Journal of Digital Imaging (2019) 32:211–220
https://doi.org/10.1007/s10278-018-0142-3

Implementation and Benefits of a Vendor-Neutral Archive and Enterprise-Imaging Management System in an Integrated Delivery Network

Chen Sirota-Cohen [1] · Beverly Rosipko [1] · Daniel Forsberg [2] · Jeffrey L. Sunshine [1]

Published online: 18 October 2018
© Society for Imaging Informatics in Medicine 2018

Abstract

The use of digital imaging has substantially grown in recent decades, in traditional services, new specialties, and departments. The need to share these data among departments and caregivers necessitated central archiving systems that are able to communicate with various viewing applications and electronic medical records. This promoted the development of modern vendor neutral archive (VNA) systems. The need to aggregate and share imaging data from various departments promoted the development of enterprise-imaging (EI) solutions that replace departmental silos of data with central healthcare enterprise databases. To describe the implementation process of a VNA-EI solution in a large health system and its outcomes. We review the background of VNA and EI solutions development and describe the characteristics and advantages of such systems. We then describe our experience in implementation of these solutions in a large integrated healthcare delivery network in northeast Ohio. We then present the process, challenges, costs, advantages, and outcomes of such implementation. The VNA and EI solution was launched in December 2015 and is still ongoing. It currently includes 54 radiology and 26 cardiology sites affiliated with the University Hospitals health system. This process was associated with more than 10% cost savings, 30% reduction in storage costs, superior support for disaster recovery, and 80% decrease in unscheduled outages. All these were achieved despite a 120% increase in archive retrieval needs and a 40% growth in image production. Implementation of a VNA and EI solution was successful and resulted in numerous measurable and qualitative improvements in a large and growing health system.

Keywords Medical informatics · Radiology information systems · Diagnostic imaging · Patient-centered care

Background

The need to effectively share data in the form of digital images fueled the initial work during the early 1980s to construct the first picture archiving and communication systems (PACS) [1, 2]. Initially, PACS focused primarily on radiology so that standards to support digital image storage and retrieval, digital imaging and communication in the medicine (DICOM) [3], were developed with radiology in focus. The integration profiles from Integrating the Healthcare Enterprise (IHE) [4] also focused initially on radiology.

✉ Chen Sirota-Cohen
Chen.Sirota-Cohen@UHhospitals.org

[1] Department of Radiology, University Hospitals Cleveland Medical Center, 11100 Euclid Ave, Cleveland, OH 44106, USA

[2] Sectra AB, Linköping, Sweden

By the end of the 1990s, digital imaging spread to other departments, and image storage and retrieval became relevant in other service lines. For some, such as cardiology, it was natural to adopt and often adapt the standards and integration profiles developed for radiology [5, 6]. For others, such as ophthalmology or dermatology, the use of DICOM was not as aligned. As a consequence, each department with digital images started to build its own somewhat specific solution for image viewing, online storage, and archiving.

Often, a single vendor would provide all components of the system to a department, which resulted in lack of strict adherence to standards and integration profiles within the vendor's own solution or product portfolio. These single-department solutions had several consequences—first, this resulted in vendor "lock-ins" (inability to combine system components from different vendors or to switch from one vendor to another), making it difficult, for example, to replace the viewer from the vendor providing the archive solution with a viewer from another vendor or to simply migrate image data from one solution to another. Second, it created data silos within each department that, while probably providing the most satisfying solution for that department needs, allowed only very limited information sharing between departments. Third, each department would require its own separate storage solutions and thereby eliminate the possibility for a shared centralized storage solution and associated cost reductions.

During the late 1990s, there were calls to start building archive solutions that would be decoupled from the viewing applications to avoid vendor lock-in. Further, it was envisioned that future PACS systems would handle digital image data from multiple departments and display them wherever needed using web-based technology [7, 8]. The need for and concepts of vendor neutral archives (VNAs) and enterprise imaging (EI) consequently emerged.

Early attempts to implement VNA and EI solutions were made during the next decade, but most were based upon home-grown solutions and were implemented with little effect beyond the involved sites themselves [9–12]. The need for VNA and EI grew as the use of digital images increased in both traditional service lines (e.g., radiology and cardiology) and new ones who started using these technologies (e.g., dermatology and anesthesiology). Further, acquisitions and consolidations of enterprises and facilities within the healthcare sector became more frequent, increasing the need to either integrate or consolidate various image archives. The concept of electronic patient medical record (EMR) holding all clinical information of a patient also gained momentum, facilitating clinicians' need to view all patient images and studies from within a single system. The modern EMR utilized a complete set of patient identifiers allowing imaging-centric service lines, such as radiology, the ability to manage patient images across the enterprise. This was further enhanced by the evolution of patient-centered care, emphasizing the availability of all patient-related information to the treating physician and broader clinical teams.

