The Patient Safety Institute Demonstration Project:
A Model for Implementing a Local Health Information Infrastructure

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ABSTRACT

The increasing focus on patient safety has uncovered many unsafe conditions in the current U.S. healthcare system. One of the most glaring problems is the inability of a fragmented healthcare system to provide critical and timely clinical information at the point of care. The Institute of Medicine has called for the development of a National Health Information Infrastructure to rectify this deficiency. This NHII will be built on Local Health Information Infrastructures, or LHIIs. The Patient Safety Institute is a potential model for an LHII that was developed and implemented in Seattle using the Swedish Medical Centers and associated ambulatory clinics. This model was piloted and evaluated among 365 clinical users across three hospitals, three clinics, and family practice residency programs involving access of records of more than 5,300 distinct patients within a five-month period and involved the collection of more than 23 million clinical data results. User responses revealed the technology was intuitive to learn, easy to use, easy to navigate, and helpful in clinical care. The PSI demonstration project has developed an approach to the creation and implementation of LHIIs that is potentially transferable to other local communities.

KEYWORDS

- Interoperability
- Local health information infrastructure
- Patient safety
- Clinical information system
- Regional health interoperability organizations
- Patient safety
- Healthcare quality

Introduction

Recently the federal government released the first annual national healthcare quality report,[1] which focuses on the quality of healthcare in the United States. This report contains evidence of significant progress in improving healthcare quality, yet it suggests that much work needs to be done in improving healthcare safety. This report comple-ments and echoes multiple efforts by other healthcare stakeholders such as The Leapfrog Group, the Joint Commission on Accreditation of Healthcare Organizations, the Centers for Medicare and Medicaid Services and the National Committee on Quality Assurance, which are focused on improving the quality and safety of care in the United States.
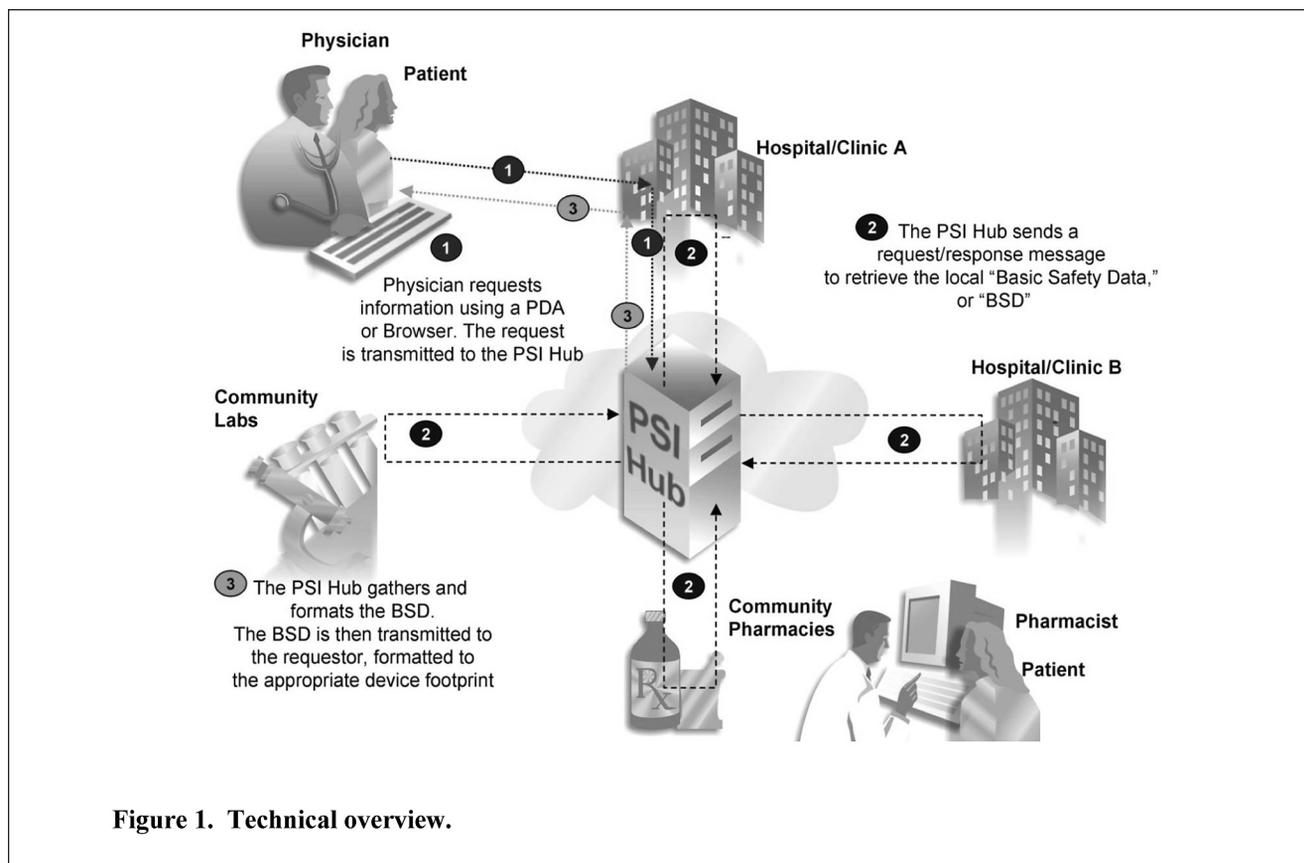
Figure 1. Technical overview.

