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The Quarterly of
Digital X-ray and PACS

Summer/Fall 2003

How to find your way
in digital radiography



Expert Interview:
Where soft-copy reading
technology is headed

News Bytes:
Pediatric hospital goes
to filmless operation

Technology Consult:
Are CR and DR competitive
or complementary technologies?

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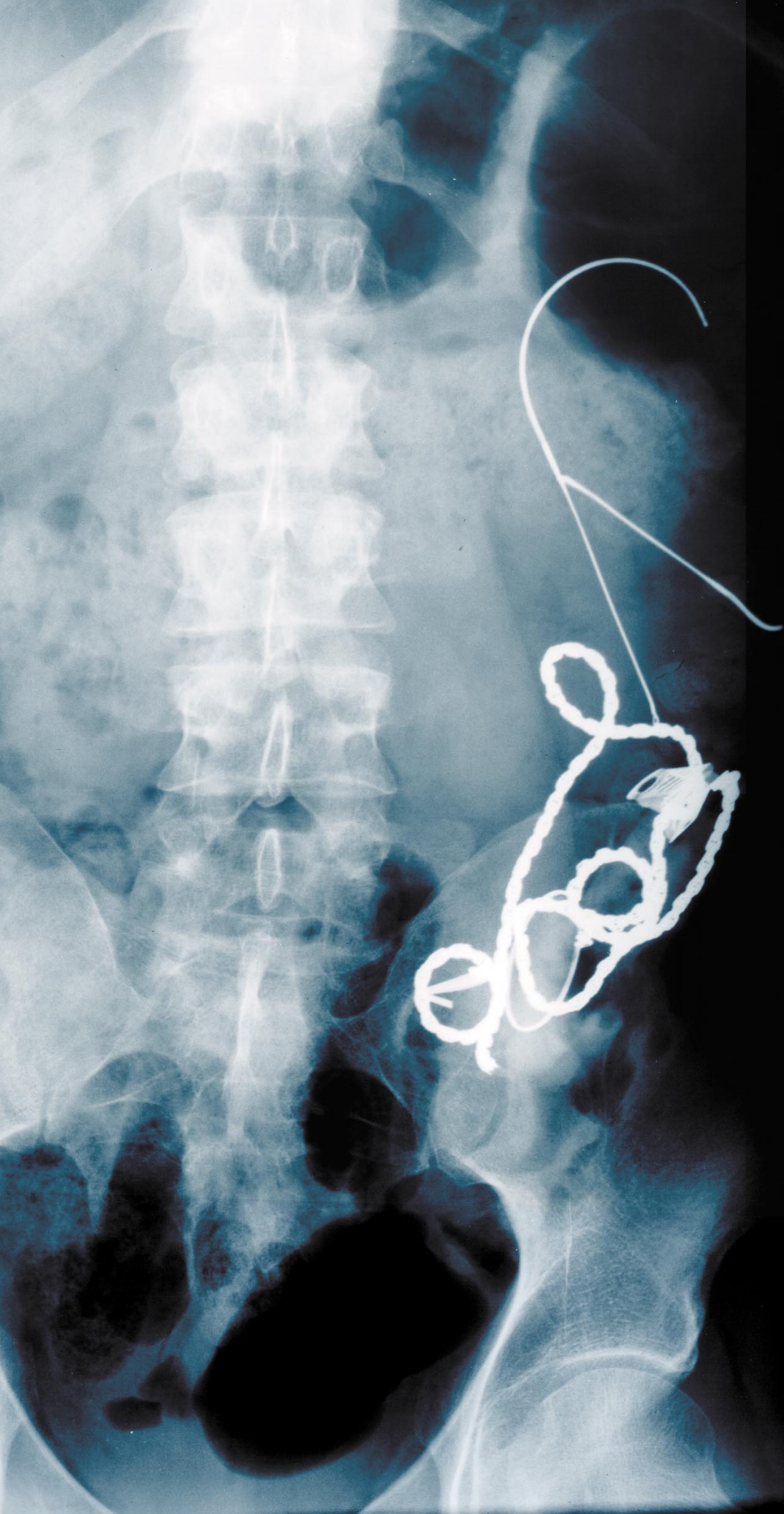


image showcase

New Way of Seeing Things

CR image of patient with a history of swallowing various items shows eyeglasses with chain, which caused an obstruction. The patient has recovered from surgery.