A few years later, IHE and various standards organizations started to present integration profiles to handle intra- and inter-enterprise sharing of clinical information, whether text-based (IHE XDS) or as images in the form of DICOM and non-DICOM (IHE XDS-I). The XDS (context-agnostic—not specifying a necessary document format) and XDS-I (extension specifically for managing DICOM data, using specific Imaging Document Source and Imaging Document Consumer actors) profiles allow different users within a group of enterprises to search, retrieve, and upload documents and images from an archive. The VNA solution incorporated these standards and further facilitated text and image data sharing across the enterprise. The first reports of vendor provided and commercially available VNA and EI implementations have emerged in recent years. However, experience with VNA and EI solutions implementation is still sparse in the scientific literature.

In this paper, we present our institutional experience with designing and implementing a VNA and EI solution along with an analysis of how this implementation has affected our operations thus far. The purpose of the paper is to share a detailed account that will allow others to decide whether VNA and EI approaches are relevant for them and if they are ready to embark upon such a transition. Furthermore, we provide a blueprint outlining the steps taken thus far in our implementation process. Finally, this paper presents an analysis of the effects of VNA and EI on our healthcare organization.

Background—VNA and EI

Although both VNA and EI have been described and implemented for a number of years, there still exist some uncertainties as to what they refer to and how they relate. Therefore, we provide a definition of the two and discuss the reasoning to support implementing a VNA and EI.

Vendor Neutral Archive

As mentioned previously, the concept of VNA has its roots in the need of PACS owners to have a greater control of their image data, to avoid vendor lock-in and to ease the deployment of new imaging applications [13]. This expanded as other vendors' solutions for medical imaging created a growing number of proprietary solutions, each requiring unique interfaces, storage solutions, and upgrade in paths. Those complexities drove institutional desires for efficiency and ease of management to seek single overarching archive and retrieval solution and in that process look for paths to better enable control of predictable future migrations of stored data. This type of solution would allow upgrading a component of the system (e.g., the viewer application) with no need for a large and expensive data migration process. In addition, integration of such a solution into the EMR would establish a consistent "multimedia" patient record, allowing certain modern application-specific functions.

A typical image (DICOM) archive provided as a part of a radiology or cardiology PACS consists of three components: storage solution, interface for imaging applications to store and retrieve data, and a database to keep track of the stored image data. This also includes interfaces for non-imaging information, such as patient encounters and visits. The same architecture applies for a VNA but with the added concept of vendor neutrality, meaning that the image management solution can function with different storage products and that different imaging applications can connect to the archive, both without any noticeable differences in performance. The ability to provide this vendor neutrality is what sets a VNA apart from traditional DICOM archives, where there typically is a preference in terms of storage solution and where a plug-and-play approach for new imaging applications is not possible without major integration efforts. Some refer to this as "architecture neutral," "content neutral," "third-party neutral," or "PACS neutral" [14]. Hence, a VNA archive could be defined as:

"An image archive capable of deployment on a multitude of different storage solutions, with data stored in a non-proprietary interchange format that enables ongoing migrations to newer storage hardware, and with a standardized interface to support image storage and retrieval from different imaging applications."

Enterprise Imaging

Although the concepts of VNA and EI emerged around the same time and were developed somewhat alongside each other, the call for an EI approach emerged from a different set of needs [15]. First was the desire to move away from department-specific archive solutions (e.g., radiology only) to more central or enterprise-wide solutions. This was related to the increased rate of enterprise and facility acquisition and consolidation and the use of digital images in various non-radiology departments with a growing number of users requesting image viewing and processing functionality. In addition, and most importantly, emerging patient-centered electronic medical records necessitated the ability to present a unified view of patient data, including image data where clinical information would not be restricted by departmental borders. As such, it is obvious how an image archive forms an essential component of any EI implementation but where the EI extends beyond the mere archiving functionality of a VNA. The HIMSS-SIIM collaboration [16] defines EI as:

> "a set of strategies, initiatives and workflows implemented across a healthcare enterprise to consistently and optimally capture, index, manage, store, distribute, view, exchange, and analyze all clinical imaging and multimedia content to enhance the electronic health record."

Combining a VNA and EI, the overarching themes become:

- Capture data from any source and in any format.
- Store data on any storage and with any strategy.
- Access and exchange any image anywhere.

As can be noted, the definitions of both VNA and EI do not provide any details on the actual technical implementations or if any (or which) standards should be used. For example, some might argue that the support of DICOM query/retrieve or storage of DICOM objects (single components of a study) in a common format such as DICOM part 10 (the section of the DICOM standard that deals with media storage and file format for media interchange) are both necessary requirements for a VNA. Although these are both sensible choices when implementing a VNA and considering integration with other systems, they are not strictly a part of VNA definition.

