Enterprise-Wide CR Implementation: The Shands Healthcare System Experience

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Major healthcare systems are comprised of hospitals and clinics of different sizes and locations. Many such enterprises are already using picture archiving and communication systems (PACS) and computed radiography (CR) in their main hospitals. The integration of other hospitals and clinics into PACS is a more complex problem. The introduction of CR in remote facilities presents problems, as patient populations, department sizes, and work flow patterns may differ among facilities, and inadequate implementation programs may lead to disruption of patient care services. Although the University of Florida has had an operating PACS for years, facilities affiliated with the Shands Healthcare System (SHS) had not been incorporated into PACS until recently. This article presents the 5-year process to convert all film-screen radiological services to CR in the main hospital, five affiliated community hospitals, and four clinics. The article shows the importance of leadership by the medical physicist from inception of the project through installation and clinical implementation.

KEY WORDS: CR, PACS, community hospitals, academic departments, technologist training

VARIOUS PAPERS¹⁻³ have documented the implementation and progress of PACS at the University of Florida (UF). Even though the UF PACS system has been in operation for over 15 years, use of computed radiography (CR) was attempted but only in a limited way on two occasions: first in 1992, with a Du Pont/Fuji AC-1 system, which provided a valuable first experience^{4,5} with CR but had a rather restricted clinical application; second in 1996, when two Kodak Ektascan 400 (Rochester, NY) systems were installed, converting most of the mobile chest radiography work at Shands Hospital at UF (SUF) to CR.⁶ Although CR studies performed during both of these periods were archived and continue to be online in the

current archive database at the SUF PACS, actual clinical reading of the studies was done from hard copies, which are also duly archived in the SUF film library. Furthermore, no other projection radiographic examinations were converted from film-screen to CR until 1998, when the hospital decided to move forward with full implementation of CR for all radiographic services performed at SUF, as well as for those at five community hospitals affiliated with the Shands Healthcare System (SHS). The conversion to CR would permit concurrent implementation of softcopy reading of the studies. This article describes the experience and the methodical approach followed by the Radiological Physics Division at SUF in the specification, vendor selection, installation, and clinical implementation of this ongoing project.

METHODS

Vendor Selection and Pilot Projects

From the inception of the main CR project, it was decided that small-scale projects would be carried out first in order to accomplish several objectives, including a reas-

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Table 1. Hospitals and Clinics Affiliated with the Shands Healthcare System and Some Characteristics of Their Radiology Departments

Shands Facilities	Radiographic Rooms	Portable X-ray Units	Annual Volume CR (×1000 studies)	Technologist staff ^a	On-site Radiologists ^a
In Gainesville					
Hospital at the University of Florida (SUF)	8	10	78.5	20	22 (faculty) 40 (residents and fellows)
Alachua General Hospital (SAGH)	4	4	43.3	12	8
Rehabilitation Hospital at Vista (SVR)	1	—	0.6	1	—
Medical Plaza Outpatient Clinic (SMP)	2	—	3.8	3	1
Park Avenue Imaging Center (SPAIC)	1	—	2.4	1	1
Sports Clinic at Hampton Oaks (SCHO)	2	—	7.9	3	2
Ayers Professional Building (SAPB)	2	—	5.2	3	—
Outside Gainesville					
Hospital at Lakeshore (SHL)	4	2	24.2	6	1
Hospital at Starke (SHK)	2	2	7.2	5	1
Hospital at Live Oak (SHLO)	2	1	12.6	4	1

^aIndicates an average from all shifts during 2002.

assessment and reevaluation of CR technology and the various systems available. This multi-stage execution also permitted the physics group to design implementation programs that would be suitable for the various clinical settings that would be encountered both in the main academic department at SUF and in the SHS community hospitals and affiliated clinics. These hospitals and clinics are all within a 60-mile distance of the university campus and encompass a variety of clinical settings, including a physical rehabilitation hospital, small rural hospitals, and a sports medicine clinic. Table 1 lists the names and basic characteristics of the various radiology departments at the SHS hospitals and clinics in this project.