Thanks to the Radiology Department at St. Michael's Hospital in Sauk Centre, Minnesota, for providing this interesting case.

Do you have an interesting image to share with *Insights & Images*? If so, please submit the image, with a brief explanation to *Insights & Images*, Fujifilm Medical Systems USA, Inc., 419 West Ave., Stamford, CT 06902. If your image is selected for publication, Fuji will send you a free digital camera! Please obscure or remove all patient identification information.

Radiology's diversity of talent makes everyone look smarter

The thing I like most about the Society for Computer Applications in Radiology (SCAR) is that it's the unRSNA. How the two organizations conduct their annual meetings speaks volumes:

- SCAR convenes in a different venue every year, most of them interesting places, like Boston and Vancouver. The RSNA has dropped anchor in Chicago, which after a few years becomes a little stale.
- The SCAR program provides lots of face-time for outstanding residents and fellows, making it quirky and fresh. The RSNA's selection process may be based on merit, but it's almost devoid of surprises.
- SCAR encourages collaboration with industry, and invites them into full membership. RSNA's members are all radiologists and scientists, and maintains a more formal relationship with industry.

With maturation comes change, however. The SCAR membership is growing in number and diversity. The academic radiologists who in years past called most of the shots for the organization are now welcoming others into leadership. There is still the perception among community radiologists in general that academics exist primarily to bail them out of trouble. SCAR would do well to bring in more community radiologists, as it has lately with administrators, so they can help address the challenges that everyone in the specialty faces.

On display at the SCAR meeting this past June was the full scope of radiology's biggest problem: the growing morass of imaging data. This issue will only become more urgent as sites convert from screen-film radiology to digital x-ray systems, and mammography gradually digitizes. Given the multidisciplinary nature of its membership, SCAR is positioned to do much good for radiology. With most radiology sites still looking at x-rays as Roentgen did a century ago, it will take an unprecedented convergence of technological acumen, imagination, and organizational moxie for radiology to transform itself in time.

The focus and flexibility that SCAR can bring to this undertaking is invaluable. A coordinated effort is required to create the IT and workflow solutions needed; today's PACS are but a first step. The fact that academic radiologists are a key constituent but not the sole driver of SCAR is indeed fortunate. The axiom that none of us is as smart as all of us has never been truer, and should be remembered in trying to bring radiology through its current trial. ■



Peter L. Ogle
Editor
peterogle@qwest.net

Editorial Advisors

Lorraine D. Kelly, R.T.
Lahey Clinic, Burlington, MA

Bruce Reiner, M.D.
Baltimore VA Medical Center

Robert A. Schmidt, M.D.
University of Chicago

J. Anthony Seibert, Ph.D.
University of California at Davis, Sacramento

S. Jeff Shepard, M.S.
M.D. Anderson Cancer Center, Houston



Fujifilm Medical Systems USA, Inc.
419 West Avenue
Stamford, CT 06902
800/431-1850
www.fujimed.com

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Staff

Peter L. Ogle
Editor

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Art Director

Tony Ross
Creative Director

Larry Weiner
Account Executive

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Workflow optimization: Where soft-copy reading technology is headed

Interview with Fujifilm's Ken Shastri

When a radiology department first moves to PACS, it's typical for new users to cling to a film-based view of the universe. But by comparing everything they do to film, they sell short the productivity gains and other workflow benefits that soft-copy viewing offers.

In an interview with *Insights & Images*, Ken Shastri, the Director of Engineering at Fujifilm Medical Systems, explains what's in store for filmless radiology and how PACS may save the day for a medical specialty drowning in imaging data.

I&I: How would you sum up radiology's predicament?

Shastri: The reference models that many people use are still based on film, and they measure everything they do against it. New scanners are generating so much data these days that you can hardly think about reading and handling them on film. New strategies are needed just to review the data. We want to show what a filmless paradigm has to offer, and how much better it can respond to this challenge of data overload.



