ORIGINAL ARTICLE

Radiation Medicine: Vol. 21 No. 2, 68–73 p.p., 2003

Operating Data and Unsolved Problems of the DICOM Modality Worklist: An Indispensable Tool in an Electronic Archiving Environment

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Purpose: We evaluated the efficacy of DICOM worklist software for radiological modalities from the viewpoint of risk management, to reduce mislabeled image data in an electronic archiving environment. We focused on the following five points: 1) the effectiveness of the DICOM modality worklist, 2) problems involving incorrect patient and image data, 3) the presence of incorrect profiles despite the transfer of patient profiles online via the DICOM worklist, 4) ways to eliminate entry failure, and 5) further examination even if data entry were correct.

Materials and Methods: Retrospective data of patient profiles with image data were evaluated both before and after installation of DICOM modality worklist management software at Sakai Municipal Hospital. All radiology modalities were connected to RIS terminals in which DICOM modality worklist software was installed. Patient profiles were transferred online from RIS terminals to the modalities. It was not necessary for technologists to type patient profiles in usual examinations.

Results: Before installing the DICOM modality worklist software, the number of data entry errors was 31 and the rate was 6.4% of 487 examinations. After installation, manual data entry occurred in 80 of 1,994 examinations. The number of data entry errors for patient profiles was two, and the rate was 0.1% of the total examinations ($p<0.0001$). Before installing the DICOM modality worklist, two wrong patient IDs that corresponded to other existing patient IDs were typed into the modality. No patient IDs were mixed up after installation of the DICOM modality worklist ($p=0.0385$).

Conclusion: The DICOM worklist was indispensable to electronic archiving because it decreased incorrect patient profiles that corresponded to image data loss. This was effective in decreasing patient mix-ups that could lead to serious malpractice. Despite the DICOM worklist, however, some incorrect patient profiles remained as a result of manual typing errors. The reasons for manual typing included emergency examinations, paper-based operations, and system shutdown. Furthermore, the risk of patient mix-ups remained even if the patient profile was correct. To eliminate or decrease medical accidents, determining why accidents happen and ensuring better data confirmation are necessary.

Key words: digital imaging and communication in medicine (DICOM), worklist, picture archiving and communication system (PACS), radiology information system (RIS), electronic archiving

INTRODUCTION

RADIOLOGY IMAGES are increasingly being processed in the digital environment. Installation of picture archiving and communication systems (PACS) has become an effective solution for image data administration. Owing to the digital imaging and communication in medicine (DICOM) standard,[1] the electronic archiving of medical images has spread throughout the world. DICOM has been developed to provide a standard for electronic communication between radiology and other hospital departments.

Electronic data archiving has many benefits. Once archived, electronic image data are more difficult to lose than radiology films. However, data archiving also has demerits. Manual typographical errors of patient

Received March 4, 2002; revision accepted December 27, 2002.

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identification numbers (ID), names, or dates of birth on radiological modalities such as computed tomography (CT), magnetic resonance imaging (MRI), or computed radiography (CR) are the root cause of unreliable image data in the PACS environment.

Historically, demographic data passed to PACS have been generated manually at the modality, despite the existence of the same data on the hospital information system (HIS) and radiology information system (RIS). There was a high possibility for technicians to mistype patient profiles with these modalities. In more current sophisticated implementations, acquisition modalities are able to receive patient and study-related data from the HIS or RIS.

To improve radiologist and technologist productivity, as well as to avoid mistyping patient profiles, DICOM modality worklist software has recently been established.[2-8] This enables a modality operator to request scheduling information for the ordered procedures and to shorten the time of patient registration to the modality. With the DICOM modality worklist, waiting patients are easily recognized, ordered correctly, and the total examination time is shortened.

In Sakai Municipal Hospital, the HIS, RIS, and PACS are all connected to each other. All modalities are connected to the DICOM modality worklist, and patient information is transferred from HIS/RIS to PACS by the DICOM modality worklist.

Here, we evaluated the DICOM worklist using operating data obtained before and after its introduction. We focused on the following five points: 1) the effectiveness of the DICOM modality worklist, 2) problems involving incorrect patient and image data, 3) the presence of incorrect profiles despite the transfer of patient profiles online via the DICOM worklist, 4) ways to eliminate entry failure, and 5) further examination even if data entry were correct. The key focus of this study was the data after we used the DICOM worklist in a practical situation.