With considerable consensus, these groups advocate the need to measure and improve the quality of care and the critical role of information technology as a key enabler in improving healthcare quality and safety. A well-publicized Institute of Medicine report, "To Err is Human: Building a Safer Health System," has highlighted the lack of clinical information available at the time and place of medical service as a major contributing factor to medical errors.[2,3]
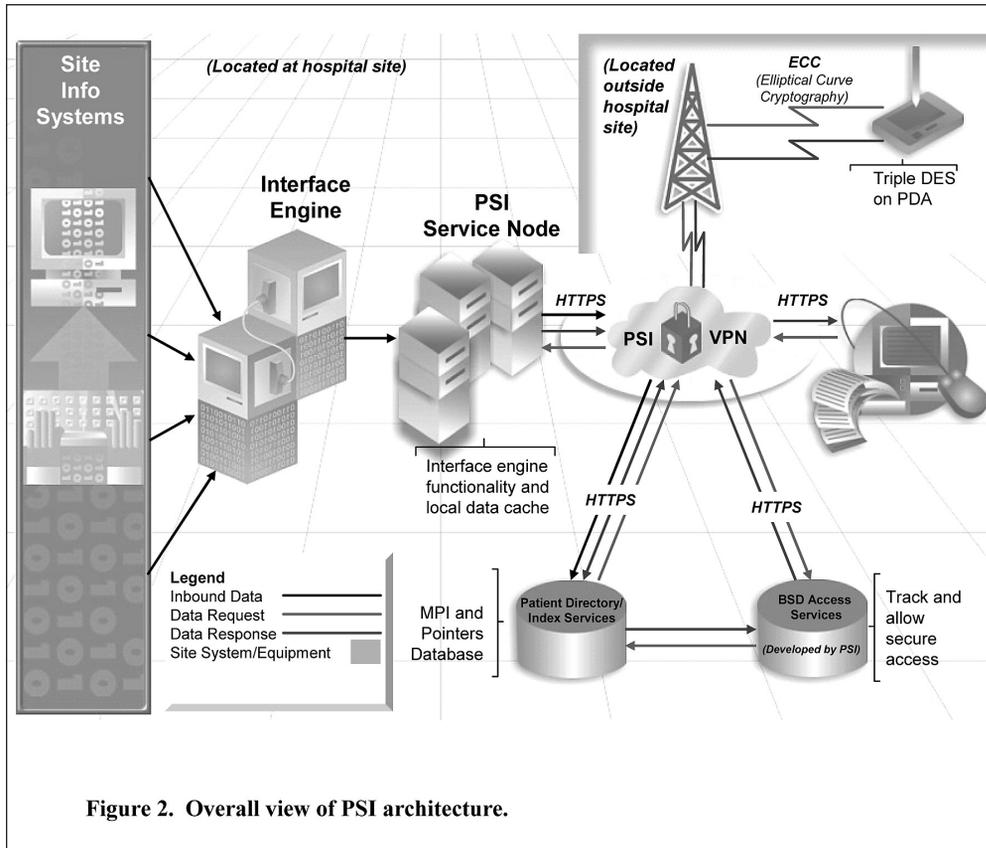
Often, critical patient information is not available to clinicians at the moment when decisions are being made about medications or a course of treatment. The lack of immediate and reliable clinical information for medical providers at the point of care can have disastrous and potentially fatal outcomes for patients.[4] To be truly effective, however, virtually all these quality initiatives will rely on patient clinical information that is available across all care delivery settings and anywhere the patient's providers need access to it.[5]

Technology, fortunately, has advanced to the point where it can meet this growing demand for making clinical information widely available across the various settings of care. If architected correctly, a clinical data exchange network can safely and privately leverage Internet technology to communicate needed clinical information across communities, regions, states, and the United States.[6] A new report from the IOM calls for the creation of a National Health Information Infrastructure as a key enabler of improving patient safety.[2,7] Now that the HIPAA privacy

rule has been implemented, several pragmatic approaches to linking patient data at the community level have emerged within the provider community.

Examples of current local health information infrastructure (LHII) initiatives to link health information at the local level include:

- The New England Healthcare Electronic Data Interchange Network, or NEHEN, a consortium initiated in 1998 and led by Computer Science Corp.[8] Membership in NEHEN is open to providers, health plans, and payers located in Massachusetts and Rhode Island; there are currently 14 members, including most of the region's largest insurers and health plans.[8]

- The Indiana Network for Patient Care, or INPC, initiated 10 years ago in Indianapolis by the Regenstrief Institute for Health Care. Currently, all 13 acute-care hospitals in the city and approximately 20 percent of the metropolitan area's outpatient physician practices are participating.[9] They created a community-wide electronic health record.[9]

- The Santa Barbara County Care Data Exchange, a regional data sharing network, initiated in 1998 through a partnership between Care Science and the California HealthCare Foundation. More than 75 percent of the healthcare providers in Santa Barbara County are participating, including medical groups, hospitals, clinics, laboratories, pharmacies, and payers.[10]

- The Patient Safety Institute in Seattle, which developed

Figure 2. Overall view of PSI architecture.

access to and delivery of patient information via a national network. PSI was created to provide an over-arching structure to facilitate patient safety, improve quality, and lower cost through a national voluntary network, much like VISA has done for the financial industry.[2,14]

System Description

The PSI application employs a federated architecture that is based on a distributed database model architecture in which the patient data at a constituent site, whether a hospital or clinic, remains in its own data center behind its own firewall. The hardware, software, and functions that occur at a specific site often are

and deployed a clinical data exchange network that addresses both the data sharing and clinician access requirements of an LHII.[11] This report describes the PSI demonstration project in Seattle.

Background

The Patient Safety Institute was founded as a response to the perceived need for a trusted "white hat" utility to provide the representative governance for a local network that shares private and confidential healthcare information. This collaborative of leading physician, hospital, and consumer advocates is working together on a private sector not-for-profit initiative[6] with public support to reduce patient adverse events through the creation and support of a secure and inclusive healthcare communications network.

