Computers in Radiology

Technologists’ Productivity When Using PACS: Comparison of Film-Based Versus Filmless Radiography

**OBJECTIVE.** The objective of this study was to assess the impact of filmless operation and computed radiography on technologists’ examination times compared with conventional film-based operation and film-screen radiography.

**CONCLUSION.** Compared with conventional film-screen operation, filmless operation using computed radiography was associated with a significant decrease in technologist examination times in the performance of general radiographic examinations. This decrease in technologist examination times in a filmless environment offers the potential for increased productivity with resulting personnel savings and improved operational efficiency.

Diagnostic imaging departments have a dual mission that requires them to maintain the highest quality and consistency of patient care while maximizing efficiency and productivity. With the increasing financial pressures placed on imaging providers, these goals often become mutually exclusive. Decreased reimbursement rates, increased penetration of managed care, and heightened competition among diagnostic imaging providers (both in and outside of the hospital) have resulted in greater pressure on radiology administrators to decrease personnel and operational expenses without compromising the quality and quantity of imaging services.

To facilitate these changes, administrators have placed greater emphasis on increasing productivity in the imaging department. Because most hospitals do not employ radiologists, the primary focus of productivity enhancements has been on technologists. This strategy takes on even greater importance in the current job marketplace given the extreme shortage of qualified imaging technologists. In a recently published national study conducted by the American Healthcare Radiology Administrators [1], only 42% of hospital-based radiology administrators reported adequate technologist staffing, with an average of 2.8 full-time equivalent technologist positions unfilled for general radiography alone.

Although work flow optimization has been well described in the industrial engineering literature [2], little to date has been published in the radiology literature. Survey data published by the American Healthcare Radiology Administrators [1, 3] describe national norms for technologist productivity in terms of the number of examinations performed by a full-time equivalent technologist, but these surveys do not evaluate the individual variables contributing to productivity measures. Although three groups of investigators [4–6] have attempted to estimate the average time for various technologist functions in the performance of general radiographic examinations, these reported procedure times vary by as much as 300% [7] because of a number of difficult-to-control variables including uneven and unpredictable patient flow; technologist fatigue;
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Materials and Methods

Prospective time-motion studies were performed at three medical centers during a 1-week period. Examination time was defined as the time from patient arrival in the examination room to the time completed images were ready for radiologist interpretation; this period was timed by independent observers using a stopwatch (Fig. 1). Any delays or interruptions during the course of each study were recorded and included in the data analysis. Data were recorded during routine weekday hours of operation, and technologists were aware that a timing study was being performed.

The two commonly performed types of radiographic examinations chosen for evaluation were chest (two views) and orthopedic examinations of the spine (three to five views). Portable examinations were excluded from the study because of the large variability in work flow steps for these studies among and within the three facilities. Conventional film-screen radiography was performed at two of the three study institutions (Fort Howard and Philadelphia Veterans Affairs Medical Centers), and filmless operation using computed radiography was used at a single study institution (Baltimore Veterans Affairs Medical Center).

For the film-based operation at the Fort Howard center, film-screen cassettes (Curix; Agfa, Ridgefield Park, NJ) were manually developed using a conventional processor (RP Xomat [model M6B]; Eastman Kodak, Rochester, NY). For the film-based operation at the Philadelphia center, film-screen cassettes were developed using a daylight processor (ML 700; Eastman Kodak). For the filmless operation at the Baltimore center, computed radiography was performed using a plate reader (AC-3; Fuji Medical Systems, Stamford, CT) that is interfaced with the hospital and radiology information systems (Veterans Health Information Systems and Technology Architecture) and a commercial PACS (General Electric Medical Systems, Milwaukee, WI).

The prospective time measurements obtained at the study institutions were correlated with the national standards for workload in a film-based department [9]. The two film-based institutions were chosen because of their similarities in technologist staffing, patient demographics, and location. The Philadelphia and Baltimore centers are also comparable in examination volume, modality mix, and presence of a strong academic affiliation.

Statistical analysis was performed using both one- and two-way analyses of variance to evaluate differences in technologist examination time among the three study institutions, between film-based and filmless operations, and between the two types of radiographic examinations evaluated.

Results

Prospective time measurements revealed significant time savings for filmless operation (Table 1) for both categories of general radiographic examinations evaluated ($p < 0.001$).

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**Fig. 1.** —Schematic drawing shows differences in work flow among imaging departments using conventional film-screen radiography with a conventional processor, conventional film-screen radiography with a daylight processor, and filmless computed radiography. Number of steps is reduced to four with filmless computed radiography because steps related to film processing and handling can be eliminated.
For posteroanterior and lateral chest radiographic examinations, significant differences were found when comparing the filmless study site with the two film-based sites ($p < 0.001$). A mean time savings of 3.4 min (31%) was observed when comparing examination times at the film-based Fort Howard center with those at the filmless center. A greater mean time savings of 6.6 min (47%) was observed when comparing the film-based Philadelphia center with the filmless center.