I&I: What hope do design advancements in PACS have to offer?

Shastri: One of the challenges engineers face is how to best design user interfaces. Now that we have all these images in digital format we have to provide physicians with new image processing tools so they can do their jobs more efficiently. It's become almost impossible to keep up using the primitive tools they have. They need more intelligent computers that don't demand too much interaction about the work that needs to be done. The people who read images need to stay at a very high level of thinking and let their computers take care of the details.

I&I: Where do we stand in this process of developing more intelligent systems?

Shastri: We're at the beginning of the process. Fuji will be introducing some new capabilities, one of which is called a reading protocol. The idea is for users to program the computer on how they intend to read cases so they can just click once to proceed to the next protocol step. This way they don't need to worry about other time-consuming tools. With just a single click the computer presents the case as it's programmed. This takes away a lot of the manual arrangement of current and comparison images.

Fuji is also investing a lot in disease-specific image processing. This would allow physicians to indicate, for example, when they can rule out a particular kind of disease. They can instruct their computer to display images so they can easily rule things out. The computer then becomes more knowledgeable about the clinical data it accumulates.



I&I: What other tools are being developed?

Shastri: There is a lot of research being done with computer-aided detection. One example is in mammography where physicians can make their own assessment of microcalcifications on an initial display. The physician might then request the computer to make its assessment of the mammogram based on an algorithm. This gives physicians an extra check of their work, or they can use the algorithm for preliminary screening so that CAD detects only abnormal cases, which are then directed to the radiologist.

Another area we're working on is in identifying results over time. Radiologists routinely measure various things, such as how fast a tumor is shrinking based on the type of treatment a patient is receiving. What the computer should be able to do, if the tumor has been identified in a prior study, is for those measurements to be automatically available in some intelligent form. To know that a tumor is shrinking in size at a rate of x percentage would be good to know. This can't be done right now. We want to take clinical information that is already available and correlate it and present it, and thus reduce the time spent going back to look for it.

I&I: Tell me about the work Fuji is doing in volume visualization.

Shastri: Volume visualization is a very important project for us. All the data that these new 16-slice CT scanners generate is essentially volume data. As you go from 50 slices to 1000 or so slices per study, the problem of visualization becomes very significant. We are developing some capabilities that easily allow the user to manipulate the volume and navigate quickly through any area of the volume and not have to pay the penalty of going through every slice of the study. CT slices are axial, but a more natural way of looking at certain volumes is in the coronal view. Creating a coronal



view takes some processing time, however, so our goal is to create the technology so users can easily manipulate the volume in real time, and then navigate through blood vessels or go through the volume at any angle or in any direction.

I&I: How does Fuji CR figure in?