Three pilot projects were undertaken within a 15-month period, starting in 1998. The first one involved the opening of a new outpatient facility adjacent to the main university hospital. This outpatient clinic was originally conceived to function as a fully digital operation, as no darkroom or hard copy-based reading rooms were projected or built. This first project allowed the physics group to perform a thorough evaluation of the three commercially available CR systems at the time. Systems were compared technically in terms of the basic design of the plate scanning units, robustness of processing algorithms, and overall image quality. Of equal importance, however, was the assessment of each system's functional design and the various user interfaces employed for cassette identification, image manipulation, and post-processing. The department has had a well-established quality control (QC) program for film-screen radiography for years, and the clinical work flow in radiography is designed to facilitate the program. Thus, it was a primary requirement that the system design would distinctively and physically separate the three basic functions of cassette identification, image acquisition, and quality control, as these functions are performed by technologist assistants, staff technologists, and technologist supervisors, respectively. Both single-plate and multi-plate scanners were evaluated from all vendors because of the variety of patient volume and physical space requirements found in different

clinical environments. On the basis of these criteria, a simple configuration of an Agfa ADC Compact, PS5000 workstation and ID station (Teterboro, NJ) was selected for the initial project, and was installed in November 1998. This first project was representative of a self-contained clinical environment.

The other two pilot projects were also representative of different environments that would frequently be encountered in the larger-scale, system-wide project. The introduction of CR into the main academic department at SUF was started in September 1999, followed by the full conversion from film-screen to CR in the second-largest community hospital in the system, Shands Hospital at Lakeshore (SHL) in February 2000. It was decided that for the next two stages, the department should continue with the same CR manufacturer to evaluate the system's performance in these very different clinical environments. These two projects were successful, particularly at SHL, where conversion was completed in only 3 weeks.

Two Community Hospitals and Two Outpatient Clinics

The success of the pilot projects demonstrated two very important facts; first, that the choice of CR manufacturer was adequate and very suitable for the Shands PACS soft copy environment; and second, that the PACS group and the physics group at SHS were ready to undertake the larger-scale CR conversion project. Thus, SHS decided to select Agfa as its sole CR supplier, and the rest of the project was divided into several phases. Table 2 lists the configuration of Agfa CR equipment planned for the entire SHS conversion project. The two local community hospitals, Rehabilitation Hospital Shands at Vista (SVR) and Shands at Alachua General Hospital (SAGH), were selected for the second phase of the project, completed between April and August 2001. The project at SAGH, the largest community hospital within SHS, was significantly demanding as it en-

Table 2. Configurations of CR Systems Installed in the Shands Healthcare System

Shands Facilities	ADC Compact Plate Readers	ADC Solo Plate Readers	PS5000 QC Workstations	ID Stations
In Gainesville				
Hospital at the University of Florida (SUF)	5 ^a	—	4	6
Main Radiology Department	2		1	2
Orthopedic Clinic	1		1	2
Intensive Care Units	2		2	2
Alachua General Hospital (SAGH)	3	1	3	4
Rehabilitation Hospital at Vista (SVR)	—	1	1	1
Medical Plaza Outpatient Clinic (SMP)	1	—	1	1
Park Avenue Imaging Center (SPAIC)	—	1	1	1
Sports Clinic at Hampton Oaks (SCHO)	1	1	1	2
Ayers Professional Building (SAPB)	—	1	1	1
Outside Gainesville				
Hospital at Lakeshore (SHL)	1	1	1	2
Hospital at Starke (SHK)	1	—	1	1
Hospital at Live Oak (SHLO)	—	2	1	1

^aEntry includes systems currently being installed (January 2003).

compassed the installation of three ADC Compact plate scanners and two ADC Solo scanners in the hospital and its adjoining outpatient facility, the Ayers Professional Building (SAPB). Cooperation from all staff levels resulted in a very successful, though not uneventful installation. Conversely, the task at SVR was completed in a week and has been relatively problem-free from the start. In addition, a second outpatient facility of SUF with a single radiographic room, Park Avenue Imaging Center (SPAIC), was also incorporated into the list of CR facilities in 2001. In both of these low-volume cases, a configuration containing an ADC Solo single-plate reader was deemed adequate.

