two times (primary and a backup copy). Now if that patient were to be transferred, for example, to Eastern Maine Medical Center, and the corresponding CT transferred electronically to EMMC, that CT would now be stored four times (twice at MidCoast, twice at EMMC.) Now suppose after having an MRI at EMMC, that same patient was now transferred to MMC, and the MRI and CT were transferred electronically as well. MMC would ultimately archive two more copies of the CT (for a total of six), as well as two copies of the MRI (for a total of four). Finally, suppose that patient returns to MidCoast a week later for follow-up care, and the CT and MRI are needed. MidCoast will likely store two copies of the MRI (for a total of six now.) Thus, a single CT and MRI exam are each stored six times. In addition to the added storage costs associated with this approach, a significant amount of effort was put forth transferring the various images between these organizations.

Therefore, we hope to go one step further and create a statewide central archive. This central archive will eliminate the need to store multiple copies of the same images at multiple organizations. Under the central archive, each study would be stored only twice, once in the PACS where it was first acquired, and once in a "central archive" (redundant copy). This central archive could then, in theory, be queried automatically whenever a patient is seen at any organization. The DICOM query would retrieve any relevant images needed at that organization.

There will be significant challenges to developing a statewide central archive. Without a robust EMPI to provide automatic identifier cross-reference, the central archive will never be

possible. Other challenges include audit and security concerns, system management, and system architecture. Nonetheless, standards like Integrating the Healthcare Enterprise (IHE) are beginning to define a model and establish specific protocols that could ultimately enable us to build such an archive. Ideally, this image archive center would be robust enough to archive every imaging exam acquired in the state. Other countries are already building central archives. For example, Canada is building a single image archive for most of its Provinces, and Great Britain has divided the entire country into just six divisions, each with a single image archive. A central archive in Maine is still many years away, but clearly a goal worth pursuing. The CI-PACS has helped to illustrate the potential of HIE, but developing a central archive would take it another step forward.

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