The Case for VNA and EI

As any implementation of an IT system is rarely straightforward and since a VNA and EI implementation will cut across multiple departments and potentially several healthcare enterprises, it is of great importance to adequately understand and correctly value potential benefits of a VNA and EI. We have already mentioned some of the issues that departments utilizing image data commonly encounter: for example, lack of plug-and-play behavior with new image applications, vendor lock-ins, lack of data ownership, limited data sharing caused by departmental data silos and lack of compliance with existing standards, and limited possibilities for cost reductions through shared IT solutions since each department requires its own specific solution. Further shifts in healthcare delivery have added an increased rate of acquisitions or mergers between entities with increased costs for data migration or integration work, a transition from a fee-for-service payment model into a value-based healthcare delivery model with associated meaningful use, now Medicare Access and CHIP Reauthorization Act (MACRA, established in 2015 aiming to change the reimbursement method for healthcare in the United States), and an increased focus on patient-centric healthcare and patient engagement.

The following outcomes are to be expected after a VNA and EI implementation:

- Reduced system complexity achieved through a consolidation of all storage solutions to a single centralized solution that can be operated more efficiently with implications on reliability and the total cost of ownership.
- Improved technology management through control and synergies in information lifecycle management (ILM), disaster recovery (DR), workflow, data security, and data mining.
- Improved interoperability and data exchange as achieved through a single point of integration. An obvious necessity is that this single point of integration provides an interface implemented through adherence to open standards.

It should be noted that the reduced system complexity, improved technology management, and improved interoperability constitute the direct outcomes but that indirect outcomes to solve most, if not all, of the previously stated issues are expected as well.

But Remember …

A VNA and EI solution in itself does not assure ILM, DR, department-specific workflow management, or data security/mining. Moreover, it does not transit an organization from a fee-for-service model into the era of value-based healthcare nor does it provide each patient with access to all their imaging data. Nevertheless, it provides an IT core solution from which these issues can be more efficiently addressed. The transition to such a modern solution necessitates full organizational strategy, pre-defined goals and success criteria, governance, and cross-organizational leadership buy-in.

Some other caveats to remember are that migration challenges and associated costs will not disappear with a VNA, since migration of data from existing or new image archives will be needed and migration from one VNA to another will still occur if a VNA is to be replaced. The same applies for vendor lock-ins and lack of data ownership. Hence, tools for data migration, a clear exit strategy, and direct data access still need to be established, as well as choosing an experienced VNA vendor with skilled technical support staff.

In summary, when considering a possible VNA and EI solution, it is of great importance to consider the potential benefits but also the amount of work required to fully utilize these.

Methods

Single Integrated Delivery System Experience

Today, our institution comprises a health system anchored by a tertiary and quaternary academic medical center and its 44 satellite outpatient centers, with additional ownership of 11 community hospitals in the surrounding geography. We directly support more than 2000 physicians in practice at more than 600 ambulatory buildings, clinics, or offices. Our history within digital imaging parallels the general development of medical imaging. For example, radiology and cardiology images were first to digitize and were later followed by dermatology and ophthalmology. To consolidate backend support, gain efficiencies and consistencies from hardware, simplify online storage and archiving for each department, enable ease of future acquisitions, and answer the increasing call for better sharing of image data, we embarked on our transition to a VNA and EI solution in 2014 with the motto “no image left behind.”

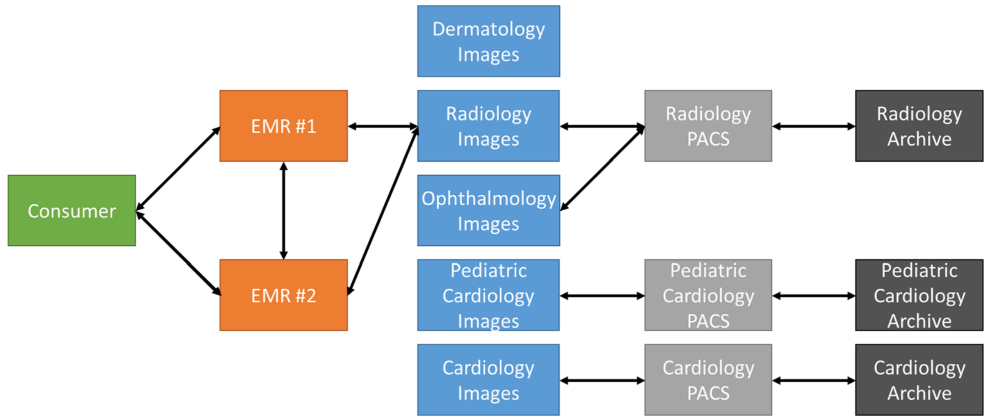
In 2014, our imaging IT architecture had a very typical structure, with three different PACS systems (radiology, cardiology, and pediatric cardiology), each of which had its own separate archive solution (Fig. 1). Furthermore, images from dermatology had no dedicated imaging application nor any long-time storage, and images from ophthalmology had just begun to be stored in the radiology PACS. In terms of image sharing outside of the respective imaging departments, radiology was the only one that provided access to its images through integrating a URL launch of the PACS viewing application into the two principal EMR systems. As expected, this setup had substantial impact on various workflows. For example, consider a cardiologist viewing cardiology images in the cardiology PACS and who decides to view the patient’s radiology images. The cardiologist then either had to open the relevant EMR, search for the corresponding patient and relevant radiology examinations before finally launching the radiology PACS to view the images, or open the PACS directly and search for the corresponding patient and relevant examinations.