The mean examination time required for a posteroanterior and lateral chest study at the Fort Howard center was similar to the national norm [9], which is approximately 10 min, whereas the mean examination time at the Philadelphia facility was substantially longer than the national average. The examination time at the filmless medical center was substantially lower than the national average.

The difference in the mean examination time for imaging the spine was also significant when comparing film with filmless operations ($p < 0.001$). A mean time savings of 5.1 min (37%) was observed when comparing film-based operation at the Fort Howard center with filmless operation at the Baltimore center. This mean time-saving with filmless operation was significantly greater when comparing the Baltimore and Philadelphia centers, with a 12.0 min (58%) savings.

The examination times from the film-based institutions are comparable to the national norms, which have been reported as ranging from 11 to 15 min for a three-view cervical spine study, 15–22 min for a five-view cervical spine examination, 8–15 min for a three-view lumbar spine study, and 20–30 min for a five-view lumbar spine examination. The lower ends of these ranges refer to ambulatory patients, whereas the upper ends refer to nonambulatory patients. The combined examination time for all spine studies at the filmless Baltimore center was at the bottom of the range for a national three-view lumbar spine study and below the national range for a three-view cervical spine study or a five-view cervical or lumbar spine examination.

### Discussion

Although time–motion analysis in technologist performance of radiographic examinations is a valuable exercise, it represents just a single phase in the complete radiography work flow process, which begins with the examination order and ends with the delivery of the final radiography report. A previous analysis of this work flow process during film-based operation at the Baltimore center enumerated 59 individual steps [10], underscoring the relative inefficiency of most film-based imaging departments and the necessity for work-flow optimization.

We found a substantial difference in the number of work-flow steps for technologists when comparing examination times for film-based and filmless operations (Fig. 1). After the technologist acquires the radiographic images, an additional seven to 14 steps were required for the film-based facilities in our study, depending on the individual department’s technology, work flow, and ancillary personnel. Using a daylight processor in lieu of a conventional processor or assigning these tasks to a darkroom aide, a technologist can eliminate the four steps related to image processing. At the same time, an additional three steps can be avoided by transferring all the responsibilities for image and report collation, transport, and hanging to file room staff. Although this transfer of responsibilities can result in improved technologist productivity, it creates additional work for and diminishes the productivity of other staff members. Regardless of whom the work is assigned to, it still must be completed in a film-based department and results in operational inefficiencies.

Filmless operation results in a reduction of these 14 steps to four steps without the transfer of additional responsibilities to other imaging department staff members. The net effect on improved operational efficiency is a substantial reduction in examination times (Table 1). Thus, using computed radiography and operating in a filmless mode save a significant amount of technologist time.

In a film-based department, technologist work flow typically consists of responsibilities that overlap with those of clerical and film library staff. Technologists are typically asked to perform functions that involve film collation and distribution. These additional steps were not fully accounted for in our study design, which recorded the interval from the time the technologist greets the patient to the time the images became available for review in the film library.

In the case of filmless operation with computed radiography, each examination ended and the timer stopped timing the examination once the images became available on the PACS for review by radiologists and clinicians. However, for the film-based operations, examinations ended after the technologist had collated the images and paperwork with the hard-copy film jacket and had returned the entire file to the film library. Although a technologist’s responsibilities in a film-based environment often involve these additional steps, we did not time these steps for our study. This omission may have resulted in the underestimation of the time-savings associated with filmless operation. Moreover, we did not record the additional time required for film-room staff to make the images available for interpretation by radiologists or review by clinicians because the focus of our study was on technologist productivity.

From the results in Table 1, several observations that are attributable to the unique characteristics of the study sites can be made. The film-based Fort Howard center is an affiliate of the Maryland Veterans Affairs Healthcare System, largely serving a less

<table>
<thead>
<tr>
<th>Type of Examination</th>
<th>No. of Views</th>
<th>Examinations Using Film-Screen Radiography</th>
<th>Examinations Using Filmless Computed Radiography at the Baltimore Center</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Fort Howard Center</td>
<td>Philadelphia Center</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mean Time (min)</td>
<td>No.</td>
</tr>
<tr>
<td>Chest</td>
<td>2</td>
<td>10.8</td>
<td>146</td>
</tr>
<tr>
<td>Spine</td>
<td>3–5</td>
<td>13.9</td>
<td>53</td>
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acute, ambulatory outpatient population. Because patient populations differ at the two film-based institutions, technologist examination times also differ: examination times at the Fort Howard facility are shorter than those at the Philadelphia facility, which serves a mixed inpatient and outpatient population. Many of these inpatients are less ambulatory and are consequently more difficult to position for the technologist performing the study. The patient profiles of the Philadelphia and Baltimore centers are similar to one another; therefore, times from these two centers present a more accurate comparison between film-based and filmless imaging operations.