PSI was formed to empower both patients and physicians by providing real-time access to requested patient-centric clinical information at the point of care over a secure, private, communications network. PSI was formed with a similar philosophy and approach as VISA to enable the international credit card, ATM, and retail point-of-purchase cashless banking revolution by providing real-time access to requested financial information over a secure, private, open architecture communications network.[13]

Just as VISA provides the governance structure for financial transactions, PSI was formed to provide the representative governance structure, community driven to facilitate

termed the front-office functionality.

As patient-specific data is acquired and added to a local site's PSI cache, a message is sent containing very specific location and demographic information to the PSI Regional Hub, where all master patient indexing functions occur, which often is called back-office functionality. The information stored at the hub does not contain the actual clinical data; rather, it indicates what specific types of data are available at specific hospitals or clinics for a specific patient. For security and confidentiality purposes, the hub stores types of data and not specifics about the data. Fundamentally, the architecture ensures that the member organization always controls the data. The overall PSI architecture is illustrated in Figures 1 and 2.

The front office application is the portion of the overall PSI application that captures and stores a site's clinical information behind the local site's own firewall. The software components of the front office are Microsoft SQLServer[15] and SeeBeyond's e*Gate Enterprise Application Integration engine.[16]

The back office application is the portion of the overall PSI application that applies the overall security, identifies a patient, routes requests for patient-specific information, and routes responses to the requester. The components of the back office are supplied by SeeBeyond's e*Gate Enterprise Application Integration engine,[16] SeeBeyond's e*Index Enterprise Master Patient Index,[17] in some cases a Microsoft
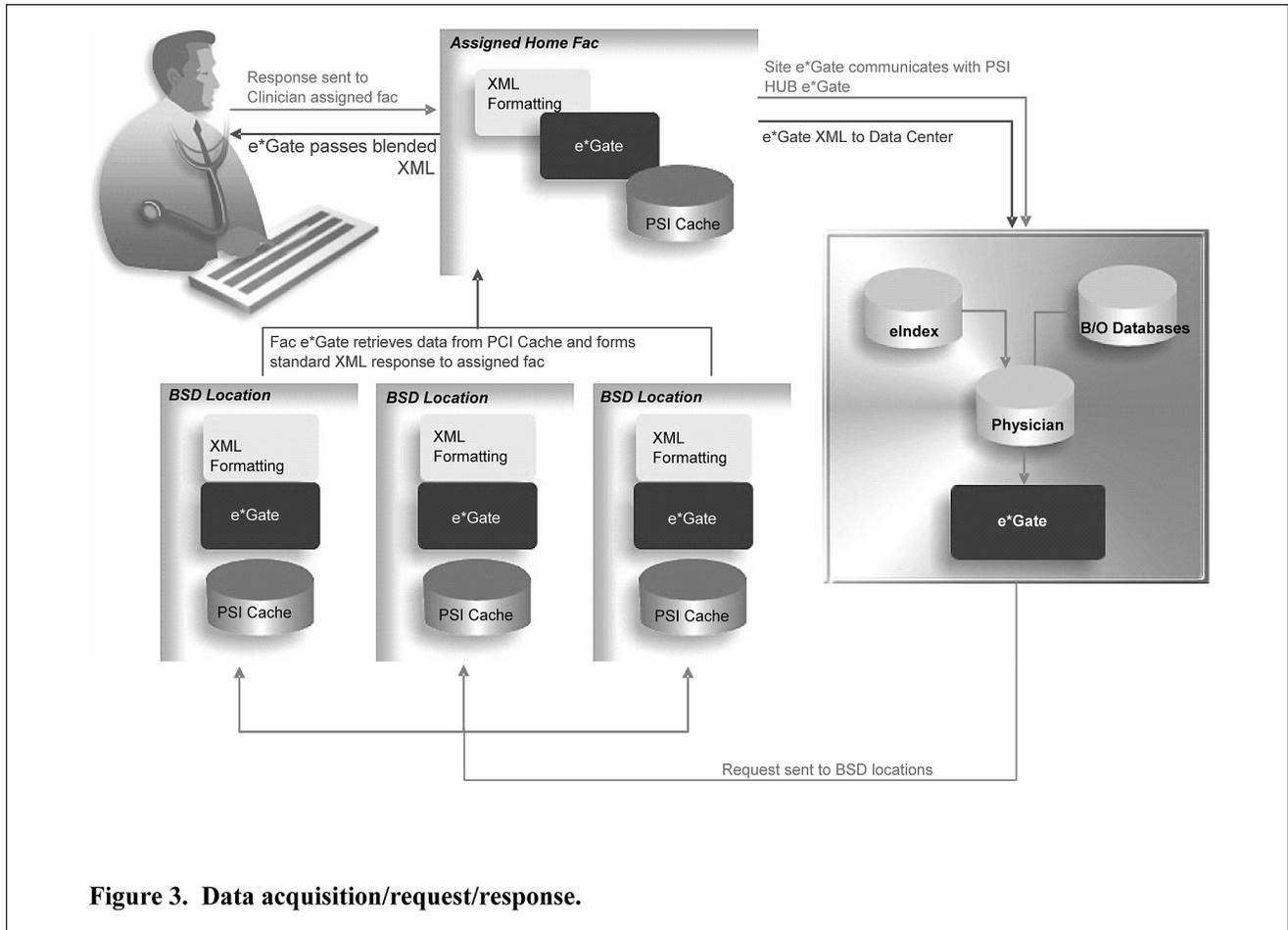
Figure 3. Data acquisition/request/response.