Following our vision of creating a patient-centric imaging record that would provide the ability to view any image from a single viewer and thus enable better image sharing according to our motto of “no image left behind,” we outlined a new system design, in which all imaging service lines would share a centralized image archive (Fig. 2). The VNA would feed both the specific departmental imaging applications (radiology PACS, cardiology PACS, etc.) and the two principal EMRs through a universal viewer, primarily used by the clinicians but capable of consuming any image in the VNA. The cardiologist from the previous example not only does no longer need to open separate cardiology and radiology PACS viewers, but can also actually view all the exams of interest from the patient’s EMR or directly from the integrated PACS.

This system would provide a single interface for the two EMRs to connect and thus allow a single image viewer to be used for any image by the clinicians, enabling a patient-centric image record. Furthermore, it would provide cost savings as a single centralized storage solution could be shared (resulting in less hardware and less service contracts). There would be no need for data migration for new imaging applications, and by having migration tools in place, any new image archives will easily be migrated into the VNA. A single storage solution would also provide better opportunities for the stated ILCM, DR, and security, additionally to more fully utilize virtualized server environments and thereby reduce the amount of work for a future transition to cloud-based archive solutions. Despite the use of a centrally shared storage solution, we still allow each department to define their own rules and configurations for their respective workflows and prefetch/routing work.

Our governance model evolved from PACS-centric to cover the wider domain of enterprise-imaging management. We began with a PACS steering committee, comprised of radiology vice chair of IT, director of radiology IT, and other department representatives. As we advanced our model and scope, this steering committee expanded to include health system leaders such as CMIO and central IT VPs and directors of technical and application domains.

Fig. 1 Original UH health network system architecture (2014, simplified)



Functional VNA and EI Requirements

Following the envisioned system architecture, a set of requirements was defined. A VNA and EI solution was desired with storage support for DICOM images, non-DICOM images (both in native format and with DICOM wrapper), and AVI movie files. All supported file formats should also have adequate query/retrieve (Q/R) support (including non-DICOM images back to native format). Furthermore, a universal zero footprint viewer with support for multiple browsers was requested, as well as tools to capture metadata of non-DICOM images and to provide work lists to non-DICOM departments. System support for routing and pre-fetch along with the ability to set department-specific rules was also listed along with dynamic DICOM tag morphing. As a large healthcare organization, there was an initial need to support the use of multiple medical record number (MRN) sources and as such to provide a consolidated patient view to any imaging application. Additional requirements included high availability options, redundancy across two datacenters, audit tools, ILCM tools, and access to database schemas to allow for independent data mining.

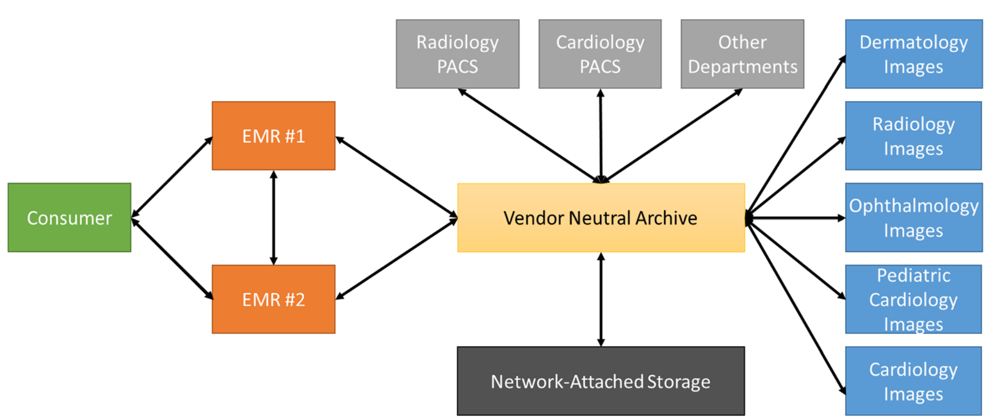
Implementation Process

The implementation process for our VNA and EI solution (by Sectra AB, Sweden) was split into three phases.

