SESSION 7: Evaluation of Systems and Workflow

Digital Radiography and Film Scanners: Automating the Transition to Filmless Radiology

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To facilitate the integration of digital radiography (DR) and legacy film/screen technology, we have devised a methodology for film digitization that optimizes workflow and integrates well with the picture archiving and communication system (PACS). This work was performed at Mercy Medical Center (Cedar Rapids, IA) using a film digitizer with built-in Digital Imaging and Communications in Medicine (DICOM) communication. The radiology department at Mercy has one DR system and three separate film/screen systems. The DR system software suite features DICOM Modality Worklist capability to provide complete radiology information system (RIS) integration functionality. This provides for patient demographic information to be automatically downloaded from the RIS worklist to populate the DICOM image header. Likewise, we have taken advantage of the film scanner's DICOM capability to develop software linking it with the hospital RIS. This capability provides a worklist downloading functionality equivalent to that of the DR. Patient demographics can then be rapidly downloaded as each film is digitized. The worklist capability of the scanner is essential in several respects. First, it guarantees that patient demographic information is completely accurate and, therefore, that the digitized x-ray image will be merged with the correct patient file in the PACS. Additionally, high film scanner throughput is achieved, guaranteeing that all inpatient-digitized films are as readily available on the PACS as their DR image counterparts. The digitized images have proven to be of diagnostic quality on the typical 1K by 1K PACS workstation. Also, as patients are admitted to the hospital, prior films from the radiology archive are digitized to form a readily available patient history for in-house physicians. Over time, we are building archival patient histories of soft-copy images that will enable increased availability of patient x-rays to both in-hospital and outside referring physicians, especially as more internet-viewing software becomes available to the out-of-hospital medical community. Finally, the results of this study

show that high-throughput RIS integration of film scanning equipment is a key component to making a graceful transition to the filmless hospital as more DR systems are installed.

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DIGITAL RADIOGRAPHY (DR) systems are beginning to selectively replace conventional film/screen equipment in high-throughput radiology departments. However, in medium and larger size hospitals, the typical radiology department still has a number of rooms equipped with film/screen systems. Furthermore, in other areas of the hospital, such as the patient floors, portable film/screen systems are routinely employed. The current utilization of both DR and film/screen equipment creates the requirement that both systems coexist while maintaining and even improving workflow efficiency. In addition, the increasing adoption of picture archiving and communication systems (PACS) for archiving and soft-copy display provides a further requirement for integration of both DR and film into the hospital network. As more DR systems have been installed, the improvements in workflow and patient throughput times have been clearly demonstrated.¹ The motivation for this current work is to show how a carefully engineered automation of a film-scanning process can effectively integrate legacy film/screen equipment into an otherwise all-digital modality PACS hospital environment. To show how effective this integration process can be, we have chosen to study the film-scanning process in a high-throughput hospital environment where 100% of overnight, inpatient films are digitized and made available to referring physicians by 8:00 AM the following morning. Films taken during the business day are digitized immediately after development and QA.

MATERIALS AND METHODS

Equipment

The scanned images in our study were produced by a Canon Film Scanner 300 (Canon Medical Systems, Irvine, CA). This scanner can autofeed up to 100 sheets of different size films and

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The image shows a computer screen with a form titled "Patient Information screen". At the top, there are two buttons: "New Exam" and "Scheduled". The form contains the following fields and values:

Name:	McGinn, Thomas E
ID #	011002
Birth Date:	2/11/1948
Sex:	☒ M ☐ F
Exam #	000578596
Accession #	(not filled manually, filled in by Worklist)
Date:	01/08/2001
Time:	12:28
Exam Desc:	Chest
Referring:	Knudson, Kenneth
Hospital:	Mercy Medical Center

Fig 1. Patient Information screen.

scan them at four sheets per minute. After scanning, the image data is processed through a real-time histogram equalizer and stored on an internal hard disk. The stored images on the scanner can then be retrieved through a standard Digital Imaging and Communications in Medicine (DICOM) output through an Ethernet connector, providing for ease of interfacing to the hospital network environment.

The Canon Scanner 300 is one of a number of other modalities that is connected into a Meditech Health Care Information System (HCIS) radiology information system (RIS)/hospital information system (HIS) provider. The Meditech system is the HIS for the Mercy Hospital environment, but also provides an optional Radiology module to give it the RIS capability. Patient registration and scheduling information are routed through the hospital network using the Health Level 7 (HL7) messaging standard. The integration between the HIS and the modalities in the radiology department is provided by another Canon product, the Canon Connector CC10. The CC10 is a hardware/software system that builds a database representing patient information using HL7 messages from the Meditech HCIS. This patient information may be sent to a cooperating PACS system, and also to the various radiology department modalities using DICOM Modality Worklist.² The PACS system uses information from the CC10 to perform patient image pre-fetching and to fill in patient demographic information that may have been missing in image headers. The modalities use the DICOM Modality Worklist protocol to query the CC10 for a list of patients scheduled for a radiology procedure. Using standard web-browser technology, the list of scheduled patients appears at the modality user interface (eg DR, compute tomography, magnetic resonance, or FLURO) where the correct patient can then be selected for the particular scheduled procedure. The patient demographic information is then automatically downloaded to the modality and used to fill-in the corresponding fields in the DICOM image header.

