Impact of Digital Radiography on Clinical Workflow

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It is commonly accepted that digital radiography (DR) improves workflow and patient throughput compared with traditional film radiography or computed radiography (CR). DR eliminates the film development step and the time to acquire the image from a CR reader. In addition, the wide dynamic range of DR is such that the technologist can perform the quality-control (QC) step directly at the modality in a few seconds, rather than having to transport the newly acquired image to a centralized QC station for review. Furthermore, additional workflow efficiencies can be achieved with DR by employing tight radiology information system (RIS) integration. In the DR imaging environment, this provides for patient demographic information to be automatically downloaded from the RIS to populate the DR Digital Imaging and Communications in Medicine (DICOM) image header. To learn more about this workflow efficiency improvement, we performed a comparative study of workflow steps under three different conditions: traditional film/screen x-ray, DR without RIS integration (ie, manual entry of patient demographics), and DR with RIS integration. This study was performed at the Cleveland Clinic Foundation (Cleveland, OH) using a newly acquired amorphous silicon flat-panel DR system from Canon Medical Systems (Irvine, CA). Our data show that DR without RIS results in substantial workflow savings over traditional film/screen practice. There is an additional 30% reduction in total examination time using DR with RIS integration.

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DIGITAL RADIOGRAPHY (DR) systems are beginning to replace conventional film/screen practices in high throughput radiology departments. Over time, as more DR systems are installed, workflow improvements and patient throughput times will more clearly show the benefits of going digital. Up to the present, there has been more documented demonstration of workflow improvements when comparing conventional film/screen practice with computed radiography.^{1,2} The motivation for the current work is to obtain similar evidence to exemplify the workflow improvements of DR over conventional film/screen systems in a

very high throughput radiology department. To make the comparison as fair as possible, we propose to compare DR with a film/screen system configured to provide as high a patient throughput as is possible with film/screen equipment.

MATERIALS AND METHODS

Equipment

The digital images in our study were obtained using a Canon CXDI-11 DR system (Canon Medical Systems, Irvine, CA). The detector in this system is an amorphous silicon thin-film transistor (TFT) plate interfaced to a Windows NT operating system (Microsoft, Redmond, WA). The plate is mounted in an upright stand configured for chest x-rays. The user interface of the DR system is driven by a flat-panel liquid crystal display (LCD) touch screen. The RIS used was IDXrad (IDX Corp, Burlington, VT) with its complementary imaging suite.

The DR system has two distinct modes of operation.³ In stand-alone mode, the operator enters in patient and examination information by hand using the touch-screen keyboard. This information is typically available from the radiology information system (RIS). In RIS integration mode, the patient and examination information are automatically downloaded from the RIS to populate the corresponding fields in the DR user interface. The RIS modality worklist is called up from the touch-screen interface panel using standard web-browser software. The operator selects the patient from the worklist to trigger the download of the patient and examination information. Once the patient is selected, the browser window is minimized and hidden to return control back to the DR user interface. When the image is exposed and the examination completed, the DR automatically returns a completion message and the time and date stamp back to the RIS.

The film/screen system employed in this study was a standard Pickerchest model with a direct feed to a Kodak RPX-OMAT Processor Model M6B (Kodak, Rochester, NY). This configuration represents the highest throughput film screen system in use at the Cleveland Clinic.

Time Measurements

The Canon CXDI-11 system is located in the cardiology outpatient department of the Cleveland Clinic. The chest film/screen system is located in the Cleveland Clinic radiology department. Although this system is used for both in-hospital and outpatient populations, all data obtained was for ambulatory outpatients only. Each examination consisted of posteroanterior (PA) and lateral views. The following times were recorded for both the film/screen and DR with and without RIS integration:

- (1) ExamBegin (EB). From the time the patient enters the x-ray room until the patient is positioned for the PA exam. This time period also includes the time to enter patient demographic information. Demographic entry for film/screen consists of loading the patient card into the x-ray film cassette. In manual DR mode, the demographic information is entered by hand on the touch-

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screen user interface. In RIS integration mode the patient demographics are automatically loaded when the patient is selected from the modality worklist.

- (2) ExamComplete (EC). This is the time to expose the PA examination, reposition the patient for the lateral examination, and complete the exposure of the lateral exam.
- (3) Development (DEV). This is the time for development for the film/screen system or the time to present a viewable image in the case of DR. A viewable QC image for the DR is available in 2 to 3 seconds.
- (4) Quality Control (QC). This is the time it takes to QC the examination until the time the patient is released from the department. The QC for DR consists of approving the preview image that appears on the touch screen user interface. For the film/screen system, it is looking at the films on a light box.

RESULTS

The mean values for the complete set of measurements for the film/screen and the two modes of DR are summarized in Table 1. Sample sizes are $n = 38$ for film; $n = 65$ for DR without RIS; and $n = 75$ for DR with RIS. The total time the patient is in the department is shown in the last column of the table. As expected, the DR with and without RIS integration is significantly faster than film. The difference between the film/screen and DR methods is statistically significant to a high degree ($P < .0001$), using two-sample Student's t test assuming unequal variances (heteroscedastic t test) to compare the total time measurements between film/screen and DR with and without RIS. Figure 1 shows a plot of total patient time in the department, with error bars representing 95% confidence intervals. The 95% confidence intervals for the film/screen, DR without RIS, and DR with RIS are ± 17.8 seconds, ± 13.5 seconds, and ± 5.8 seconds, respectively. The ExamBegin (EB) time is significantly different for each of the three methods. The screen/film method has the smallest time, 36 seconds, since the patient information comes preprinted on the patient demographics card. The ExamBegin time for the DR with RIS is somewhat longer than the film/screen method, 47 seconds, because it takes a few seconds to switch to and scroll to the name of the

Table 1. Breakdown of Individual Timing Steps for All Three X-Ray Methods

	EB	EC	DEV	QC	Total
Screen/film	36	31	169	91	307
DR, no RIS	81	37	3	21	142
DR, RIS	47	31	3	17	98

NOTE. Total column gives total time patient in department. All values in seconds.

Fig 1. Total patient time in department. Error bars represent 95% confidence intervals.

current patient on the modality worklist appearing at the DR user interface. The DR without RIS has the longest ExamBegin time since all of the patient information is manually typed in at the DR user interface. The film screen development time (DEV), 169 seconds, and Quality Control time (QC), 91 seconds, are significantly longer than that for either of the DR methods. These longer times account for more than 80% of the film/screen total patient time in the department of 307 seconds.

DISCUSSION

The most impressive result of this study shows the improved throughput attained by having patient and examination information from the RIS immediately available at the DR modality. These findings were specific for chest x-rays only and most likely could be generalized for other types of x-ray procedures. Since these results were obtained for the fastest screen/film system at the Cleveland Clinic, we expect that the reported differences between the DR methods and the film/screen to be very conservative.

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