Phase I—Installation, Configuration, Integration, Testing, and Preliminary Migration

During the installation phase, our IT server storage team worked closely with the vendor to ensure that hardware specifications were met. This phase also involved software installation by the vendor. After basic testing of the installed hardware and software, configuration was initiated. This included configuring the systems that are supposed to share data with the VNA and modalities that send data directly to the VNA, as well as application set up, departmental archiving rules, and viewer settings. HL7 interfaces were set from numerous radiology information (RIS) and ADT systems, which necessitated utilization of numerous resources from both the vendor and the sites. Image links were configured for each EMR from the VNA for Radiology and Cardiology at some locations. Heavy testing was required throughout this phase to ensure stability and function of interfaces and integrations, especially

Fig. 2 Planned system architecture at project launch



considering the complexity of six different RIS feeds (from various vendors, such as Meditech, Syngo, and GE) with different MRNs following our rapid health system growth through acquisition. Patient linking functionality was implemented by the vendor at this stage.

Phase II—DICOM Images Migration

Once the systems were set, configured, and tested, migration of DICOM images was initiated. Images, pointers, orders, and reports as well as data that resided in other systems and locations were all migrated into the VNA. This process had to be seamless and non-disrupting to the users and was performed mainly by the vendor, although the necessary tools and abilities to perform this independently are now available to us. Prior to full migration, thorough testing was necessary to ensure image data was viewable, HL7 records mapped accordingly, and all mandatory fields included. Once the migrations were completed, a final validation step was performed to confirm all data was migrated and stored appropriately.

Phase III—Non-DICOM Images

The last phase of implementation is to migrate the non-DICOM data, such as that from the dermatology and ophthalmology databases, into the VNA. This phase is also performed mainly by the vendor and is still in process in our institution.

Results

Our VNA and EI solution was formally launched on December 1, 2015. At that point, the system included 36 radiology and 3 cardiology sites (one of which was pediatric cardiology), from 9 hospitals and 27 outpatient health centers. During the following 2 years, 3 additional hospitals and 15 outpatient health centers joined the University Hospitals (UH) network. Currently, 54 radiology and 26 cardiology sites are connected to the VNA and EI. Of note, all these changes translate to over 40% increase in exam production rate, compared to the pre-implementation state. The number and type of department sites, production and retrieval rates, and storage volume are presented in Table 1.

The transition from numerous archives to one shared centralized archive has proven cost-effective. In UH hospitals alone, three archives (namely radiology archive, cardiology archive, and pediatric cardiology archive) were replaced by a single EMC Isilon archive. The consolidation of these three archives into a single archive resulted in estimated cost savings of 10–15% by eliminating service contracts, maintenance, and resources to support multiple systems. To that, the value of incorporating archives of three other medical centers into our VNA should be added (exact cost savings were not evaluated). Our ability to manage a single archive also translated into new storage cost reductions per gigabyte-NAS ($4.47/GB in 2014 to $3.06/GB in 2017, 31.5% reduction). Additional financial costs incurred from hardware for redundant and test servers with added networking and power. These represent about 10% of the costs.

Table 1 VNA system status and progress during first 24 months

	Pre-implementation state[1]	Current state[2]
Number of sites	39	80
Radiology	36	54
Cardiology	3	26
Production rate[3]	913,000	1,316,000
Archive retrieval[4]	91,000	211,000
Storage volume (terabytes)	226	527

[1] Pre-implementation state captured on November 2015, including data from UH core PACS

[2] Current state captured on December 2017, including data from the VNA

[3] Exams per last 12 months, rounded to the nearest thousand

[4] Exams per month, November 2015 vs. November 2017, rounded to the nearest thousand

The human costs of the implementation included a project manager from the vendor and the medical center; three people for system build, configuration, and interfaces; and two for applications, training, and workflow assessment (hours spent varied—from peak 20 h a week for 4 weeks during the initiation down to a single person for 15 to 20 h per week for the following 8 weeks to assist in testing and migration), and we required only 1200 of 1700 budgeted external professional service hours. Several other resources engaged in the implementation arose for server storage team to set up hardware, configure, troubleshoot, and test the system, the radiology informatics team, and a cardiology informatics team. These aggregate to 50–60 h per week combined for 6 weeks. These resource efforts were absorbed as additional duties to their routine, which was possible due to the vendor's heavy involvement.

Ongoing human costs include 5 h per week from the cardiology department and 15 h per week from the radiology informatics team to oversee data integrity, respond to issues, edit configuration, train as needed, and continue service testing and configuration for upgrades or new modalities being added.

On top of cost benefits, the new VNA-EI solution is now widely used by clinicians and promotes patient-centric care. Currently, more than 200,000 exams are retrieved from the archive every month, compared with about 90,000 exams/month before implementation (> 120% increase). Beyond radiologists and cardiologists who have direct access to PACS, other clinicians are now viewing exams directly from the patients' EMRs, rather than from various external viewers and applications, currently over 140,000 viewer hits per month.

