Implementation of a Radiology Electronic Imaging Network: the Community Teaching Hospital Experience

Manuel Arreola, Harvey L. Neiman, Amy Sugarman, Larry Laurenti, and Ron Forays

Because of their typically small in-house computer and network staff, non-university hospitals often hesitate to consider picture archiving and communication system (PACS) as a solution to the very demanding financial, clinical, and technological needs of today's Radiology Department. This article presents the experiences of the 3-year process for the design and implementation of the Radiology Electronic Imaging Network (REIN) in the Department of Radiology at The Western Pennsylvania Hospital (WPH). WPH embarked on this project in late 1994 to find a solution to the very pressing demands to reduce operating costs and improve service to primary care clinicians, both on-site and at WPH-affiliated clinics. A five-member committee consisting of in-house medical, administrative, information services, and medical physics staff was formed to design a network that would satisfy specific needs of WPH by using a phased mini-PACS approach and to select the various vendors to implement it. Suppliers for individual mini-PACS were selected to provide modality-specific solutions. For the backbone network, vendors were evaluated based on their technological progress, competence and resources, the commitment of the company to the imaging network business, and their willingness to embark on a mid-sized PACS project such as this. Based on patient volume, workflow patterns, and image quality requirements, the committee produced proposals detailing number and location of workstations, short- and long-term memory requirements, and so on. Computed tomography/magnetic resonance imaging, computer radiography, ultrasound, nuclear medicine, digital fluoroscopy, and angiography mini-PACS have been implemented over the past 2 years, and most of these are already integrated into the main REIN. This article presents detailed information concerning the design, selection and implementation processes, including storage requirement calculations. This indicates that PACS implementation is achievable for community hospitals with small computer, networking, and physics departments. Also presented are recommendations concerning design and vendor selection, that may be helpful for similar institutions. Copyright © 1997 by W.B. Saunders Company

KEY WORDS: PACS, CR, RFP, RIS, display workstation.

From the Departments of Radiology (MA, HLN, AS, LL) and Information Services (RF), The Western Pennsylvania Hospital, Pittsburgh, PA.

Address reprint requests to Manuel Arreola, PhD, Radiation Oncology and Physics, The Western Pennsylvania Hospital, 4800 Friendship Avenue, Pittsburgh, PA 15224.

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VARIOUS PAPERS have been published in recent years describing the experiences of different picture archiving and communications systems (PACS) installations.^{1,2} Some of these include a "how to" approach that can be used for other sites in their own design and implementation of PACS. These articles, however, describe commercial or home-grown systems installed in large academic institutions that possess large computer science (CS) and information systems (IS) departments. Usually, such large institutions can conceive, implement, and maintain a large-scale PACS without significant assistance from manufacturers or third-party consultants. In 1994, when the Western Pennsylvania Hospital (WPH) made the decision to investigate the feasibility of PACS implementation, it was evident that a large-scale approach would not satisfy the needs and achieve the goals of a smaller hospital. WPH, a 540-bed teaching community hospital located in the heart of Pittsburgh, represents a very common type of healthcare institution. Information systems operations have been out-sourced to a third-party contractor with no PACS experience, and there is no such thing as a CS department in the institution. This article describes the experience and methodical approach followed at WPH in the design, specification, selection, and implementation of WPH's Radiology Electronic Imaging Network (REIN). We believe that our experience should be useful for many institutions with goals, staff, and financial constraints similar to our own.

MATERIALS AND METHODS

Producing a Request for Proposal (RFP)

From the very conception of the REIN project, it was evident that producing an adequate RFP required the previous completion of two tasks. First, to assess how compatible PACS implementation was with the long-term plans of the hospital regarding electronic patient records (EPR). Second, to do an evaluation of the status of commercial PACS technology and whether or not it could realize the short- and long-term plans of the department, especially the establishment of a filmless environment. A five-member committee was formed to under-

take these tasks. The limited committee membership (department chairman, administrative directors, IS director, and medical physicists) was ideal to maintain a focused decision-making process throughout the project. The presence of IS was also important to keep the project in pace with the hospital's EPR plans. The committee developed a set of forms and spreadsheets to gather information and facilitate the process of determining various departmental needs, such as wide area network (WAN) and local area network (LAN) architectures and bandwidth specifications, digital storage requirements, number and type of digital workstations, as well as a detailed cost-benefit analysis. An example of the type of decision processes used is shown in Fig 1, namely the determination of the number and type of digital workstations required. Information was obtained from questionnaires provided to the heads of the various areas in the department. Determination of storage and network needs, as well as the fundamental cost-benefit analysis, which can be significantly more involved,^{3,4} were simplified by creating and using various Microsoft Excel spreadsheets, an example of which is presented on Table 1. The table shows a simplified way of determining the network bandwidth and storage requirements during the busiest hours of the day in the department. The numerical entries shown were obtained from patient volume statistics as well as simple questionnaires provided to the chief

technologists in the various areas of the department. As other facilities are incorporated into the REIN, these questionnaires and spreadsheets will become very valuable to assure proper incorporation of those areas into the digital network.