Materials and Methods

Sakai Municipal Hospital has an HIS, RIS, report system, and PACS from NEC (Tokyo, Japan). To improve the workflow of radiology examinations, a DICOM modality worklist manager was also installed. All the radiology modalities in the hospital were connected to RIS terminals: two computed tomography (CT) units, two magnetic resonance imaging (MRI), three digital radiography (DR), two digital subtraction angiography (DSA), four computed radiography (CR), two single photon emission computed tomography (SPECT), and one film digitizer unit.

Usual radiology examinations were held during the daytime on business days, as ordered by physicians via HIS terminals. The orders were transferred to RIS via the HIS server, which were connected to each other.

Patient and study information including patient ID, name, sex, and date of birth were transferred to the modalities by the DICOM modality worklist management software from the RIS terminal online. These demographic data were integrated to the image data in the modalities when the examination was carried out. The image and patient data in the modality were then sent to the DICOM servers. Patient ID, examination date, and type of modality were the keys used when queried from image viewers (Fig. 1).

We analyzed all patient profiles with image data from radiology examinations conducted over two weeks (nine business days and five non-business days) at Sakai Municipal Hospital. The examination type and number, date and time of examination, correct or incorrect patient profiles, transferred online or typed manually, and the types of entry failures were recorded in order to evaluate the DICOM modality worklist.

We also analyzed the patient profiles of radiology

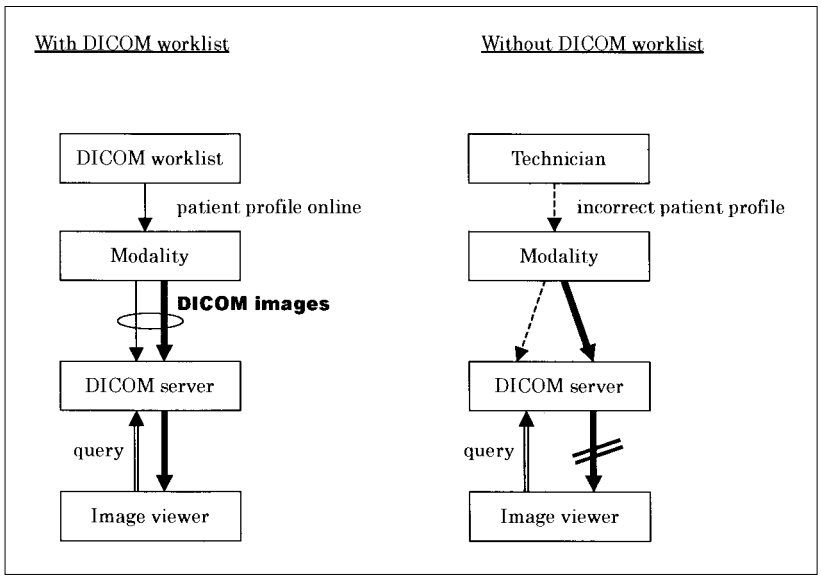

Fig. 1. Flow of patient profiles in the information systems and radiological modalities. If an incorrect patient profile was registered in the modality, then query and retrieval of the corresponding image data were impossible. When incorrect patient profiles were registered by the technician, patient profiles and image data were mismatched. In the query from an image viewer, corresponding patient profiles seemed to disappear and the DICOM image data were not retrieved.

examinations, except for CR examinations, before installing HIS, RIS, PACS, and the DICOM modality worklist. During one week, all the patient examination profiles were typed manually and printed on the radiology image films.

RESULTS

Before installation of the DICOM modality worklist software, the total number of examinations during the period was 487 cases. There were 31 examinations with incorrect patient profiles, which was 6.4% of the total (Fig. 2).

After installation of the DICOM modality worklist software, the total number of examinations during the period was 1,994. Of these, 1,914 cases were transferred from RIS terminals to modalities online, accounting for 96% of all examinations. Eighty patient IDs were typed manually to the modalities, which was 4% of the total examination number (Fig. 3).

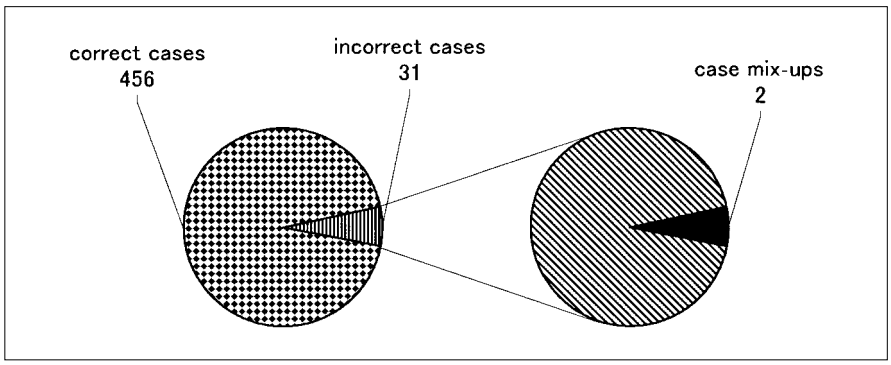

Fig. 2. Number of examinations before installation of the DICOM modality worklist.