All participating departments experienced improved functionality, including enabled bi-directional electronic image sharing, routing of data from single location alleviating additional destinations on each modality, availability of images in central location with single viewer, and image lifecycle tools to purge data as it hits retention requirements. The cardiology service reported specific improvements, including redundancy of data, continued availability of data during cardiology PACS upgrades or downtimes, accessibility of images in our various EMRs, and the ability to view cardiology and radiology images concurrently from one viewer. Ophthalmology reported improved redundancy, availability, and portability of images.

Other advantages of transitioning to the new system include improved system recovery and redundancy. Prior to the VNA and EI solution implementation, the radiology PACS was the only archive that had backup and recovery capabilities, while currently, all archives (100%) have these capabilities. During the 12 months prior to the implementation (12/2014-11/2015), the UH hospitals multiple PACS suffered 372 min of unplanned downtime (> 1 min long) occurring over four different months. This excludes any additional potential downtimes of hospitals that were not part of the UH network during that period (data not available). In comparison, the VNA suffered 60 min of unplanned downtime (all in one single month) during the comparable 12 months between 12/2016-11/2017, which represents an 84% improvement.

The new solution presents several additional non-measurable advantages. Among those are the improved security, central auditing, access-monitoring capability, centralized monitoring of system performance, and central organized database for robust research studies, such as machine learning-based projects.

Most of our goals were defined a priori, and some were added during the implementation process. Table 2 describes the goals of the implementation process, as well as future steps. The primary implementation was completed with the onboarding of the major service lines to the VNA-EI system and was achieved for the three main services—radiology, cardiology, and ophthalmology. The Dermatology Department data has not been joined into the project at this point, although originally planned as part of primary implementation. The issues under review are providing specific needs of that service (front application performance with separate archive) that were not met by the original implementation process, with an alternative suggested solution not yet accepted by the end users.

Discussion

In this paper, we have described our experience in implementing a VNA-EI solution in a large multi-center regional integrated health delivery network. After a design phase for an organizational strategic plan, the system was launched at the end of 2015 and has since continued growth to include additional sites, departments, and services.

Although the process required capital investment, the cost savings integrated in it are actually quite substantial. We were able to migrate multiple archives into one centralized, robust, scalable image repository, reducing IT support needs, maintenance costs, number of vendors and contracts, and even hardware costs. We report our captured benefits, including the following: supported 40% growth rate in image production feeding into single image management system, 10–15% cost savings in service and maintenance, more than 30% volume-based reduction in storage unit costs, support of > 120% increase is archive retrieval, wider coverage from intrinsic disaster recovery redundancy, and > 80% improvement in unscheduled outages. The system's improved performance metrics are detailed in Fig. 3 and have shown relative to pre-implementation baselines. Although some aspects of system functionality (such as decreased downtime, enhanced recovery capabilities) arise from the implementation, other aspects, such as image volume or production rate, are probably multifactorial.

Overall, the ROI is complex though great when considering the patient care benefits, the clinician efficiency factor, clinician satisfaction, and overall improved quality of care by providing a patient-centric image record. The financial ROI will take about 2.5 years to recoup, given the scope of the project and the timeline to consolidate the various archives onto a single hardware solution. The core benefits derive from key elements of operational efficiency. First, we enabled image sharing among organizations with reduction in media, postage, and resources from generating and exchanging physical media. Second, we improved image lifecycle management allowing us to recoup archive space for reuse. Third, we have consolidated and reduced costs of multiple vendor support contracts. Next, we have reduced human resources required to manage multiple archive platforms. Finally, we have enabled a single efficient path for clinical and patient image viewing.

This modern solution combines the advantages of a VNA with those of an EI. These include data sharing and exchange across the enterprise facilities and incorporation of external data into the UH system. It also enables sharing of DICOM and non-DICOM data between multiple service lines, while still allowing every line or department to optimize system configuration to their individual needs, workflows, and preferences. The solution is especially advantageous in a constantly growing health network since it facilitates the introduction of new applications and incorporation of additional archives as the network expands, with no migration costs. In addition to this flexibility, the system also has shown remarkable durability by improving our disaster recovery capability, decreasing unplanned system downtime, pushing our backup coverage to 100%, and focusing our data security efforts on a centralized modern archive.