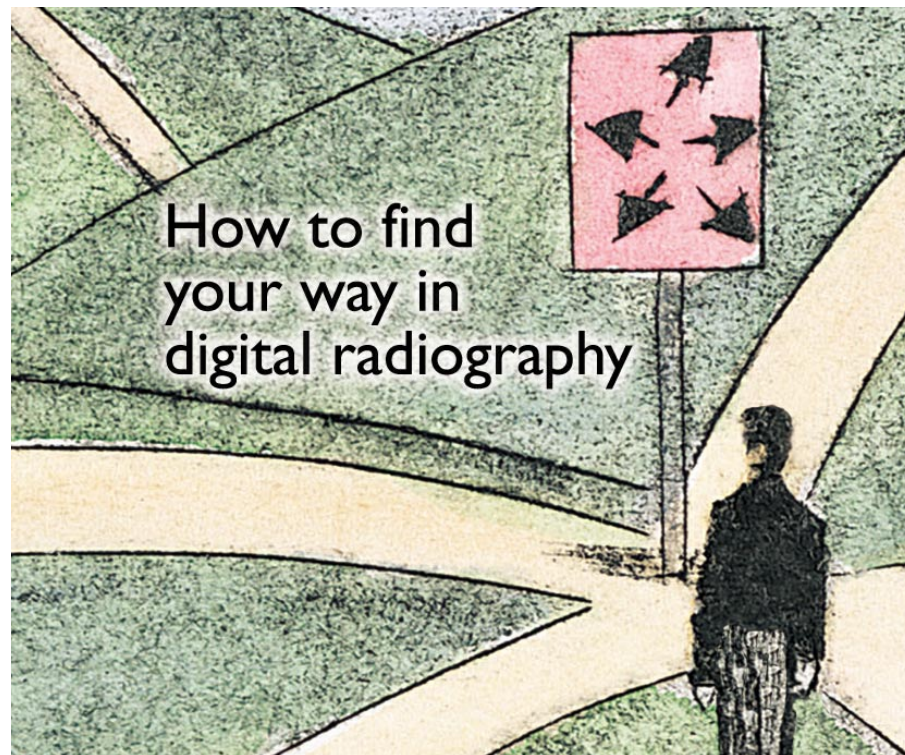
Shastri: CR is always one of our priorities, since Fuji developed CR and is a pioneer in this area. Where CR may be going is into new areas of image processing. We have a very close relationship with our research division in Japan, and they are continuing to develop new image processing algorithms to better enhance the quality of CR. Plus they're getting more into typical anatomical and diseases-specific processing. One of the interesting technologies they're working on is temporal subtraction, which allows an image to be subtracted from a prior image, which better highlights the pathology. There's continuous research in CR image processing.

I&I: Given the growing volume of image data, will radiology ever get off the treadmill it seems to be on?

Shastri: I think it's kind of an exciting treadmill. You get more energy as you're on it—there's just so much to do. In projection x-ray there are going to be 50-micron

mammography studies, which have very large amounts of data, so processing power and capabilities are going to have to quadruple to handle them. Image fusion is another area of interest for us. You're starting to see PET and CT images fused together, for example. There are lots of opportunities in learning how to deal with these images, and in helping people extract

the information they need from them. This is where everything is headed: How can we automatically extract the information that's relevant for what the user is trying to do? ■



There's no denying the efficiencies of digital radiography, regardless of which competing technology you pick

By J. Anthony Seibert, Ph.D.

Dr. Seibert is a Professor of Radiology at the University of California Davis Medical Center in Sacramento.

Digital radiography plays a crucial role in the design and implementation of an all-electronic imaging department. There are many choices to make about this technology if you are to succeed in achieving the workflow efficiencies and the high-quality service that digital radiography affords.

With the notable exception of radiography, all imaging modalities are inherently digital and can be integrated with relative ease into a PACS. Radiography is still film-based at most locations and thus represents a major gap in the implementation of a PACS. In addition to being largely analog, radiography far exceeds other modalities in total imaging volume, although this fraction (60% to 65%) is in decline as cross-sectional imaging continues to evolve. It is thus clear that to fully realize the potential of PACS you must have a digital radiography strategy that is appropriate to your site.

Three key questions to ask prior to migration to digital radiography are:

1. What digital systems possess the imaging capabilities you need to replace screen-film imaging?
2. What are the respective advantages, limitations, and costs of these CR and DR options?
3. How would these systems fit into your plans for an all-electronic department?

Before addressing these questions we must first ask why we should bother with digital imaging in the first place. The answer is quite simply that efficiency improves when all imaging data is digital. Because of how digital images are acquired, you can gain efficiencies by 1) reducing image retakes caused by under or overexposures, 2) allowing for image processing that can improve image quality, 3) assisting radiologists in making differential diagnoses, and 4) providing exact copies of images for distribution to referring physicians and other healthcare providers.

Until recently, computed radiography (CR) was the only practical and affordable form of digital radiography. It was generally interfaced to PACS that were confined to radiology reading areas and that couldn't easily distribute images anywhere else. Today, there are many types of digital radiography devices, including CR and several types of direct-display digital radiography (DR). The challenge for users is to determine what best fits their imaging requirements. While upfront costs are important, you must also consider patient throughput, system maintenance costs, positioning capabilities, and other factors that contribute to overall operational expenses. This means there is no single "best" system for everyone.