Internet Information Services server,[18] Netegrity's SiteMinder,[19] and a Lightweight Directory Access Protocol (LDAP) directory.[20]

LDAP is a standard technology for network directories—specialized databases that store information about devices, applications, people, and other aspects of a computer network. For PSI, LDAP is a core piece of the security model that provides information about various permitted users and their associated access profiles using the JBoss application server[21] with the Apache Tomcat servlet container and Custom Java code (see Figure 3).

PSI relies on the local site's information systems for the contribution of actual patient-centric information. This information is captured from the site's interface engine outbound stream of Health Level Seven data. These data are processed and the components of the Basic Safety Data are stored in the PSI cache. Basic Safety Data includes laboratory results, medication history, medical problem list, allergies, immunization history, and clinical notes; these notes were expanded to include dictations, history and physicals, discharge summaries, radiology reports, cardiac catheterization reports, operative notes, consultant notes, and any other notes dictated within the inpatient system and emergency department, as well as scanned physician and

nursing notes. The local site's PSI cache is deployed behind the local site's firewall and stores the actual clinical data.

In conjunction with storage of Basic Safety Data in the site's PSI cache, the PSI interface engine transmits very specific location and demographic information to the PSI regional hub. The information transmitted and stored to the hub does not contain the actual clinical data; rather, it indicates what types of data are available at specific hospitals or clinics for a specific patient.

Data Request

A provider authorized to use the PSI system may issue a request for a patient's BSD via a browser or wireless device. The user's request is transmitted via PSI's virtual private network to the PSI regional hub, where the permissions associated with the specific user are verified using the Netegrity Siteminder product. After the user's opt-in/opt-out status is verified and a patient is selected, the location of the patient's specific data locations are identified using components of the SeeBeyond e*Index product. After the locations are identified, the requests are translated into SQL queries and are sent to the PSI cache at each location storing the patient's data (see Figure 3).

When the data request is received at the various sites,
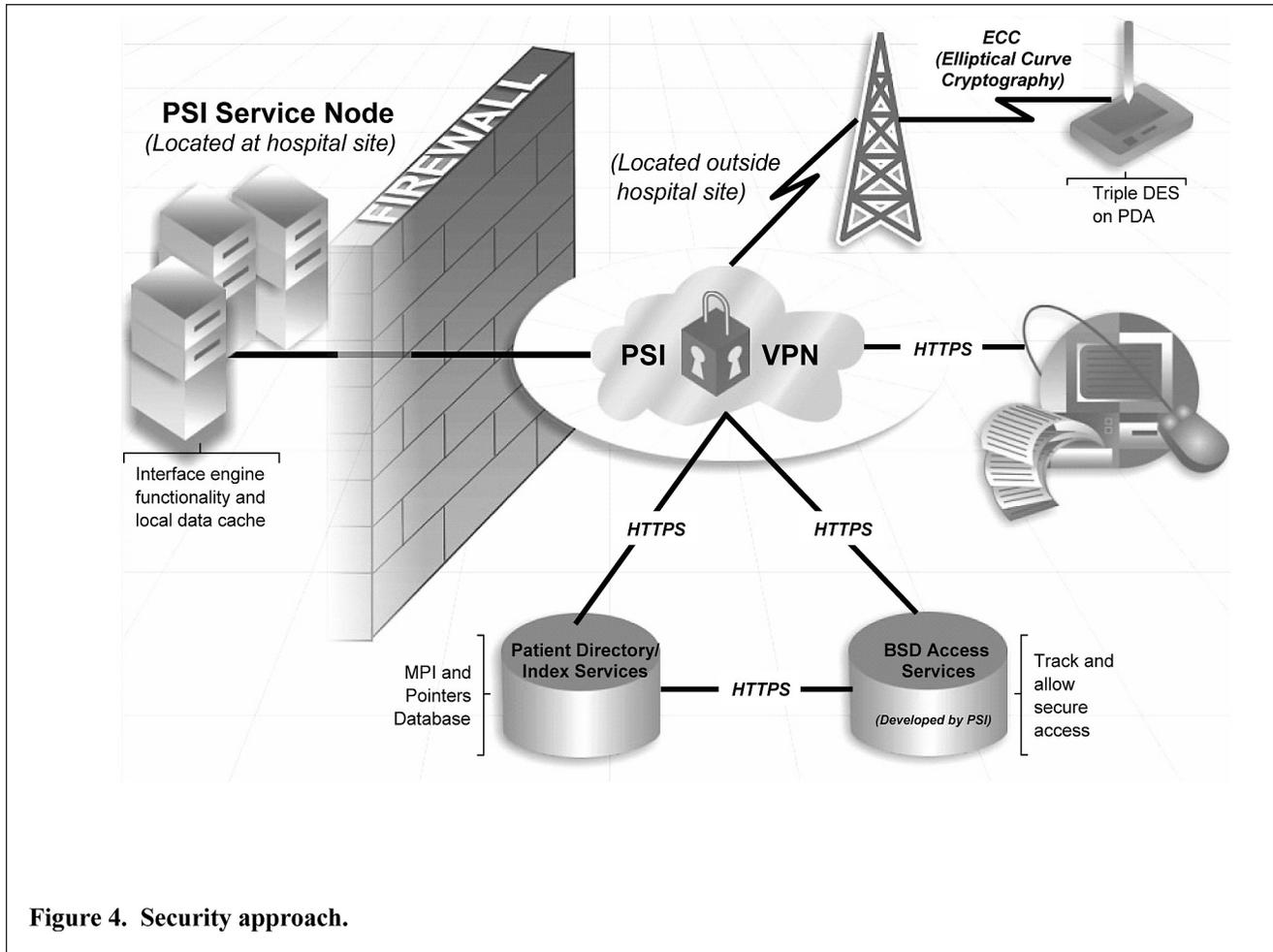
Figure 4. Security approach.

the site's local PSI cache is queried. The patient-specific data is gathered and returned, again via PSI's virtual private network, to the PSI back office using a PSI-defined and developed XML-tagged document. The back office gathers all the responses into a PSI-developed master XML document, applies specific form-factor formatting, and sends it via the VPN to the requestor's location in a secure, encrypted read-only format.