Table 2 Implementation goals and future steps

Goals	
All departments in statement-of-work migrating from current storage location to VNA	Defined a priori, achieved (excluding dermatology service)
Ability to view images via EMR from single viewer platform	Defined a priori, achieved
Ability to access images from a single location and view at the same time if needed without logging into independent applications	Defined a priori, achieved
Archiving point of care ultrasound images from the emergency department	Defined during the implementation process, achieved
Image capture into the VNA at the bedside, in the office, etc.	Defined during the implementation process, achieved
Future steps	
Adding further modalities (fetal imaging, gastrointestinal imaging, digital pathology) including some who currently do not archive at all (images saved on the device only)	
Embedding workflow and dataflow review of newly purchased imaging applications into the institutional final approval process to assure VNA compatibility	
Integration of image capture functionality to launch directly from the EMR	
Ability to capture images from a VNA image capture device and for an order to be created in the EMR from the VNA	
Migrating disparate cardiology PACS into enterprise Cardiology PACS and archive to VNA	

Beyond the cost savings and the inherent advantages of a modern solution that complies with the latest standards in data sharing and exchange, perhaps the most pronounce improvement is in patient care. Many in our region consume health services from multiple sites, centers, and physicians within the UH network. By implementing the VNA-EI solution, we facilitate communication between providers caring for the same patient, support clinical decision-making, and allowed our caregivers across the network to easily access patients' imaging data through the EMR. Caregivers no longer need to open third-party viewers, download applications, or handle external CDs. Patients no longer need to care for their copies of exams or CDs and more importantly do not need to re-take radiology exams when moving between network facilities. Vest and colleagues have shown that providing access to external imaging exams reduced the chance of repeat imaging by up to 25% [17]. All these advantages enable our caregivers to focus on patient-centric care through streamlined workflow and increased caregiver as well as patient satisfaction.

It is important to review the successes, failures, challenges, and lessons learned during our implementation process, in the hope of aiding others when considering a similar project in another health system:

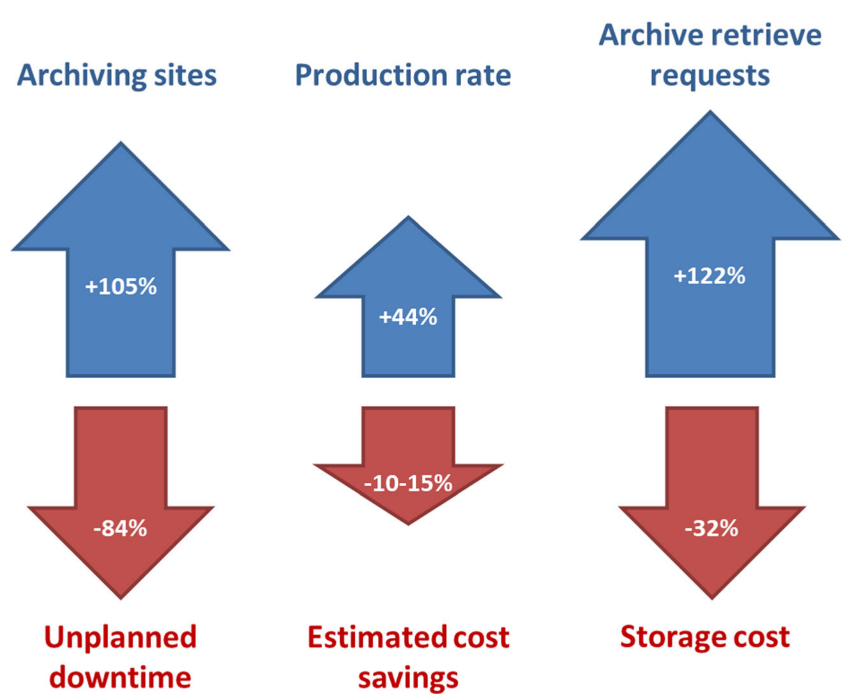


Fig. 3 Post-implementation vs. pre-implementation status of the image management system

1. Not all vendors can send to an archive—even though VNA is vendor neutral, the sending vendor needs the ability to send to and retrieve from an archive.
2. Assigning a unique identifier for each order can be challenging—not all departments use orders for each study. We were able to overcome this by tying studies to visits and encounter numbers.
3. A major issue to be addressed and discussed during the planning phase is the entity owning and managing the VNA.
4. Some historical data was not uniquely identified and we were therefore not able to migrate it
5. Engaging other vendors and departments in the process as soon as possible is paramount.
6. Emphasizing how the process is aimed at enhancing functionality without intent to interfere with workflow to department key opinion leaders should be proactively pursued.
7. Suggest implementing a single system that has all needed functionality and added resources to keep systems optimally synchronized.
8. We had a unique situation in which the same vendor provides both our radiology PACS and the VNA. But ultimately, we highly recommend where possible using your radiology PACS as the enterprise-image archive system while keeping current image and workflow systems in place. This can eliminate the need for keeping the VNA and PACS systems synchronized.
9. As mentioned before, although part of our original statement of work, we were not yet able to incorporate the dermatology service images into the system, due to difficulty in overcoming specific departmental needs currently not optimally provided by the system.
10. We successfully consolidated six archives for different geographical locations into a single central archive.