PACS have also changed dramatically in the past decade, most notably with web-based distribution of images. In

addition, commercial off-the-shelf hardware for workstations and display devices has dramatically lowered costs and spurred interest in PACS.

How CR Works

In terms of data handling and display, CR and DR are similar yet distinct. CR uses a digital detector that closely emulates the screen-film detector and that requires substantial handling, but which also provides the greatest flexibility in positioning. Separate processing in a CR reader is required. DR, on the other hand, acquires and subsequently processes and displays images without user intervention. These definitions are somewhat arbitrary, as there are some advanced CR systems with automated capabilities.

CR is by far the most common form of digital radiography. While CR has existed for 20 years, it was not until the early 1990s that the costs and the size of cassette readers came down sufficiently to make CR feasible for portable imaging and trauma care. The ability to drop CR into an existing screen-film infrastructure is perhaps its best attribute. This flexibility means that a single reader and several imaging cassettes can service several rooms simultaneously, making for a cost-effective and rapid implementation of digital radiography. The labor needed to handle the cassettes and to process them in a separate external reader may also be its greatest shortcoming, however.

The CR detector is comprised of a cassette made of a low attenuating carbon-fiber plastic, which houses a photo-stimulable storage phosphor (PSP) imaging plate. The imaging plate itself is not particularly light sensitive, and its signal will fade with exposure to high intensity white light. This is how the plate can be re-used after an x-ray exposure. When exposed to x-rays, the barium fluorobromide phosphor absorbs the x-ray energy and has a proportional number of electrons injected into a crystal "trap" of higher energy. Laser light is used to excite the electrons from the trap to a higher energy level, which then fall back to the ground state energy, thus releasing blue light photons that are captured by a light collection guide and converted into a corresponding digital signal.

There are several cassette sizes that are adaptable to specific exams. This is an advantage for positioning and acquiring image data that more closely matches the field-of-view requirements of the exam being performed.

The CR detector is used like a screen-film detector, with only minor adjustments in techniques required. In terms of x-ray detection efficiency and noise, it is classified as a

"200-speed" system for typical adult imaging procedures. It can be used over a range of system speeds from 50 to 1000 and beyond, which makes it flexible and tunable to a specific acquisition procedure.

The CR reader extracts and processes the latent image from the imaging plate and formats the information into a digital image matrix. The raw data is then transferred to a workstation for subsequent image processing, including contrast and edge enhancement. While this is usually done automatically, the technologist can intervene to modify the presentation, as necessary. Once the data is verified and checked for quality, images are forwarded to the PACS workstation using the DICOM standard, and images are displayed. Film printing may be required in PACS that are not fully deployed, but this practice should be eliminated or reduced in volume to capture the efficiency gains for which PACS is generally purchased in the first place.



CR systems continue to progress technologically with smaller footprints, faster readout, lower costs and higher detection efficiency detectors. (For more information about CR technology, visit Fujifilm Medical Systems' web site at www.fujimed.com).

How DR Works

Alternatives to standard CR detector technology is an automated CR changer, which scans a fixed imaging plate in a manner similar to most DR devices, or the purchase of DR technology itself. The obvious benefit of DR is the "direct" acquisition of the image without user intervention, which frees a substantial portion of the technologist's time otherwise required to handle and process CR cassettes. DR costs are typically much higher than CR, and usually require the purchase of an x-ray system as well.

DR exceeds CR in system speed and detection efficiency, especially those systems that employ thin film transistor (TFT) flat panels. Advances in system designs and x-ray converter materials and readout methods are closing the gap among digital detectors in terms of detection efficiency. While patient dose is an important consideration, it is more important to obtain images of the appropriate quality and detail, which most detectors can deliver, albeit at a slightly higher dose for a given signal-to-noise ratio.

The primary categories of DR detectors are charge-coupled device (CCD), complementary metal oxide

semiconductor (CMOS), and flat panels. There are notable differences among these detectors in terms of signal acquisition, such as line-scan CCD arrays versus fully two-dimensional acquisition CCDs with one or several CCD “chips” for image acquisition and conversion.

