Digital imaging makes inroads in orthopedics

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The Oakland Athletics medical and training staff, preparing for spring training prior to the 2004 baseball season, considered the options for obtaining and reviewing radiographic studies. In past seasons, players went by van, five or so at a time, to local imaging facilities and offices in Phoenix and then returned to training. The process was repeated daily until examinations for the 80 or so players were completed. The films were interpreted, filed, or retained at the spring training site for later review by the orthopedists and medical staff and then traveled with the A's to California for the start of the season.

The team orthopedist's private office had recently converted to digital imaging, and the company providing the filmless system was asked about the feasibility of digitally acquiring and transmitting the images obtained in Phoenix for review in Oakland or at home. A local mobile x-ray operator using a digital imaging system in Phoenix similar to the one installed in the orthopedist's Oakland office agreed to come to the spring training site, and 11 radiographic procedures were performed in one morning.

The images were then transmitted to local radiologists as well as to the orthopedic offices in Oakland and nearby San Ramon. The team orthopedist was able to review the images the next morning when he came in to the office and made immediate determinations as to each player's status and what other examinations might be needed. All this took place within one day. No player had to leave the training facility. The training staff had all the images available for the rest of the season on their laptops and on CDs. The power of digital imaging and
PACS brought improved efficiency, patient convenience, service, and cost savings (Figure 2).

**FILMLESS IN ORTHOPEDICS**

In increasing numbers, orthopedic offices are acquiring and operating imaging equipment. Any assessment of the requirements for a filmless imaging system in orthopedic offices requires understanding of this trend. With the emergence of MRI, new techniques for joint replacement, and less invasive joint disorder examinations such as arthroscopy, orthopedic surgeons rely more heavily than ever on imaging procedures to assess their patients.

Their offices now serve as mini-imaging centers. More efficient patient management that avoids referrals to remote facilities and captures the technical revenues from these examinations has accelerated this trend. Patient acceptance is excellent. Patients can often have imaging procedures performed and reviewed and see their treating physician all in one visit.

For optimal performance, the systems used for converting orthopedic offices to filmless must have attributes similar to those that exist in the PACS installed in radiology departments and imaging centers:

- User-friendly software and display devices;
- PC-based platform and software compatible with business systems already in place;
- complete multimodality viewing on all workstations, including tiling or stack mode review of MR examinations;
- immediate availability of images via wired or wireless networks for orthopedists and patient review;
- ability to transmit images offsite for consultation and primary interpretation by radiologists;
- capability to e-mail images from all workstations to referring physicians and other necessary individuals;
- ability to burn CDs of imaging studies for referring physicians, patients, review in the operating room, conferences, and research collaborations;
- Health Insurance Portability and Accountability Act compliance and security of images and patient information; and
- affordability, with costs comparable to hard-copy screen-film-based studies.

**ORTHOPEDICS VS. RADIOLOGY**
Orthopedic surgeons face extremely heavy caseloads in their days in the clinic, and workflow must be efficient. If imaging procedures are required, these need to be available at the time the orthopedic surgeon sees the patient and discusses treatment options and progress.

The relatively rigid scheduling of patients common in hospitals, based on staffing and radiologist availability, is not acceptable in the orthopedic office. Patients undergoing imaging procedures are generally being seen by their physician on the same visit, most often immediately following the completion of the imaging procedure. When the patient is in the examination room, the images, as well as related prior exams, need to be available. This places a different demand on the x-ray unit.

Almost every imaging procedure performed in an orthopedic office is reviewed with the patient. This custom requires a means for transmitting the images throughout the clinic or office. Ethernet and wireless connections facilitate image delivery and make the ease of viewing software critical. Speed of transmission and immediate patient access for viewing images are less critical in radiology departments. Similarly, radiology departments generally have in place sophisticated infrastructure from decades of filmless experience with nuclear medicine and CT and MR devices, along with backup technologists and staff familiar with these systems. No such prior experience is common in orthopedic offices.