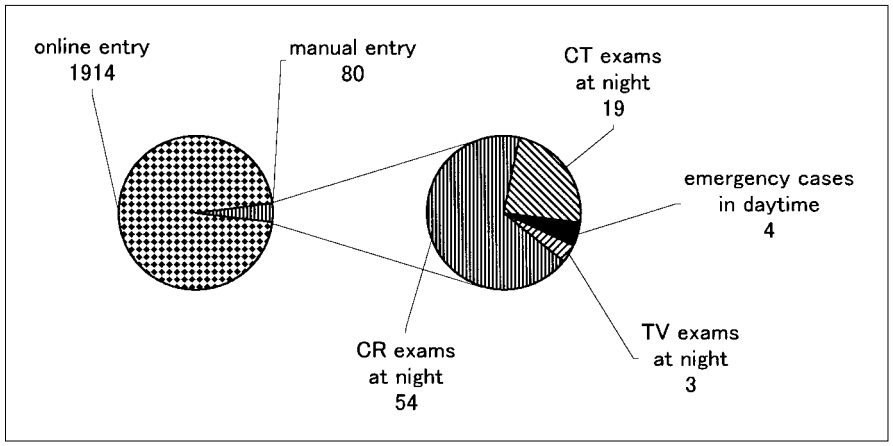

Fig. 3. Number of examinations after installation of the DICOM modality worklist. The number of examinations with online patient entry was 1,914 (96%). The 76 examinations typed manually were made at night or on non-business days. No online transfers were made in four emergency examinations which were performed during the daytime.

There were three reasons for manual typing entry. One was emergency examinations, in which an emergency patient who had never consulted our hospital had no patient ID. Thus, urgent examination or care was given preference over patient registration to the HIS and RIS. Patient profiles were used for manual typing to the modality. Furthermore, even if patients had their own ID, there was a transmission delay from HIS to RIS in our system. Technicians sometimes typed information to avoid this transmission delay. Four examinations were typed manually despite being made during the daytime on a business day, because they were emergencies (Fig. 3).

The second reason for manual entry was paper-based operations. HIS and RIS were not operated at night or on holidays because part-time technicians or physicians were not always able to handle the RIS or HIS terminals with ease.

The last reason was system shutdown. This was due to system maintenance, system backup, or system failure. A few hours of system backup was necessary every night. RIS failure, RIS terminal failure, and DICOM interface failure occurred outside the target period.

Seventy-six examinations were carried out during non-business hours, with their profiles typed to the modalities manually, including 19 CT, three DR, and 54 CR examinations (Fig. 3). Incorrect patient profiles were discovered in two examinations, which was 2.5% of the 80 manual entry examinations and 0.1% of the 1,994 total examinations (Fig. 4). These incorrect profiles were mistyped by temporary technicians who were dispatched from other hospitals during non-business hours. These mistaken profiles were corrected on the next business day by other full-time technicians. In comparison with the examinations before installation of the DICOM modality worklist, incorrect patient profiles decreased markedly and the p-value of Fisher's exact probability test was less than 0.0001 (Table 1).

Before installation of the DICOM modality worklist manager, there were two wrong patient IDs that corresponded to other existing patient IDs (Fig. 2). One case occurred when a mistyped patient ID accidentally corresponded to another existing patient ID. The other case occurred when a technician forgot the terminating

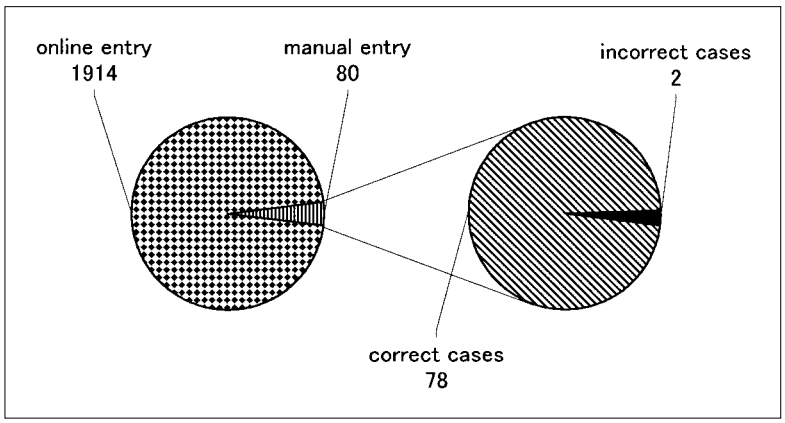

Fig. 4. Number of examinations with correct or incorrect patient profiles. Patient profile errors were seen in only two cases (0.1% of the total examinations). No incorrect cases were found among online entry examinations.