From a physics standpoint, DR detections can be further subdivided into “indirect” and “direct” acquisition of the x-rays transmitted through the patient. An indirect DR detector first converts x-ray photons into light photons through an absorption and conversion process, with the emitted light distribution then converted into a proportional charge via a photodiode detector. A direct detector eliminates the x-ray-to-light conversion process through the use of a semiconductor detector that directly converts x-rays into a corresponding electronic charge.

Most of the interest in DR detectors is currently focused on systems based on thin film transistor (TFT) technology. TFT detectors have arisen out of the multibillion dollar investment in TFT displays, which have produced a large field of view display that produces a transmitted light pattern through LCD cells that can change their transmissive characteristics based upon input signals. The active matrix detector uses an array of TFT switches that combine with storage capacitors to acquire locally generated charges resulting from the absorption of x-rays. Image acquisition is performed with active readout capabilities and externalized electronics without user intervention. The active matrix array detector elements for conventional radiography have a size range of 100 to 200 microns, which is similar to the effective pixel size of other digital detectors based upon CR or CCD technologies.

The indirect and direct TFT detectors look alike, and perform similarly in terms of image quality, system speed, and positioning flexibility. They typically find a home in a dedicated chest room or an outpatient environment that requires high throughput and minimal positioning. Many improvements are overcoming positioning problems with interesting equipment designs, automated positioning aids, and multiple detectors per room. Although DR systems in general have higher initial costs than CR, the efficiency provided by direct acquisition and display and increased patient throughput can potentially result in reduced long-term costs.

Complementary Technologies

The digital acquisition, display and archiving of imaging data are here to stay. Screen-film systems will soon be replaced at those institutions that have chosen to adopt PACS for reasons of efficiency, patient care and long-term cost. This conversion is an imperative for nearly every-

one, including those who mistakenly believe that film and digital capability can cost-effectively coexist. For those not yet ready for full-blown digital radiography, the advantage in waiting is watching technology improve and costs decline. To decide against a complete digital conversion, however, is to consign oneself to more work, more cost, more frustration, and more heartache.

It should be noted that going digital is not a panacea. The system you install is only as good as the weakest link in its imaging chain. When you buy a digital radiography system, be sure that funding is also arranged for preventive maintenance, software upgrades, continuous quality control, and quality control phantoms. The purchase of a CR and/or DR system does not conclude your investment. A long-term commitment to service and quality from both buyer and seller is necessary to ensure the success of this endeavor.

As has been noted, there are several pathways and systems that can provide the needed capabilities to implement digital radiography. It is imperative that the correct system be chosen based on needs matched to specifications. Right now, conventional CR is the most common and cost-effective solution for most sites. DR and possibly automated CR, however, can be more cost-effective when you consider throughput enhancement and the long-term costs/benefits related to such intangible issues as ease of use, user confidence, and technological leadership in the imaging community. One must also consider construction and installation costs in selecting the appropriate technology.

For the foreseeable future, the best approach to digital radiography for most sites is likely to be either CR alone or a hybrid mix of CR and DR systems. By assessing your imaging requirements, the types of exams your facility performs and its throughput requirements, your existing equipment, PACS interface and modality worklist needs, workflow enhancements and other issues, it should become evident which approach is best for you. ■

Pros

- Flexibility of use
- Proven technology
- Range of systems and costs to match needs

Cons

- Extends screen-film paradigm
- Limited DQE (higher dose for same SNR)
- Issues with integration/interfacing

Pros

- Acquire and display (no extra steps)
- High DQE (better dose efficiency)
- Superior integration/interfacing

Cons

- Single room use only
- New technology
- Higher costs for detector and x-ray source

Quebec's largest pediatric hospital goes to filmless operation

A Synapse PACS from Fuji has allowed Hôpital Sainte-Justine in Montreal to become one of the largest pediatric hospitals in North America to shift to filmless operation.

A 350-bed affiliate of the University of Montreal, the facility is Quebec's largest pediatric hospital. It conducts more than 140,000 imaging exams annually in radiology and nuclear medicine, as well as 18,000 obstetrical ultrasounds. Imaging modalities include an MR unit, CT scanner, angiographic interventional suite, digital fluoroscopy room, nine ultrasound imagers, two gamma cameras, and six x-ray rooms, one of which houses a Fuji specialized digital scoliosis unit.