All data transported throughout the PSI network is encrypted. To achieve this, PSI uses various levels of encryption to ensure security of patient information. The encryption includes 128-bit Hypertext Transfer Protocol over Secure Socket Layer, used to encrypt the patient information for movement of data for all wired transmissions,[22] and Elliptical Curve Cryptography as a second layer of encryption of all data moved via wireless/cellular transmission (see Figure 4). This is used to ensure the data is encrypted even at the Wireless Access Protocol (WAP) Gap, commonly known as the "WAP Gap,"[23] and is created using a Triple Data Encryption Standard (DES), used to encrypt any data stored on a personal data assistant,[24] and hashing, used to encrypt user names and passwords at the PDA level.[25]

As at the PSI database, data stored at each provider site

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is encrypted. Data stored in each site's data center is thus secured to the same level as other data stored at that site. Data stored in the site's PSI cache is currently not normalized to any specific vocabularies. Any data displayed using the PSI browser-based viewer will be flushed from all local caches upon session termination. PSI does not employ the use of cookies for any browser session. Any data stored locally on PDAs is encrypted using Triple DES. In addition, locally stored user names and passwords are encrypted using industry accepted hashing techniques.

A user interacts with the PSI application via a Web browser, wireless device, or a custom-designed application (Figure 5). In all cases, the user interface points to the PSI application Web site, which validates the security credential (i.e., user name and password) with a third-party authenti-
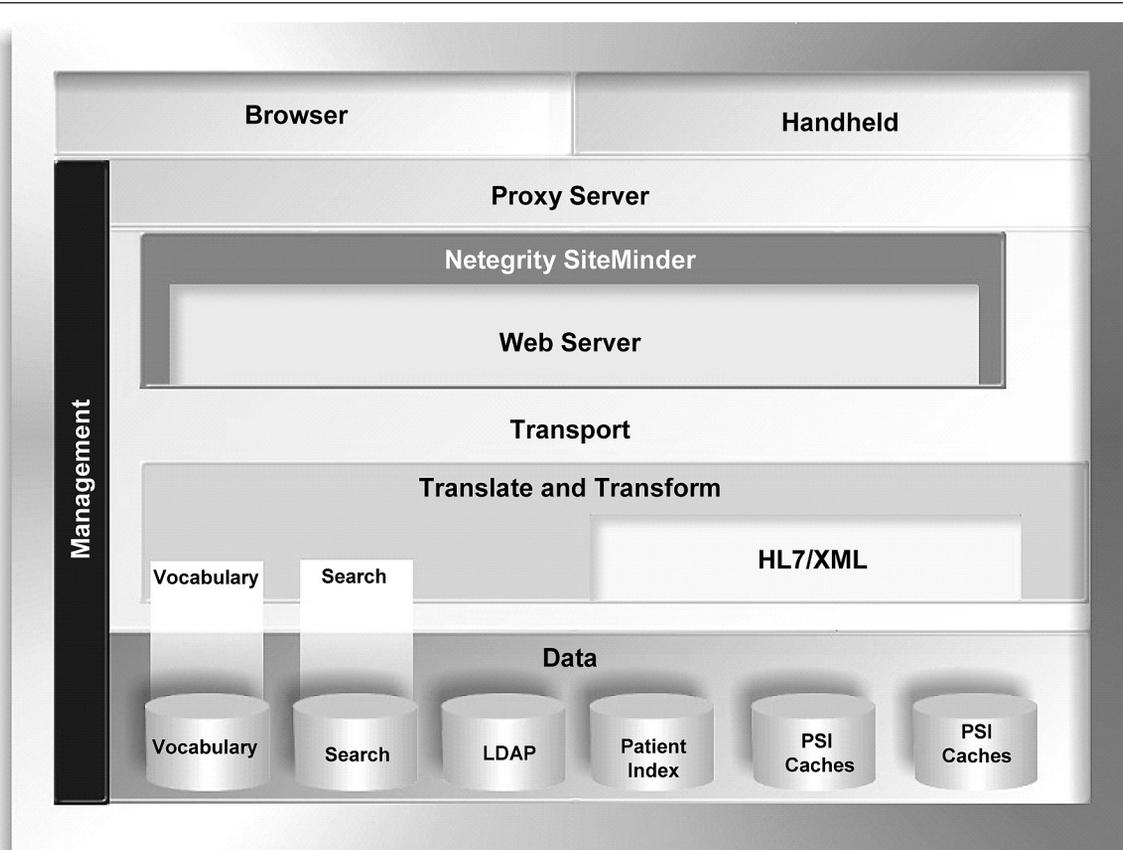
Figure 5. Architectural framework.

cation and authorization product called SiteMinder (from Netegrity). The SiteMinder product ensures that everyone using the PSI application is logged on with an approved user name and password. The product is capable of all levels of authentication, from user name and password to digital certificates.