We demonstrated the implementation process by providing data describing our changes in our systems before and 2 years after the implementation. Nevertheless, our report has limits as health systems and health practices tend to improve over time from many reasons other than the introduction of a new imaging solution. The increase in number of exams, storage consumption, and study retrievals should not be exclusively attributed to the implementation of the new system, yet also to the growth of the integrated health network. The system's ability to cope positively with this growth does reflect on its durability and capability to incorporate additional archives and medical centers.

Conclusion

Although our primary implementation process is completed, we are still looking forward for future challenges. These include the inclusion of additional sites from the expanding UH network, incorporating further service lines (such as expanding ophthalmology or adding wound care), and expanding research efforts based on the growing database.

Compliance with Ethical Standards

Conflict of Interest DF is an employee of Sectra AB, Linköping, Sweden. All other authors declare no conflict of interests.

References

1. Marceau C. What Is A Picture Archiving And Communication System (PACS)? In: Duerinckx AJ, ed. 1st Intl Conf and Workshop on Picture Archiving and Communication Systems. Vol 318. International Society for Optics and Photonics; 1982, pp 24–31. doi:https://doi.org/10.1117/12.967618.
2. Cox JR, Blaine GJ, Hill RL, Jost RG. Study Of A Distributed Picture Archiving And Communication System For Radiology; In: Duerinckx AJ, ed. 1st Intl Conf and Workshop on Picture Archiving and Communication Systems.Vol 318. International Society for Optics and Photonics; 1982, pp 133–142. doi:https://doi.org/10.1117/12.967635
3. DICOM Standard. Available at: https://www.dicomstandard.org/. Accessed April 18, 2018
4. Integrating the Healthcare Enterprise. Available at: http://www.ihe.net/. Accessed April 18, 2018
5. Thomas JD: The DICOM image formatting standard: its role in echocardiography and angiography. Int J Card Imaging 14(1+):1–6, 1998. https://doi.org/10.1023/A:1006018614132
6. Silva AF D, Costa C, Abrantes P, Gama V, Den Boer A. Cardiology-oriented PACS. In: Horii SC, Blaine GJ, eds. Medical Imaging 1998: PACS Design and Evaluation: Engineering and Clinical Issues.Vol 3339. International Society for Optics and Photonics; 1998, pp 248–256. doi:https://doi.org/10.1117/12.319775
7. Thrall JH: Directions in radiology for the next millennium. AJR Am J Roentgenol 171(6):1459–1462, 1998. https://doi.org/10.2214/ajr.171.6.9843271
8. Ratib O, Ligier Y, Bandon D, Valentino D: Update on digital image management and PACS. Abdom Imaging 25(4):333–340. https://doi.org/10.1107/s002610000011
9. Ratib O, Swiernik M, McCoy JM: From PACS to integrated EMR. Comput Med Imaging Graph 27(2–3):207–215, 2003. https://doi.org/10.1016/S0895-6111(02)00075-7
10. Cao P, Hashiba M, Akazawa K, Yamakawa T, Matsuto T: An integrated medical image database and retrieval system using a web application server. Int J Med Inform 71(1):51–55, 2003. https://doi.org/10.1016/S1386-5056(03)00088-1
11. Huang HK: Enterprise PACS and image distribution. Comput Med Imaging Graph 27(2–3):241–253, 2003. https://doi.org/10.1016/S0895-6111(02)00078-2
12. Bandon D, Lovis C, Geissbühler A, Vallée J-P: Enterprise-wide PACS: beyond radiology, an architecture to manage all medical images. Acad Radiol 12(8):1000–1009, 2005. https://doi.org/10.1016/j.acra.2005.03.075
13. DeJarnette WT. What is a Vendor Neutral Archive? White Paper Series. 2009. Available at: http://www.dejarnette.com/downloads/get.aspx?i=45047. Accessed April 18, 2018
14. Agarwal TK, Sanjeev: Vendor neutral archive in PACS. Indian J Radiol Imaging 22(4):242–245, 2012. https://doi.org/10.4103/0971-3026.111468

15. Bellon E, Feron M, Deprez T, Reynders R, Van den Bosch B: Trends in PACS architecture. Eur J Radiol 78(2):199–204, 2011. https://doi.org/10.1016/j.ejrad.2010.05.025
16. Roth CJ, Lannum LM, Persons KR: A Foundation for Enterprise Imaging: HIMSS-SIIM Collaborative White Paper. J Digit Imaging 29(5):530–538, 2016. https://doi.org/10.1007/s10278-016-9882-0
17. Vest JR, Kaushal R, Silver MD, Hentel K, Kern LM. Health information exchange and the frequency of repeat medical imaging. Am J Manag Care 20(11 Spec No 17):eSP16–24, 2014. Available at: http://www.ncbi.nlm.nih.gov/pubmed/25811815. Accessed April 19, 2018