TECHNOLOGY CHOICES

When orthopedic surgeons' offices pursue the transition to filmless imaging, several options require consideration. In addition to selecting the appropriate partner, these surgeons and their staff also face a variety of technology choices. The primary alternatives for converting offices from hard-copy screen-film to soft-copy filmless are direct radiography and computed radiography. CR devices use phosphorous plates in cassette systems, while DR uses a noncassette image receptor, such as amorphous selenium or silicon, or CCD detectors.

There is no longer any debate over the quality of images produced from either digital technique in standard radiographic examinations. The decision should be based solely upon the functionality of the technology and its cost-effectiveness in a particular practice. The chief attribute of the more expensive full-room conversion involved with DR is the reduction in the number of steps required in the radiographic process and, debatably, superior image quality compared with CR.

We find that while the higher DQE of DR produces less noise in the image for a given dose, CR and DR produce equivalent images, assuming dose adjustments are made for each technique. Both CR and DR produce clinically acceptable images, in most cases superior to screen-film, especially when employing the inherent advantages of digital imaging: enhancements such as
window and level (adjustments of brightness and contrast), magnification and zoom features, onscreen measurements, and angle calculations.

DR has been touted as leading to improved workflow and throughput. The issue of workflow and throughput was largely anecdotal until recently, when studies emerged specifically addressing the subject (Reiner, Andriole). These studies performed at several of the most prestigious institutions by thought leaders in digital imaging and PACS have concluded that, except in unusually high utilization environments (facilities operating at 80% or greater capacity utilization), DR has no economic, workflow, or throughput advantage over CR.

All these studies indicate that, while DR is technologically more compelling, when technologist productivity, equipment purchase, maintenance costs, procedure volumes, and capacity utilization are considered, the productivity advantages of DR are disproportionately offset by its associated higher equipment purchase and maintenance costs. The cost differential can amount to $50,000 to $75,000 per year (Reiner).

Features and benefits available on the preferred digital imaging systems for orthopedic offices include electronic preoperative planning tools, such as implant templating and "stitching." This creates long films from overlapping or separate images that are seamlessly fused electronically for full leg and spine viewing and subsequent measurement of Cobb angle, leg length, and other calculations (Figure 1). A variety of packages can perform this function, and the ones that employ anatomically based algorithms are invariably better for the user.

Similarly, the ability to perform technique-related window and level adjustments on the images prior to stitching is extremely desirable. The cost benefit of electronic templating and stitching has yet to be validated, but they clearly provide for a permanent archived record of both the native and measured images, and image quality is improved over conventional screen-film images. Attention to magnification and calibration of images is crucial to this process, and the more advanced software packages address this need.

Another important factor for orthopedic offices in making the CR versus DR decision is the relatively restricted positioning imposed by fixed DR detectors. In an orthopedic setting, certain specialized views, such as Merchant, Sunrise, and curved cassette views (e.g., shoulders), can readily be achieved with CR plates and readers but not DR devices.

The perception that CR is yesterday's technology has not proven accurate. Institutions and clinics in the U.S., including the most progressive and technologically advanced, continue to acquire CR devices over DR by a factor of more than seven to one. Advances in plate and CR reader technology, as with DR receptor technology, continue to improve system performance.
and speed. The decision of DR or CR is an economic one best addressed by each institution and its vendor partner, based on local cost issues and operational demands. The overall economic investment is weighted strongly toward CR in most clinical settings.

INTEGRATION WITH EMR

Virtually all orthopedic offices considering filmless imaging simultaneously evaluate the benefits of the electronic medical record. The conversion to a paperless office has been the subject of recent attention from both the government and the lay press. Studies have begun to demonstrate the cost-effectiveness of this technology as well as the benefits to patient care. It is clear that a paperless conversion will go hand in hand with the filmless office, and that these technologies and systems will need to be integrated. The degree of integration can range from straightforward sharing of header file demographic information between the systems or use of simple work list management to full consolidation wherein film files reside in the same folder on a desktop in the office.