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After it is authenticated, the request continues through the PSI back office. The request is made for one of the three use cases—patient lookup, select a patient, or select a BSD category. The system understands each of these requests. Requests are sent to specific locations for data retrieval; data are gathered and returned to the PSI Back Office via an XML document. After requests are received, a master XML document is built, and the appropriate style sheets are applied. The back office has a custom code to "timeout" if a specific information location is not responding, and this location will be denoted on the user interface as not responding. The XML response is converted into a combination of HTML/JSP and dispatched to the user.

For patient consent, opt-in/opt-out is the common approach used to describe a patient's ability to consent to participate in the PSI project. Opt-in/opt-out can be implemented in two fashions; either all patients are opted in and must choose to opt out, or all patients are opted out and must choose to opt in. PSI, with the support of the Swedish Medical Center Institutional Review Board, chose the former approach.

From a technical perspective the implementation of patient consent was straightforward. Within the PSI master patient index, a patient is able to be "flagged" as opted out. Once this flag is set, that patient's existing data is unavailable to any users within the PSI network. Conversely, if the patient decides to opt back into the network, this flag is reset, and the data is available, but information is not available from the time period in which the patient opted out.

The implementation of this patient consent is a two-pronged approach, independent of which consent method

is chosen. The Swedish board required PSI to develop a series of descriptive documents detailing the PSI network and the details of the study. These documents included a description of the opt-out procedure, along with a toll-free phone number for information and opting out, which were distributed to all patients having inpatient or ambulatory visits at any of the participating institutions by inclusion in the standard admission or visit paperwork. All patients were asked to read the materials and then told the procedure if they wished to opt out of the PSI project.

The Demonstration Project

Swedish Medical Center is comprised of three distinct locations: Swedish First Hill campus, Swedish Ballard campus and the recently acquired Providence campus. Swedish is considered one of the major locations to receive inpatient and outpatient medical care in the Pacific Northwest. In 2002, Swedish Medical Center operated 1,296 licensed beds, had more than 47,000 inpatient admissions and 270,000 outpatient visits. Its 58 operating rooms handled more than 39,000 surgical cases.

The selection of Swedish by PSI was based on its community leadership, patient-centric care delivery focus, and ability to serve as a proxy for a healthcare community to test linking technology in different organizations and IT environments. From a technological perspective, The First Hill and Ballard campuses use HBOC Star, SMS, Cerner Pharmacy, The Phillips Picture Archival and Retrieval System (PACS), and a variety of transcription vendors. The PSI application does not store PACS images; rather, it enables Web access to the PACS system and can interface with any PACS system that is Web-enabled. The Providence campus uses Phamis/Last Word, a sunsetted IDX product. The campuses were not interconnected by any electronic data sharing capabilities before the PSI pilot, and thus the three campuses functioned as two independent hospital systems with islands of clinical information, not accessible to clinicians in an electronic manner (see Table 1).

The pilot proposal was reviewed by the Swedish Medical Information Systems Team, which comprises physician leaders and members of the Swedish IS department. The team reviewed the scope of the project, determined clinical data to be interfaced to the PSI system, selected physician pilot demonstration participants, determined success metrics, functioned as a clinical advisory group to PSI, participated in weekly review and feedback of the application development, and determined final success and accept-ance of the project. The PSI project was granted IRB approval at Swedish before the start of the pilot demonstra-tion. Pilot participants included SMC Family Practice Residency Program and SMC Emergency Department physi-cians at First Hill, Providence, and Ballard.

The demonstration technology project goal was to provide clinicians at all Swedish Medical Centers with relevant information from all three campuses and specified outpatient sites. This clinical information included allergy data, medication history and problem list history with relevant CPT and ICD-9 codes; laboratory results, both for inpatients and outpatients; transcribed notes, including dictations, history and physicals, discharge summaries, radiology reports, cardiac catheterization reports, operative notes, consultant notes, and any other notes dictated within the inpatient system and emergency department; as well as scanned physician and nursing notes.

> *"The demonstration technology project goal was to provide clinicians at all Swedish Medical Centers with relevant information from all three campuses and specified outpatient sites."*

The pilot participants selected specific clinical data elements for review, which they considered to be the most clinically relevant data elements necessary for medical decision-making at the point of care (see Table 1). Pilot participants assisted in determining which of the data elements should include a historical data conversion and which data to limit; for example, access to laboratory results was limited to results reported within the last year. A goal of the pilot demonstration was to include more than 75 percent of the clinicians in the emergency departments and family practice residency program at Swedish First Hill, Swedish Providence, and Swedish Ballard sites.

The application icon and online tutorial were installed in November 2002, with initial rollout December 2002 and full deployment by January 2003 to the whole pilot group of physicians. The pilot continued through April 13, 2003. The users were surveyed online regarding use and perceived system value. The pilot participants were offered a short demo or an online tutorial, but no formal training was undertaken, by design. The project team wanted to assess the ease of use and intuitiveness of the application as described by the pilot participants. Communication with physicians was by email, phone, and in person, if needed. All user IDs and passwords were sent by secure e-mail.