At that time, the successful completion of the early phases of the conversion to CR prompted two decisions regarding the printing of hard copies: first, all printing of CR studies at facilities already using CR was discontinued; and second, all remaining CR installations would work exclusively in a soft copy reading environment.

Two Rural Community Hospitals

The next phase of the project involved some different challenges. Two low-volume rural community hospitals were scheduled for conversion to CR in the first two months of 2002: Shands Hospital at Live Oak (SHLO) and Shands Hospital at Starke (SHK). Unlike the main academic hospital and the larger community hospitals, which had some experience with soft-copy reading of other digital modalities (e.g.,CT) and functioning radiology information system (RIS) in place, radiology personnel at these two smaller hospitals had little prior experience with computers and the use of even simple software interfaces. Training of the staff at all levels (clerical, technical, medical, and even administrative) needed to be done from a different perspective to accommodate the different work flow patterns in these smaller community hospitals.

The Orthopedic Clinics

Radiology at SUF serves two major orthopedic clinical sites. One site is located in the hospital, serving inpatient and outpatient populations, both adult and pediatric, and the other is an orthopedic and sports medicine clinic located 3 miles from the main hospital. An aggressive and nationally renowned orthopedic surgery group refers patients to these two high-volume radiological clinics. To avoid a mixed environment of film and soft copy reading while assuring full availability of studies for the surgeons, the installations of CR in these two facilities were scheduled to take place within a couple of weeks of each other. Cassette identification stations were installed in each x-ray room of the in-hospital clinic with the intention of evaluating improvement in work flow efficiency. The conventional configuration of a single identification station was installed in the remote clinic at Hampton Oaks. Installation took place in the spring of 2002, and technique charts for extremity images and the corresponding speed class settings in the Agfa system were revised and reevaluated at that time.

The imaging of scoliosis and long leg studies, both of extreme importance in orthopedic imaging, presented a significant challenge for this part of the implementation. Preliminary testing of Agfa image stitching software had been done in 1999 at the outpatient facility in SMP, with very unsuccessful outcomes. The process was labor-intensive, involving manually transferring three CR imaging plates to a screenless 35 cm × 91 cm scoliosis cassette for exposure, then back to their original CR cassettes for processing. Image stitching was slow and often inaccurate. The idea had been practically abandoned until 2002, when Agfa introduced their design of a scoliosis/long leg CR cassette holder and grid. After the physics group performed phantom testing successfully, the first cassette holder was put in service at the hospital orthopedic clinic. The resultant

studies were deemed satisfactory by both orthopedic surgeons and radiologists. A second cassette holder was scheduled for installation at the remote clinic at Hampton Oaks in January 2003.

RESULTS

Pilot Projects

The pilot project at the outpatient facility Shands Medical Plaza (SMP) was started in November 1998 and provided valuable information for designing implementation plans for subsequent phases of the project. This first installation provided the PACS group at SUF with the opportunity for evaluation and validation of digital imaging and communication in medicine (DICOM) for the Agfa systems. It also provided the physics group the opportunity to design and perform an extensive acceptance testing of the plate reader, the plates, and the cassettes themselves, as well as to evaluate the MUSICA (Agfa Corp., Teterboro, NJ) image processing setup provided by the manufacturer. Training of the small staff of two technologists and one technologist assistant was relatively simple and straightforward. The self-contained, low-volume characteristics of the installation at SMP provided an excellent environment for identifying and solving basic problems of both a technical and functional nature, which would have been difficult to address and resolve quickly in a more hectic environment. Another significant advantage of this initial installation was the excellent communications channel established between the staff technologists and the physics group, which provided a model to follow in terms of training and continuous support.