Vendor Selection

The RFP submitted to four commercial PACS manufacturers resulted in a year-long selection process. A phased or mini-PACS implementation approach was selected for various operational and financial issues, but mostly to pursue a multivendor approach that would allow installation of modality-specific mini-PACS, as in the case of our ultrasonography and nuclear medicine areas. We discovered early on at this stage that the knowledge about PACS we have obtained in writing the RFP had become extremely valuable. The RFP became our strongest aid, allowing us to successfully negotiate hardware and software upgrades to all workstations at no cost, as well as other financial guarantees.

Approval of the REIN Project by the Hospital's Administration

Another positive result of the detailed RFP and the intense vendor evaluation process was the solid proposal presented to

Fig 1. Determination of number and type of workstations

Table 1. An example of a spreadsheet to determine storage and bandwidth requirements

Area	Patients/ hour (Estimated)	Series/ Patient (Average)	Images/ series/ (Average)	MB/ image (Typical)	MB/ hour
MR imaging	2	4	35	0.125	35
CT	6	3	35	0.52	327.6
ED	8	1	8	8	512
Chest room	8	1	2	12	192
Computed radiography	20	1	8	4	640
Digital fluoroscopy	8	1	30	0.5	120
ICU chest	15	1	2	8	240
Ultra-sonography	12	1	60	0.25	180
Nuclear medicine	10	1	60	0.032	19.2
Angiography	3	5	25	2	750
Totals	96	19	265	29.427	3015.8

Note. Total heavy hourly traffic = 3 GB. Hours a day that are considered as heavy traffic hours = 5 hrs. Total daily memory required from heavy hours = 15 GB.

Abbreviation: ED, Emergency Department.

the hospital's board of directors for approval. The implementation plan and cost-benefit analysis proposed were properly structured and justified, not only resulting in immediate, unanimous approval of funds, but, most importantly, the board's full support for the entire project, a crucial point for its success.

RESULTS

Network and Storage

Because of our limited expertise in the installation of high-speed digital networks, part of the contract with the selected vendor included the installation of an asynchronous transfer mode (ATM) network that will allow for future expansion without the need for network hardware upgrades. The network consists of six $2k \times 2k$ and five $1k \times 1k$ primary diagnosis stations located in the department, and seven clinical review stations in various units of the hospital. A 700-GB jukebox was installed for storage of studies. Such a jukebox will be replaced by a 12-TB device in early 1998 and will have the capacity to hold 4 to 5 years' worth of patient studies. A dedicated server provides teleradiology capabilities from remote sites.

Pre-implementation Process

In order to identify operational and functional issues that result from a filmless operation, modality-specific mini-networks were implemented in the ultrasonography and nuclear medicine areas in late

1994; these became filmless operations in the summer of 1995. The transition to a digital environment provided the medical and technical staff with an awareness of the numerous ramifications in the daily clinical routine of a filmless operation. For the radiologists, it forced changes in their reading habits (eg, batch vs. continuous reading); for the technologists, a change in their study QA procedures; for the clerical staff, modifications to registration, add-on and study request procedures, production of hard copy for referring physicians, and so on. Knowing that these situations would magnify a 100-fold upon implementation of the department-wide REIN, a set of subcommittees was formed to address these and many other workflow and operational issues. Among these, two of significant importance: first, the implementation of computed radiography (CR) and second, the establishment of a digital interface between the REIN and the radiology information system (RIS). The membership of these subcommittees included radiologists and other physicians, radiology residents, technologists from all areas in the department, physicists, administrators, and clerical staff. The actual daily operation of the digital department has been based on the recommendations given by these committees. They also have served an important and valuable purpose of providing all personnel with a high sense of enthusiasm and responsibility for the REIN project.

Implementation Phases

The initial phases of the project included computed tomography (CT), magnetic resonance (MR) imaging, digital fluoroscopy, and CR. Angiography, ultrasonography, and nuclear medicine networks will be incorporated into the main REIN this summer, upon their upgrade to DICOM 3.0 standards. The areas of the department where adaptation to the filmless environment has been apparently more difficult include radiography, fluoroscopy and MR imaging. This is due to various reasons. In the first two cases, the change in workflow for the technologists and the significant changes in reading habits for the radiologists have been difficult. Adaptation to CR also has been difficult. Changes in MR reading are significant, using a dual-monitor reading station and that, at this point, it still is being evaluated.

Interfacing With the RIS

A crucial part of the project still in progress is the interfacing of the REIN with the RIS. Full interface capabilities will allow for extremely important features such as automatic routing of studies to appropriate workstations, automatic pre-fetching and routing of previous studies, and on-screen display of reports to be available this summer, according to our vendor. The subcommittee dedicated to the configuration and implementation of this interface is still holding weekly meetings to properly establish auto routing and pre-fetching criteria. For these purposes, questionnaires have been sent to the heads of the various areas in the department. We anticipate a significant impact in the department's workflow upon implementation of the interface.

DISCUSSION AND CONCLUSION

Our experiences from the last 2 to 3 years have shown that PACS implementation is possible for the typical community hospital, simply by recognizing the institution's strengths and limitations. Full support of the hospital, indispensable for a successful implementation, only can be obtained from a carefully planned project. Thus, an adequate RFP and an intensive and aggressive vendor selection process are crucial. These difficult processes can be completed successfully by a committee of key players. Upon initial installation, the day-to-day routine of a filmless department can be decided by committees with representatives from all staff levels. A realistic approach, patience, and flexibility are essential ingredients to a successful PACS implementation.

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