Table 1. Number of examinations before and after installation of the DICOM modality worklist and the p-value of Fisher's exact probability test

	Total number of examinations	Number of rofile errors	Number of mixed-up patient IDs
Before installation	487	31 (6.4%)	2 (0.4%)
After installation	1,994	2 (0.1%)	0 (0%)
Fisher's exact probability test		p<0.0001	p=0.0385

process of the previous examination and a new patient examination was done with the previous patient profile. Both errors were corrected after a time, and no practical damage occurred.

After installation of the DICOM worklist and RIS, no patient IDs were mixed up. In comparison with the examinations without the DICOM worklist, the patient mix-ups significantly decreased, and the p-value of Fisher's exact probability test was 0.0385 (Table 1). No patient data were mixed up when we observed the images in PACS and reported them with the reporting system. No patient was examined with the order entry of another part of the body after the introduction of RIS and PACS. No other examinations contained incorrect patient information. No trouble with the computer system or network occurred during the test period.

Discussion

Historically, radiology images have been filed in a film-based system and the demographic data have been generated manually at the modality.

To improve radiologist and technologist productivity, as well as to avoid mistyping patient profiles, DICOM modality worklist software has recently been developed. DICOM was developed to provide a standard for electronic communication between radiology and other hospital departments. In more current, sophisticated implementations, the acquisition modalities are able to receive patient and study-related data from the HIS or RIS. DICOM modality worklist software can send patient profile data to the connected modalities from the RIS terminals without the need for manual typing by technologists. Without the DICOM modality worklist, an electronic link between the acquisition modalities and HIS or RIS would not be possible.

1) In what ways was the DICOM modality worklist effective? The DICOM worklist had the following five benefits: a) it markedly decreased incorrect data entry, b) eliminated patient mix-ups in radiology examinations, c) eliminated body part mix-ups in the same patient, d) eliminated patient errors in diagnostic imaging, and e) improved the throughput of examinations.

a) The DICOM worklist decreased incorrect data entry to the modalities. Before the introduction of DICOM worklist software in our hospital, the mistype rate was 6.4% of 487 examinations. After its introduction, the net error rate decreased to 0.1% of a total 1,994 examinations. In comparison with the examinations before and after installation of the DICOM modality worklist, the p-value of Fisher's exact probability test was less than 0.0001 (Table 1). Thus, the DICOM modality worklist software was very effective for decreasing the number of incorrect patient profiles. However, incorrect data were not eliminated completely, and some errors persisted.

b) No patient was mixed up with any other patient.

Before installation of the DICOM modality worklist manager, there were two wrong patient IDs that corresponded to other existing patient IDs. After installation, no mix-ups occurred. In comparison with the examinations before and after installation of the software, the p-value of Fisher's exact probability test was 0.0385 (Table 1). It was considered that the link between the RIS and the modalities provided by the DICOM worklist prevented patient mix-ups.

c) No patient was examined under an order entry for another part of the body after introduction of the RIS and PACS. A statistical evaluation was not possible as we did not have data for the period before the DICOM worklist was introduced. It was assumed that the link between the RIS and the modalities as a result of the DICOM worklist prevented errors involving body parts.

d) No patient errors occurred when observing images in the PACS and reporting findings with the reporting system. A statistical evaluation was not possible as we did not have the data for the period before the DICOM worklist was introduced. It was considered that the link between the reporting system and PACS as a result of the DICOM worklist prevented errors involving patients. The paper-based reporting system and film-reading system would have probably generated more errors.

e) It was considered that the throughput of examined patients was improved, although we did not have throughput data on patients; thus we were unable to make an evaluation at this time.

2) What problems occurred when patient and image data were incorrect? Problems included the inaccessibility of image data with an incorrect data entry and the problem that the wrong ID corresponded to another existing patient ID.

In the PACS environment, incorrect data made image data inaccessible. An incorrect patient ID or name had not been a serious problem in the film-based environment, because a film with the wrong ID or name attached to it did not significantly affect workflow. Films with incorrect patient profiles were stored in the film jacket of the correct patient, and images were not lost or mixed up as such.