The pilot project in the main academic department at SUF was approached somewhat differently. Because of the significantly large number of technologists and technologist assistants in that department, it was clear that the one-on-one communication channel established with technologists at the SMP could not be replicated at SUF. Thus prior to system installation, the physics staff provided 2 hours of training on the basic physics of CR and specific training on the use of the Agfa CR system for the purpose of establishing a uniform knowledge background for technologists and tech-

nologist assistants. This knowledge was augmented by the applications training provided by the manufacturer immediately after installation of the systems. The equipment configuration included two centrally located ID stations, one ADC Compact plate scanner, one ADC Solo plate reader, and one PS5000 QC workstation accessible only to the supervising technologist. This configuration was selected to provide redundancy and to optimize clinical work flow and patient care. Although not restricted, extremity and bone studies are only performed occasionally in this main area of radiology; thus, adjustments to default speed classes and MUSICA parameters were minimal at this stage. Attention was given to the development of clinical protocols, including the proper approach to collimated views and multiple views exposed on a single imaging plate.

The project at SHL also involved significant preliminary training and education of technologists and a somewhat different approach to clinical implementation. The work flow in this department requires every technologist to evaluate the quality of his/her own work, while the clinical supervisor only conducts periodic QC evaluations. Unlike elsewhere in SHS, the department at SHL did not use separate single-screen film-screen cassettes for extremity exams prior to the CR installation; therefore extremity exams were performed at a higher system speed setting. To minimize the impact on work flow and prevent a high initial number of repeated views/studies, the CR speed class for extremities was adjusted so that no major changes to established technique charts were necessary. Both physicists and radiologists deemed image quality to be adequate, and the CR conversion of SHL was completed as planned within 1 month.

It was during these stages that two significant technical issues were addressed. The first issue involved the proper use of nonreciprocating grids with CR, both in chest stands and in portable radiography. It is well known that aliasing artifacts are generated in CR images when a standard 33 line/cm stationary grid is positioned with the gridlines parallel to the CR plate scanning direction. The budgets of both SUF and SHL were not able to accommodate the purchase of new higher line-density grids at

the time of CR installation; therefore, grid orientation charts were generated for staff use so that artifacts could be prevented.

The second technical issue involved the calibration of automatic exposure control (AEC) systems for use with CR. Detailed calibration procedures were generated for use by the in-house x-ray service engineers. Initially, calibrations of AEC systems were performed using a flat field image of an acrylic phantom processed at a speed class of 200. The calibration procedure would later be changed to a more representative simulation of the typical clinical situation by processing the flat field at a speed class of 400.

The Community Hospitals

The largest of the four community hospitals that were converted from film-screen to CR, SAGH, presented a significant challenge over the 3-month implementation period. Once again, preliminary education and training facilitated a smooth transition. Identification of two lead technologists, who quickly embraced the project, as CR superusers, was instrumental in easing the frustration of the rest of the staff during the first few weeks of implementation. Training was also an important factor in the acceptance of soft copy CR reading by radiologists at SAGH, whose concerns and questions were resolved through proactive interaction with physicists.

Similar situations occurred at the two rural hospitals, where clinicians were significantly resistant to the use of CR, as it forced a change in their work routine. Through dedicated interactive sessions between physicists and clinicians, these physicians became comfortable and were able to recognize many of the benefits of soft-copy reading. The technical issues of grid use and AEC system calibration, identified during the pilot project and described in the previous section, were properly addressed as well, including a problematic single-phase x-ray unit at SHLO.

Technologists Training and Education

An interesting pattern was recognized a few months after the initial installation of CR had

been completed at the various facilities. A significant number of mistakes and low-quality images were identified by radiologists and QC technologists from all four facilities. Although technologists had indeed been trained on proper use of the equipment, they were not very familiar with the use of computers and software interfaces before CR implementation took place. It became apparent that this lack of familiarity had caused them to focus their attention during initial training on learning and memorizing which actions to perform in order to get their work done, rather than on understanding the basics and the processes involved. This is an ongoing problem, as new staff members are hired. It is not uncommon to encounter technologists of excellent reputation and experience who are practically computer illiterate. The physics group at SHS is currently developing continuous training and educational programs to address this very important issue. Several retraining sessions have been successfully carried out, providing the technologists with a better understanding of their role and the impact they have on the quality of CR studies. Incorrect cassette identification, either by selection of the wrong accession number or patient name from the work list or by incorrectly typing patient information, is clearly a critical issue in patient care. A large portion of the training sessions is concentrated on these critical issues.