All x-ray rooms are equipped with Fuji XG-1 readers, and all modalities benefit from worklists.

The PACS project, which started up last September, was jointly planned by the hospital's radiology department staff, biomedical engineers and technicians, and information and telecommunication personnel. Direction was provided by the hospital's professional services group and various clinicians, in partnership with the Christie Group, a Canadian medical technology distributor.

Hôpital Sainte-Justine provided an opportunity for three information systems to be integrated into a filmless environment: Synapse PACS from Fuji, RadImage RIS from Artefact, and DigiDictate computerized dictation from Crescendo. The interface between the PACS and RIS systems is bi-directional.

"Ste-Justine has been completely filmless now for the last several months and the system is working very well," said staff radiologist Dr. Denis Filiatrault. "This is the first step for Hôpital Sainte-Justine in establishing a network between referring hospitals near and far from Montreal, and which will eventually be extended to all of Quebec." ■

Improved productivity alone can't justify DR's higher cost at lower volume sites

Timing studies conducted at the University of California at San Francisco have shown that a DR dedicated chest unit had higher patient throughput than CR in an outpatient environment, but that improved productivity alone cannot justify DR's high cost relative to CR in lower volume settings.

The study, reported by Katherine P. Andriole, Ph.D., in the *Journal of Digital Imaging*, included two-view chest x-ray studies on about 50 patients per day. While both CR and DR exceeded the patient throughput of screen-film exams, DR's advantage over CR was not statistically significant. Patients can be released from the radiology department sooner when either digital modality is used in place of a screen-film system, noted Andriole, an associate professor of radiology at UCSF.

In addition, the digital units are perceived by technologists to improve workflow, and to be easier-to-use and more reliable. CR and DR used with a PACS are about equal at increasing the overall speed-of-service from exam ordering to diagnosis, she noted.

The time saved with DR may not justify its higher cost over CR. The cost justification for DR appears to be tied predominately to high patient volume and continuous rather than spurious patterns of use, she said. ■

The PACS network is distributed to more than 80 locations in the hospital. There are stations in the emergency area, intensive care units, neonatology and pediatrics, oncology, urology, orthopedics, operating room suites, and various clinics and hospital units.

All exams are available online for one year and will then be stored on DVD for 21 years, as required by Canadian law.



Hôpital Sainte-Justine provided an opportunity for three information systems to be integrated into a filmless environment, noted staff radiologist Dr. Denis Filiatrault, shown here at a Synapse workstation.

CR vs. DR: Competitive or complementary technologies?

By Michael J. Cannavo

The author is president of Image Management Consultants of Winter Springs, FL. He can be contacted at pacsman@ix.netcom.com

Healthcare facilities embarking on PACS and wanting to go completely filmless are often faced with a choice between computed radiography (CR) and direct radiography (DR). While both technologies have their virtues, it's not always easy to determine which is best in a particular setting. A strategy for converting to digital x-ray should take into account the clinical applications for which the modality will be used, image mix, trends in procedure volume, staffing, and room use.

For radiologists, the choice between CR and DR is largely based on technical factors, most notably image quality. Each technology has its supporters and detractors. There are also camps that endorse the competing DR technologies—"direct" amorphous silicon systems versus "analog" CCD-based systems—just as there are devotees of a particular CR vendor's line pair resolution, post-processing algorithms, and technologist interface.

For chief financial officers, however, the purchasing decision usually skips right past the technology and comes down to money. Let me explain.

The painful fact is there's no difference in reimbursement between radiographs made by a conventional film-based system and those made by CR or DR. It's obvious, therefore, that the most cost-effective digital x-ray system is the one that usually gets the nod. But determining cost-effectiveness can be tricky. While DR can legitimately boast higher throughput based on enhancements in technologist workflow, CR with at least moderate throughput can be shared between two rooms, allowing for a major reduction in per-room costs. This is a critical factor for most radiology departments. Five CR units at a cost of \$200,000 each (\$1 million total) can handle up

to 10 rooms (if adjacent to one another) and easily take the place of \$4 million worth of dedicated DR rooms (10 systems at \$400,000 each). Service costs are also reduced with CR.