Here again, as with the CR/DR debate, cost of the integration and functionality will be the primary drivers. In this environment, Web-based systems seem to have great appeal, as the size and complexity of image files dwarf the capacity and speed of the retrieval requirements for hard drive and onsite media-based archival systems in the larger, busiest offices. Both EMR and digital imaging implementers are continuously working on the ultimate goal of the fully integrated system. Until that effort is completed, toggling back and forth between EMR and digital imaging software programs on the desktop affords a cost-effective method for implementing a paperless and filmless office.

ECONOMIC CONSIDERATIONS

The economic justification for converting orthopedic offices from film to filmless depends heavily on the nature of the practice, its volume, and specific workflow issues. To make a meaningful comparison of the costs of film-based and filmless systems, the office managers must understand its fixed and variable costs, including storage, number of retakes and lost films, retrieval, and staff productivity, as well as other hard costs associated with film-based technology, such as film, chemicals, folders, stickers, and labels (Table 1).

Orthopedic offices must also compare the tax advantages and incentives of capital equipment acquisition versus the more familiar operating expenses associated with disposables and consumables. These models have been refined, and breakeven analysis and return on investment calculations are important considerations. It is in these models that the workflow and throughput determinations discussed have the greatest impact on economic decisions in most offices (Table 2).
IMPLICATIONS

While we recognize the emotional impact of economic, self-referral, and turf issues, orthopedic surgeons are employing more and more imaging procedures in their practices and increasingly insourcing these services. This trend will undoubtedly continue, and imaging by nonimaging specialists has become a reality in contemporary healthcare delivery. We estimate, for example, that there are 80,000-plus offices in the U.S. performing routine nondental radiographic procedures on a daily basis. Orthopedic offices constitute a large portion of those offices, performing far more procedures than any of the other categories. As a result, many radiology groups and practices are dedicated specifically to remote interpretation of studies generated outside of radiology departments and practices.

The Internet and broadband access to images permit faster turnaround and availability of specialists particularly skilled in musculoskeletal imaging, especially MRI, as well as projection images. Local radiology groups have begun to accept the "half a loaf" philosophy of interpreting the images while not participating in the technical revenues. The decision of an orthopedic group to contract with local radiology groups has merit. It creates a tighter bond between the orthopedic group and its radiology associates and encourages a more collegial relationship, as many of the patients will be hospitalized and require imaging services from the local group.

Remote interpretations have typically featured specialists with outstanding credentials in musculoskeletal imaging, a luxury often not afforded by smaller radiology groups and practices. Service (fast, accurate, and clear reports of procedures) and price influence the decision about which individual or group will be selected to interpret the studies obtained in orthopedic offices.

Increasingly, orthopedic surgeons' offices also employ part-time and full-time radiologists in increasing numbers. This decision is justified, as some groups are now performing well over 3000 MRI and 50,000 projection-imaging procedures per year. The in-office orthopedic surgery imaging market will continue to grow as much as 20% per year, according to some estimates, and radiology groups need to make a conscious decision to be in or out of this part of the imaging business. Pretending that it does not exist will not be in the best interest of either the practice or patients.

It is always treacherous to predict the future in diagnostic imaging, healthcare, or technology. But it is clear that existing modalities are finding their way into orthopedic practices at a rapid rate. Plain-film (now filmless) imaging, MRI, CT, and DXA are common in most large orthopedic practices and moving into smaller ones. New software for advanced image processing, 3D reconstructions, higher resolution imaging, and functional evaluation of musculoskeletal structures and diseases is already present in many academic and clinical practices.
The advent of broadband communications and user-friendly software leads to more efficient and higher quality orthopedic practice. Integration of filmless capability with paperless EMR systems as part of healthcare delivery will be the major step forward for orthopedic practices in the next five years, and it will fulfill the mandate of presidential and congressional proclamations that EMR will be the standard in medical practice.

Orthopedic surgeons and their offices are actively engaged in the conversion to filmless environments. The challenge for industry and clinical leaders is to make the adoption of this compelling technology affordable, reliable, user-friendly, and efficient.

The imaging community will include both radiologists and nonradiologists, and their cooperative spirit and relationships will create a better, more cost-effective system for patients. That should be the goal of all participants in the pursuit of the paperless and filmless healthcare enterprise.

**Bibliography**


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