Pilot Project Results

During the three-month pilot demonstration project, a total of 365 unique physician users accessed the program at all of the Swedish sites, and 469,500 patients were entered into the system via the admission-registration process and from Swedish historical data loads. Overall, more than 23 million clinical data results were collected in the system as part of the pilot project. During the pilot, the system identi-

Pilot Interfaces

System	HL-7 I/F	Historical Data	Source Data	BSD Type
Swedish First Hill and Ballard Medical Centers				
HBOC Star	✓Yes	✓Yes	ADT and Diagnosis	Demographics/Problems
Antrim LIS	✓Yes	✓Yes	Laboratory Results	Lab Results
SMS COR (Invision)	✓Yes	✓Yes	Laboratory Orders	Lab Orders
ECode/EMap (Lynx)	✓Yes	No	ED ICD 9 Diagnosis	Problems
Medword Transciption	✓Yes	✓Yes	Transcribed Notes	Notes
Cerner Pharmacy	✓Yes	No	Medication Orders/Dispense And Allergy Records	Medications/Allergies
Swedish Providence Medical Center				
IDX Last Word	✓Yes	✓Yes	ADT, Med/Lab Orders, Allergies, Diagnosis	Demographics, Meds, Allergies, Problems
Cerner PathLab	✓Yes	✓Yes	Laboratory Results	Lab Results
Edix Transciption	✓Yes	✓Yes	ED Notes	Notes
SoftMed Transcription	✓Yes	✓Yes	Admit, Discharge, Procedure Notes	Notes
NCoder Medical Records	✓Yes	No	ICD 9 Codes	Problems
Swedish Family Medicine Group				
MISYS	✓Yes	No	ADT, Registration, Diagnosis, Allergy Records	Demographics, Problems
Pathlab (Hosted at SMC-Povidence)	✓Yes	No	Family Medicine, Lab Orders and Results	Lab Orders and, Results

Table 1. Data sources for PSI pilot.

fied 48,155 duplicate patient records within the 469,500 original patients, which were "cleaned" and merged into unified patient records. Approximately 5,300 patient records were accessed during the 90 days.

After the demonstration project, physician users were surveyed about the PSI System. Some 127 physician users from the initial group of 365 participating physicians responded. Of those, 92 percent said they believed it was easy to log into PSI; 71 percent believed the search function was easy to use; 64 percent found the patient summary screen valuable; 64 percent found it easy to navigate between the detail and summary screens; 79 percent thought response time was adequate; 43 percent found the tutorial valuable; and all respondents believed the ongoing investment in PSI was a good decision for Swedish.

When physicians were questioned as to why only a minority found the initial tutorial valuable, the project team found that many participants believed the system was very intuitive and thus they did not feel the need to use the tutorial. Users expressed an interest in access to other data, including outpatient dictations and PACS/EKG images.

After the demonstration project, Swedish decided to maintain the system and has increased the overall scope of the initial demonstration project. As of January 30, 2005, 310 additional physicians had received access, increasing the total of physicians having access to the system to 875. As of that date, the PSI application stored data on more than 675,000 unique patients, or approximately 40 percent of the greater Seattle patient community. The PSI cache has grown to contain a total of 18.7 million laboratory results, 2.1 million unique patient allergies, 4.7 million different patient problems or diagnoses, 385,000 distinct patient medications, 1 million different clinical notations and 1.7 million patient visits. As of January 30, 2005, of the 675,000 patients in the PSI network, only four have opted out, and one of these four later opted back in.

In addition to the increasing volumes of basic safety data, PSI has interfaced a Dictaphone dictation system, a LYNX Emergency Department application and patient information from several large multi-specialty physician groups. By the end of 2005, PACS and EKG images will be available.

Discussion

This project demonstrated the viability of a distributed clinical database vs. a central repository storing clinical data. PSI's patient advocate board members mandated a distributed database model for security reasons. Although this is

an uncommon approach within healthcare delivery organizations and local communities, the distributed database model with a pointer system for data location is made feasible by the use of a new approach to the unique patient identifier. The PSI approach used the physical separation of the unique patient identifier from the clinical data itself, providing another layer of security and flexibility.

PSI manages the automated system as a master patient index of only patient names and their identification numbers. The integrity of each hospital's or clinic's method for identifying its patient data is maintained by PSI, linking each provider's identifier to the PSI Enterprise Master Patient Index. Another unusual approach was the use of XML as a critical part of the transfer and transport of all clinical information from the local facility to any user.

> *"PSI has integrated commercial-grade industry products in each area of its core solution, thus preventing a homegrown approach with potentially limited accessibility or scalability."*

In addition, this project has used commercially available products in a best-of-breed integration approach, using a common-source model rather than customizing each aspect of the project and creating a totally unique technology. PSI has integrated commercial-grade industry products in each area of its core solution, thus preventing a homegrown approach with potentially limited accessibility or scalability.

Finally, this project also involves an interesting patient participation approach. During the pilot, patients were given information on how to opt out of the program at the point of care. If they chose not to participate, their information was excluded from the system. Initially, patient participation authentication was accomplished through established local site procedures.

PSI's approach contrasts with other similar initiatives around the country. One such project is the New England Healthcare Electronic Data Interchange Network, or NEHEN, which provides members that pay a flat monthly fee with access to a secure network for sending and receiving transactions. Members can either integrate NEHEN functions directly into their own management systems or access the NEHEN network using Nihility, a Web-based application. This application is focused on eligibility as an American National Standards Institute X12 standard, paying particular attention to the claim's information. Initially, NEHEN's effort did not use XML as the transport standard, although it appears NEHEN now has decided to adopt aspects of XML for transporting information. The NEHEN project differs

from PSI in its emphasis on sharing patient financial information as opposed to patient clinical information. Because much of the data is "batch processed," the need for sub-second response time is not as critical as it is for delivering clinical information to a physician at the point of care.

Another example of a regional data-sharing network is the Santa Barbara County Care Data Exchange, initiated in 1998 through a partnership between Care Science and the California HealthCare Foundation.[8,27,28] More than 75 percent of the healthcare providers in Santa Barbara County are participating, including medical groups, hospitals, clinics, laboratories, pharmacies, and payers. Santa Barbara enables rapid and secure delivery of patient data to authorized users who have informed consent.