In the PACS environment, however, even minor errors in data entry can cause severe disruptions in workflow by rendering images inaccessible, because image references require a query with the patient ID. Images with an incorrect patient ID but correct patient name may be queried by patient name, but patient name queries also caused problems. Many transliterations of Japanese names to romanized format prevented effective queries. Incorrect patient profiles that interfered with a correct image query meant that no image was obtained. The lack of image data would constitute malpractice in a certain sense.

Before introducing DICOM worklist software in our hospital, the mistype rate was 6.4% of 487 examinations. The error rate of 80 cases manually typed with the DICOM worklist was 2.5%. Reiner *et al.* reported that the failure rate of manual data entry without the DICOM modality worklist was 5.2%.[9] Thus, typographical errors amounting to a few percent were typically generated. More than 50,000 examinations are done in our hospital per year. If all patient profiles had been typed manually and a few percent were typed incorrectly, then two or three thousand incorrect patient profiles would be generated in a year. It is unacceptable for two or three thousand examinations per year to be inaccessible in an electronic archiving environment. To manage the correct data, the DICOM worklist software was indispensable to the electronic archiving environment.

Another problem occurred when incorrect patient and image data with an incorrect patient ID corresponded to another existing patient ID. Before installation of the DICOM modality worklist manager, sometimes a wrong patient ID accidentally corresponded to another existing patient ID, and the images were treated as those of another patient. This is clearly malpractice and must be prevented by all means.

3) Why did incorrect profiles remain in spite of the DICOM worklist that transferred them online? In all cases, such errors were due to incorrect manual typing in the modalities.

Manual typing, the root cause of incorrect patient profiles, occurred in the following three situations: emergency examinations, paper-based operations, and system shutdown due to maintenance, backup, and failure.

An example of the first situation, emergency examinations, would be an emergency patient who had never consulted our hospital had no patient ID. Urgent examination and care were given preference over patient registration to the HIS and RIS, and patient profiles were used to type manually to the modality. Furthermore, even if the patient had possessed an ID, a transmission delay from HIS to RIS was present in our system, and technicians sometimes used manual typing to avoid this transmission delay.

In the case of paper-based operations, part-time physicians and technicians who worked at night or on non-business days were not accustomed to the HIS or RIS terminals of this hospital, and a paper-based operation system was indispensable during this period.

The last case was system shutdown. System maintenance or backup of HIS, RIS, and PACS took a

few hours every night. RIS failure, RIS terminal failure, and DICOM interface failure did not occur during the target period, but they did occur outside the target period.

There are many hospitals with different rates of manual typing and incorrect data. The error rate itself is not important. What really matters is analysis of the situation and the medical risk involved.

Emergency examinations and system maintenance are inevitable. To eliminate data entry failure, we must clarify situations in which we cannot operate the DICOM worklist software system.

4) How can entry failure be eliminated? To eliminate incorrect profiles, it was necessary to decrease manual entry.

Emergency patient registration to the system is expected to be terminated in a short time. The hospital must give more training to part-time physicians and technicians who work at night or on non-business days so that they can use the HIS and RIS easily. Then, the system can be operated even at night and on holidays. The system vender must minimize system down time and system backup time.

If profiles have to be typed manually, careful confirmation of the entered data is needed. It is important to confirm patient name and ID before and after examination.

5) What problems occurred even if data entry was correct? This involved confirmation not of the patient profile, but of the patient him- or herself.

Danger remained even if the DICOM worklist was used correctly and manual typing was not done. If the technician neglected to perform the terminating process of the previous examination, the new patient examination was done with the previous patient profile. Correct patient profiles were meaningless when a different patient was examined. As introduction of the DICOM worklist decreased input labor and incorrect patient profiles, a better confirmation process was possible.

The system operation of not only the DICOM worklist but also HIS and RIS were not necessarily perfect. To eliminate medical accidents, we need to establish why accidents happened and pay careful attention to the confirmation process of examinations.

Conclusion

The DICOM worklist was indispensable to the electronic archiving environment because it decreased the incorrect patient profiles that corresponded to image data loss. The DICOM worklist was effective in decreasing patient mix-ups that lead to serious malpractice. Despite the DICOM worklist, however, incorrect patient profiles remained as a result of manual typing errors. The causes of manual typing errors were emergency examinations, paper-based operations, and system shutdown. Furthermore, the risk of patient mix-ups remained, even if the patient profile was correct. To eliminate or decrease medical accidents, we have to determine why accidents happen and achieve better confirmation.

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