Another staff-related issue is that of x-ray technology students-in-training. It is debatable whether clinical rotations through filmless departments provide adequate x-ray technologist training. Such rotations no longer provide the opportunity for students to learn the techniques for adequately exposing film-screen cassettes and processing films to generate images of high quality in a clinical setting. Also, the wider latitude of CR plates, as compared with film-screen, may give trainees an incorrect perspective on proper and safe radiation exposure levels in radiography.

The Orthopedic Clinics

In many ways, the four-year CR conversion experience at SHS prior to implementation in the two orthopedic x-ray facilities effectively

served as preparation for the formidable task of converting these high-volume, high-image-quality-demanding practices. All education, training, and technical preparations were conducted in the same way as before, and the emphasis this time was in planning a high-efficiency work flow configuration. This configuration included the installation of cassette identification stations in each of the x-ray rooms and the training of technologist assistants in the routine duties of cassette identification and loading and unloading of cassettes in the multi-plate scan readers. The physics staff took the opportunity at that time to revise extremity and general purpose technique charts to generate a single, system-wide set of technique charts, which has been in use for several months. In general, technique charts were generated to ensure images of high quality and low noise utilizing a speed class of 400 for most general-purpose studies, while most of the extremity studies are done utilizing a speed class of 25. All cassettes in the orthopedics areas, regardless of size, were initialized to be scanned at high resolution to ensure superior image quality.

Regarding scoliosis and long leg imaging, the cassette holder commercially available by the manufacturer is adequate but limited in its applications. The stitching software does not eliminate light banding across the stitched image resulting from the imaging plate overlap. Orthopedic surgeons particularly dislike the superimposed wire frame in the cassette holder, which is used as a fiducial marker for automated image stitching. Nevertheless both surgeons and radiologist have deemed the images to be adequate for their clinical applications.

Completion of the Conversion Project

SHS realizes that PACS and CR implementation projects have no completion stages, as the technology evolves and newer systems and components become available constantly. The advent of digital radiography (DR) has already affected the radiological environment, and will be included in the ongoing digital conversion at SHS with the installation of DR and CR in the Emergency Department at SUF in the spring of

2003. Planning has also begun in scheduling the replacement of older CR systems in the SHS with newer CR and DR systems. Such a process has already begun, as the first dedicated chest DR unit at SHS was installed at the main academic department in August 2002 and the 7-year-old CR units serving the ICUs were planned for replacement in January and February 2003.

DISCUSSION AND CONCLUSIONS

The successful implementation of CR in the highly varied clinical radiology environments of the different hospitals and facilities that are part of the Shands Healthcare System required the leadership of the medical physicist during all stages of the project. In the initial planning stages, the physicist's understanding of the technology is crucial for the department in making decisions regarding specification of equipment and vendor selection.

Preliminary education and training of the staff technologists has proven to be a very important factor in the success of a CR implementation project. Training not only helps in introducing the staff to this new technology, but it can also help them understand the important fact that CR is not simply "digitized radiographs." During training, the physics staff establishes rapport with the technologists that is useful in early identification of leaders (i.e., future superusers), who are crucial in carrying communications between technologists and physicists. It is critical to identify and empower these lead technologists, as they become extremely important during the first few months of implementation, which can be extremely frustrating at times.

Three very critical educational issues appeared months after the initial implementation. The first critical issue is that of continuous education and training for the staff, especially for those who are generally unfamiliar with computers and their use. The second issue is that of the education and training of newly hired technologists, who are unfamiliar with the system and who may also be nearly computer-illiterate. In-house training programs should be developed and instituted for both of these situations, including task-specific competency

assessments. The third critical educational issue is that of x-ray technology students conducting their clinical practicum in filmless radiology departments. Because they do not have the opportunity of learning how to produce quality clinical images utilizing film-screen radiography, it is necessary for medical physicists to establish ties with the training programs in order to modify curricula and clinical training to encompass both the analog and digital environments.

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