DR supporters note that DR can shave two minutes or more from a 10-minute general x-ray exam due to process changes over CR or analog film. Let's examine this argument. If you reduced FTEs by 20% (two staff positions), you could possibly save up to \$100,000 in salaries per year. This is a far cry from the \$3 million disparity in the purchase price between CR and DR described in the scenario above. Even if we were to translate the two minutes in potential time-savings into additional revenue (representing a 20% increase in general radiographic volume), DR would still not break even. This assumes the facility does 100,000 general radiographic (GR) procedures per year and

has net collected revenue for the technical component of \$45 per study. This assumption also requires the facility to convert 100% of that saved time into procedures—which never happens—and to show a 20% growth rate for GR procedures. Unfortunately, few facilities are experiencing growth in GR. Volume has actually declined slightly at most facilities as new applications for MR and CT continue to emerge.

CR is typically a hands-down favorite from an economic standpoint, given that a CR system is priced at less than half the cost of a dedicated DR room and can be shared by two rooms. Multiple CRs in a department also provide for the redundancy needed to maintain operational efficiency and security. Many CR units provide higher throughput than the rooms in which they are installed can handle, so having available redundancy raises the confidence of end-users.



A key consideration in selecting a digital x-ray system should be the technologist interface. A well-designed interface can reduce the throughput differential between CR and DR by 50% or more, and save up to three minutes per study over conventional film processing. This is a critical factor, given the persistent technologist shortage and the need to optimize existing technologist resources. The interface varies dramatically between systems, however, so it's important to have the chief technologist on the CR evaluation team to provide input on this.

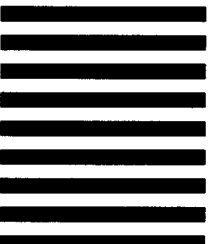
So where do CR and DR fit, respectively, in the PACS environment? DR is best used in high throughput settings where several patients per hour can be accommodated using a table or dedicated chest unit.

CR can be used in the same settings as DR, with the added flexibility of performing x-rays from remote locations, such as in the emergency department, and doing exams that cannot be done with fixed equipment, such as extremities studies.

If additional reimbursement for DR were made available, the argument between CR and DR would become more technical than cost-related. Until this happens, however, CR appears to provide much better value for those choosing digital x-ray technology. ■



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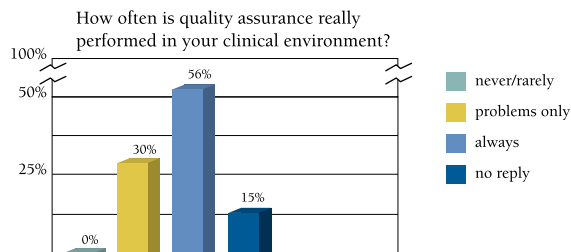
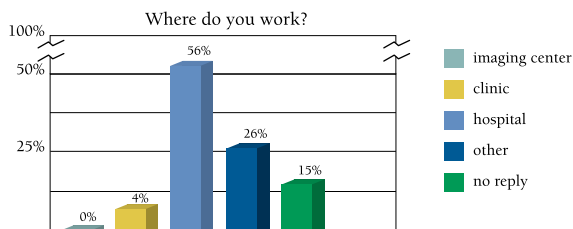
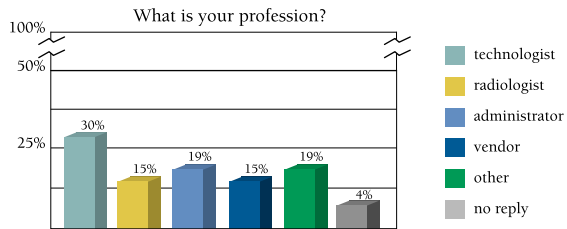
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readers poll

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Do you have CR at your facility? Yes No

Do you have DR at your facility? Yes No

Which technology do you expect to be more important in the future?

CR DR Both technologies will be important

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