A Patient Information Screen, as shown in Fig 1, was provided at the Film Scanner. This screen has two distinct mode of operation. By selecting the "New Exam Button", the technologist can enter patient and examination information by hand using the PACS keyboard from the X-Ray Requisition Card printed out from the HCIS. The information on this card is

derived from the physician order and is entered when the patient arrives at the Radiology reception desk. Pressing the "Scheduled Button" causes the patient worklist to appear, allowing the technologist to select the patient and automatically populate most of the fields on the screen. The technologist has only to fill in the Exam Time and the Exam Description using the keyboard.

Time Measurements

The Canon Film Scanner 300 is located in the Radiology Department of the Mercy Medical Center. Although the film scanning process can be used for in-hospital and outpatient populations, all data in this study were taken for in-hospital patients only. Mercy has its own DR (digital x-ray) room, which is used for most of the outpatient population. In-hospital patients typically have a variety of film x-rays taken from portable x-ray systems located throughout the patient floors. These and the films taken from the three other film rooms in the radiology department are the ones scanned in this study.

There were two sets of time measurements recorded, Manual Entry of patient data and automated DICOM Worklist Entry. Each measurement is based on filling in the information shown on the Patient Information Screen shown in Fig 1. The scanning process begins when the technologist places a stack of films onto the feeding mechanism of the Scanner 300. The technologist pushes the scanner start button and each film is scanned in sequence. The technologist then sits down to the PACS workstation with a set of X-ray Requisition Cards sequenced in the order in which the films were scanned. The technologist then selects the New Exam Button on the Patient Information Screen and proceeds to type in each field from the information on the X-ray Requisition Card. The technologist has a view of the scanned film next to the Patient Information Screen so that the correspondence between the film and patient information can be visually verified. The Manual Entry data time is then measured from the time the technologist selects the New Exam button to the time that the last data field (Referring Physician) is entered. In the Mercy Medical PACS system, the Exam# and the Accession# are treated the same, therefore, the technologist skips entry of the Accession# field. The Hospital field always comes up filled in with "Mercy Medical Center" for both Manual Entry and Worklist Entry methods. Additionally, the Mercy PACS system has a bar code reader which is capable of reading the Exam# and ID# bar codes printed on the X-Ray Requisition Card. Some of the technologists in this study made use of the bar-coded information. This, of course, tends to reduce the Manual Entry input time. Data from technologists who used the bar code reader were accepted, as this feature would only make the comparison between Manual Entry and Worklist Entry more conservative.

For purposes of this study, the technologist then cancels the Manual Entry and proceeds to the DICOM Worklist Entry method. The measurement begins as the technologist enters the first 4 letters of the patient's last name in the "Name" field of the Patient Information Screen. Next, the "Scheduled Button" is selected and within 2 seconds a list of scheduled patients with alphabetically similar last names appears as a selection box. The technologist selects the correct patient by verifying that the "Exam#" field is identical to the one on the X-ray Requisition Card. When the patient is selected, all data fields except the Exam Time and Exam Description fields are automatically

Fig 2. Total data entry time for each method.

populated. The technologist then proceeds to fill these fields in using the keyboard, and the measurement process ends.

RESULTS

The mean values for the complete set of measurements for the Manual Entry and Worklist Entry were 39.8 ± 14.8 (SD) and 16.1 ± 5.4 , respectively. The sample size for each entry method is $n=112$. As expected, the Worklist Entry method is significantly faster than Manual Entry method. The difference between Manual Entry and Worklist Entry 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 the two. Figure 2 shows a plot of total data entry time for each method. The 95% confidence interval for Manual Entry is ± 29.6 seconds and ± 10.8 seconds for Worklist Entry. The relatively large confidence interval for the Manual Entry method is explained by the difference in typing speeds between the various technologists employed in this study. Data for the Manual Entry were taken from a group of 10 technologists. No attempt was made to select technologists based on their data entry skills. In contrast, the confidence interval for worklist data entry is smaller since the only input required from the technologist is typing the first four letters of the patient's last name. The time it takes the PACS system to respond with the list of

patients scheduled once the technologist selects the Scheduled Button is included in the total time for Worklist Entry. This response time for the Mercy PACS system was very consistent and on the order of 1 second. Most of the Worklist Entry time was consumed by the technologist matching the Exam# on the patient scheduled list with the same number on the X-Ray Requisition Card.

DISCUSSION

During the course of a day, approximately half of the inpatient x-ray films are taken during the night hours and accumulated in batches to be digitized between 5 AM and 7 AM the following morning. This workload can amount to several dozen films on a given morning. The ability of the Film Scanner 300 to accept a stack of films onto its feed mechanism is an essential capability in optimizing the workflow in the Mercy Radiology Department. Using the Worklist Entry method, the technologist can rapidly attach patient demographic information to the scanned images and send them off to PACS storage. Previous attempts to use single-sheet scanners were too slow and cumbersome. Typically, the digitizing technologist has other morning work waiting and therefore desires to get through the scanning process as rapidly as possible. As a result, prior to Worklist Entry the error rate in manual patient data entry typically exceeded 20%. The error rate not only resulted in reduced same-day availability of images from the PACS, but also required significant manual intervention by senior technologists and radiology management to debug and correct the errors after images had already been archived on PACS storage. The correction process also created needless duplicate image storage on the PACS archive. The final result of this study shows that with the benefit of Worklist Entry and batch scanning capability, patient demographic information errors are essentially eliminated, resulting in significant manpower savings in the radiology department, reduced archive storage requirements, and greatly improved image availability to referring physicians on the patient floors.

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