The musculoskeletal imaging studies were heterogeneous, both in terms of the patient populations and specific types of examinations. For ambulatory patients, who predominate at the Fort Howard facility, the examination times tended to be shorter because of the relative ease in positioning the patient. In addition, these examinations were typically requested on a nonemergent basis for chronic conditions, such as lower back pain. On the other hand, a larger percentage of the orthopedic examinations at the academic facilities (Baltimore and Philadelphia centers) were of nonambulatory patients and were urgent in nature.

Both of these factors tend to be associated with greater technical difficulty for the technologist, resulting in the expected increased examination times. These differences in patient population and ambulatory status are addressed in the national benchmarks, which illustrate the major differences in examination time between these different patient populations.

One of the limitations of our study was the relatively small sample size for each individual category of examination studied, which precluded a detailed analysis of ambulatory and nonambulatory patients or of a specific anatomic region (e.g., cervical vs lumbar spine). In spite of the sample size, however, significant differences for the examination categories were observed for all three study sites evaluated.

In addition to the use of computed radiography and a filmless mode of operation, the use of a radiology and hospital information system and the degree of integration with computed radiography and the reliability of these systems are critically important to work-flow optimization. The hospital and radiology information systems can be used to improve work flow in patient registration; examination ordering, scheduling, and tracking; image management; reporting; billing; and statistical analyses.

A number of specialized integration enhancements, such as a Digital Imaging and Communications in Medicine (DICOM) modality work list, are available to further augment technologist productivity. The use of this feature can markedly reduce errors in patient and study identification and can result in automatic, more rapid entry of patient information into the computed radiography system. For example, another study evaluating CT transmission failure rates in a digital imaging department described an initial failure rate of 8% [11]. Of these transmission failures, 69% were the direct result of human error, specifically data entry errors. These errors caused significant time delays for the technologist. With the advent of the modality work list, transmission failure rates decreased by 56%, resulting in enhanced operational efficiency and technologist productivity [11].

Another software enhancement, the performed-procedure step, can be used to further increase operational efficiency by notifying the hospital information system automatically of examination status information. The automation of these processes, which were previously performed manually by technologists, improves work flow, reduces transfer error rates, and minimizes technologist fatigue.

Fatigue and stress seem to play a surprisingly important role in technologist productivity, but these issues have been largely ignored in the radiology literature. Two other studies found in the film-based radiology literature suggested that up to 20% of a technologist's examination time is attributable to stress and fatigue [7, 12]. After transition from the film-based to filmless operation, using computed radiography and PACS, technologists reported reductions in perceived levels of stress and fatigue [13, 14].

The concept of job-related stress takes on even greater importance in the current imaging environment because of the increasing shortage of qualified radiology technologists. According to data from the American Society of Radiologic Technologists (McElveny C, personal communication), the number of first-time technologists taking certification examinations in radiography decreased by 49% between 1994 and 2000, with a decrease in the number of technologist training programs of 19% over the same time period. The Bureau of Labor Statistics estimates 50,000 additional radiology technologists will be needed by 2006 (Devereaux K, personal communication). As the shortage of technologists increases, work demands and stress will continue to increase, potentially diminishing technologist productivity.

A number of potential improvements can address technologists' increasing stress levels and reduced productivity. As previously discussed, work-flow optimization is a critical objective and can be further enhanced by software developments, which continue to reduce the number of manual steps required in the processes of data entry, image acquisition, review, and processing. Greater distribution of computed radiography plate readers throughout the medical enterprise can further reduce technologist travel time to and from the sites of image acquisition.

Areas of high volume, such as emergency departments, intensive care units, and outpatient clinics, should have dedicated plate reviewers to facilitate faster image processing. An industry response to this need has been the development of computed radiography systems with in-room plate reviewers. At the same time, newer digital technologies are available that eliminate the need for cassettes, further reducing the number of steps required for technologists and enhancing work flow.

These newer technologies include direct (flat-panel) radiography and cassetteless computed radiography. Recently published studies [15–17] have reported improvement in work flow with the use of these in-room digital systems.

The transition from use of film-based to filmless technologies in an imaging department offers tremendous potential for work-flow redesign and, consequently, improvements in operational efficiency for technologists in the performance of general radiographic examinations. Although filmless operation at the Baltimore center was associated with substantially lower examination times than the two film-based facilities or with national benchmarks, we believe that additional improvements are possible with the use of in-room radiography systems and increased system integration. As imaging departments become increasingly integrated with the rest of the health care enterprise using tools such as the DICOM modality work list and the performed-procedure step, technologists in both film-based and filmless departments will likely continue to become more productive without concomitant increases in fatigue and stress.
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References
2. Barnes RM. Motion and time study: design and measurement of work. New York: Wiley, 1966

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