With the Indiana Network for Patient Care, participating institutions pay a fee for access to selected electronic information that forms the basis for an operational community-wide electronic medical record, which includes reports from emergency department visits, laboratory results, admission notes and discharge summaries, operative reports, radiology reports, surgical pathology reports, inpatient medications, immunizations, and a tumor registry.[29] Each healthcare provider retains its patients; however, selected information in those data sets can be shared among organizations through use of a Global Patient Index. INPC not only enables the secure storage and exchange of clinical information, but also provides clinical examples of content necessary for the creation of a national health information infrastructure. Significant work has been performed by INPC in the area of vocabulary normalization and lab test vocabulary standards, decision support, and public health surveillance and reporting.

Patient Safety Implications

A lot of effort in patient safety has focused on building systems for collecting, reporting and analyzing errors, and creating cultures of safety. However, a report from the IOM suggests that information and communications infrastructure can contribute to improvements in four areas of relevance to patient safety: communication, access to patient information, knowledge management, and decision support.[2]

Because of considerable pressure to prevent medical errors, many organizations have focused on the use of information technology systems with clinical decision support systems. These systems include computerized provider order entry (CPOE), which can prevent many errors from occurring,[30] increase adherence to care protocols, [31] and enhance clinical decision making at the point of care.[32] Yet, the much less complex task of just providing immediate access to clinical information, such as results of laboratory and radiology tests, enables more efficient decision making and more effective decision support.

In addition, the availability at the point of care of more comprehensive clinical data, such as medication and labora-

tory information, holds promise for better integration and connection of clinical research and patient care practices.[33] Furthermore, this sharing of clinical information can be used for communication among all authorized members of the care team, including primary care providers, specialists, nurses, pharmacists, home health aides, the patient, and lay caregivers. This capability is especially important for the chronically ill.

These capabilities provided by clinical information systems cannot be achieved, however, without a standards-based infrastructure founded on a national health information infrastructure (NHII). The NHII is defined as a set of technologies, standards, applications, systems, values and laws that support all facets of individual health, healthcare, and public health.[34] The NHII will yield many other benefits in terms of new opportunities for care access, efficiency and effectiveness, public health, homeland security, and clinical and health services research.

> *"…few studies have been performed outlining the economic benefits of these LHII initiatives. Such studies might be very helpful in justifying the significant investments for creating and operating LHIIs.*

To facilitate the development of the NHII, the Institute of Medicine recently proposed several demonstration projects aimed at establishing state-of-the-art healthcare information and communications infrastructure at the community, state, and regional levels.[7] More recently, another IOM committee has suggested that patient safety cannot be assured without this NHII and has made specific recommendations about the key capabilities of the electronic health record, including the potential implementation of such a system across the settings of care.[2]

However, building the NHII replete with myriad LHISSs to form the care continuum will be a significant undertaking and require significant investments and public-private partnerships. Funding local initiatives for community data sharing is a major issue facing local communities.

Unfortunately, few studies have been performed outlining the economic benefits of these LHII initiatives. Such studies might be very helpful in justifying the significant investments for creating and operating LHIIs.[2] A recent study on the potential impact of a PSI approach was based on published research, studies in progress, interviews with clinical and technology experts, and discussions with health plan, health associations, and industry leaders.[35]

Conservative estimates on a limited number of measures implemented nationwide calculated an aggregated annual

net savings of $10 to $14 per person per month, or almost $40 billion per year for the nation. When integrated with advanced clinical applications installed at care delivery sites, the estimated total net benefits reach almost $47 billion. The total estimated cost to build a national PSI NHII using infrastructure was approximately $2.5 billion. Annual recurring costs to operate would be less than $500 million. Using these estimates, the potential return on investment is nearly 20 to 1, with quantifiable areas of highest potential return including avoiding inpatient admissions, reducing duplicate diagnostic testing expenses, and better managing patient medications.

Another recently published study created a cost-benefit model based on a national model of electronic healthcare information exchange and interoperability and estimated that that a fully standardized exchange with national implementation could yield $77.8 billion in net value per year and that a less standardized exchange could yield $21.6 billion in net value.[36] However, both these studies were based on theoretical models and not based on the study of actual implemented LHIIs.

This current study has several limitations. It was designed as a proof of concept project for a technologic approach to an LHII and not as a rigorous scientific evaluation of LHIIs. It did not evaluate the impact of LHIIs on clinical outcomes, safety related issues, clinician behavior, or economic outcomes. Although this project was focused on creating a technologic solution to building an LHII, it was initially implemented only within one integrated delivery system of hospitals and clinics. However, it did link information from numerous different vendor products used across the inpatient and outpatient facilities of the system, and the approach was developed with the capability for easy scaling and generalization to a community level. This approach subsequently has been used to successfully implement a similar initiative within a large IDS in the Midwest and is currently being implemented within a community in the Northeast. The success of these other sites suggests that the PSI model may be a generalizable approach and deserves further study.

All these studies only outline the critical need for rigorous and robust evaluations of the actual economic and safety benefits of LHIIs as they are implemented. The benefits that future studies might include, for example, could be reductions in hospital admissions or outpatient visits because of improved treatment of high-impact chronic disease, such as congestive heart failure; reduction of hospitalizations or outpatient visits because of decreased side effects of high-risk medications, such as anticoagulants and chemotherapeutic drugs; and more effective and accurate reconciliation of medication use across the continuum of care.

Research also should focus on various economic models, using an approach that evaluates economic benefits not

only to providers, but also to payers, employers, and patients. In addition, research should evaluate a variety of sustainable business models for creating LHIIs with appropriate and aligned incentives for government, payers, and providers that might enable the creation and ongoing support of LHIIs. Only through thoughtful and careful studies will sustainable LHII models be developed and successfully implemented, setting the stage for the realization of a true NHII.

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