DICOM-Based Multi-Center Electronic Medical Records Management System

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Abstract

In the past, many of the medical information produced by hospitals (such as medical records or imagery) have had trouble being transferred from place to place; the main reason for this being the difference in the many formats that are used by each and every brand. With the development of the ages, the need for exchange of medical information has increased. Thus, imagery medical information uses the DICOM（Digital Image and Communication in Medicine）standard. The goal of this study is to establish a reformatting interface using the DICOM file management system to transfer paper-based records into DICOM format. Once in DICOM format, these records can then be sent to the DICOM server so that they may be accessed via the DICOM Viewer cross hospitals. This study also aims to transform text information into DICOM format so that files may be exchanged with other hospitals through DICOM's secure system so that medical records can be incorporated into hospitals' image systems to form a congregation of hospital resources.

Key Word: *DICOM, Electronic Medical Records Management System, Multi-Center*

1. Introduction

For medical institutions, the use of information technology in management has become key to the modernization of hospitals in order to meet the demands that future developments might bring [2]. Environmental changes faced by hospital management arose from the establishment of various large privately owned hospitals. It would seem that the management of hospitals is, as of now, favoring expansion and dispersing of staff and resource. With each branch hospital holding its own stash of medical case files, the exchange and organization of files on a cross-branch basis has become difficult to manage.

This research aims to develop a system to organize paper-based case files in the PACS stead in order to improve the quality of service. This system aims not to override the original system, but to assist in the management and of the former and any new material which may arise.

This study will focus on a setup that can digitalize files into DICOM, one that can scan files to fit DICOM's standards and be sent via the 'web not just in connection to DICOM, but also to other places to form a setup that manages the digitalization of medical files and other digital communication. Within the setup there is a medical information processor, a scanner, a DICOM code-switcher, a video transmitter, a digital video encoder and compressor and a document organizer. This entire setup will provide medical personnel with the feedback and training they may need to enhance the effects of medical information and improve the quality of medical care in general.

2. Literary Review

As medical procedures become more and more complicated with the NHS holding tighter reins on the number of beds available and overall efficiency, the present flaws in the file management system becomes obvious. First of all, preserving traditional files need sufficient labor and space; secondly, as there is often only one copy of any file, misplacement would need help from additional persons which would prevent the doctor from making a timely diagnoses and lower the overall quality of care [3]. However, a DICOM digital file would resolve both of the above problems. For example, it would make multiple simultaneous perusals of the same file possible while saving the hospital a lot of space [4]. Moreover, the imaging choices available present doctors with the ability for quicker and more accurate diagnoses.

With the popularization of the use of digital information in the field of medicine, researchers have attempted to set up systems for clinical use, including those purely for the organization of text, images and video. However, clinical use would be much elevated if data collection compatibility ceased to be a problem and data search was made possible. The two main points in this study are: (1) to transfer non-traditional medical image systems using the （Digital Imaging and Communication in Medicine, DICOM）[7][8] interface and (2) to insert search functions into various databases and explore the possibilities therein.

Since 1982, the America College of Radiology (ACR) and the National Electrical Manufacturers Association (NEMA) have formed a committee to explore the connections between digital imaging equipment and computers. In 1992, the ACR/NEMA 3.0, also known as DICOM 3.0, was named. It includes the hardware needed for transmission of regular images and a data dictionary as well as commands for transmission plus a message principle, which weaves a stream of commands into messages to make convenient the communication between facilities [6]. Thus, meeting the standard of DICOM 3.0 not only allows all digital imagery to be linked via the ‘web, but also for doctors to search for patient images and records to put hospital resources to better use. Moreover, DICOM 3.0 is compatible with the existing standards so that former investments need not be put to waste [5].

There are three main sub-systems to medical imaging systems: Image Acquisition, Image Archiving and Image Display [1]. These three sub-systems, through a standard interface, is connected via a computer network. Figure 1 shows that the technicalities involved in an image archive includes (1) image acquisition, (2) image processing and display, (3) image archiving and management, (4) a communication network and (5) an equipment interface and standard.

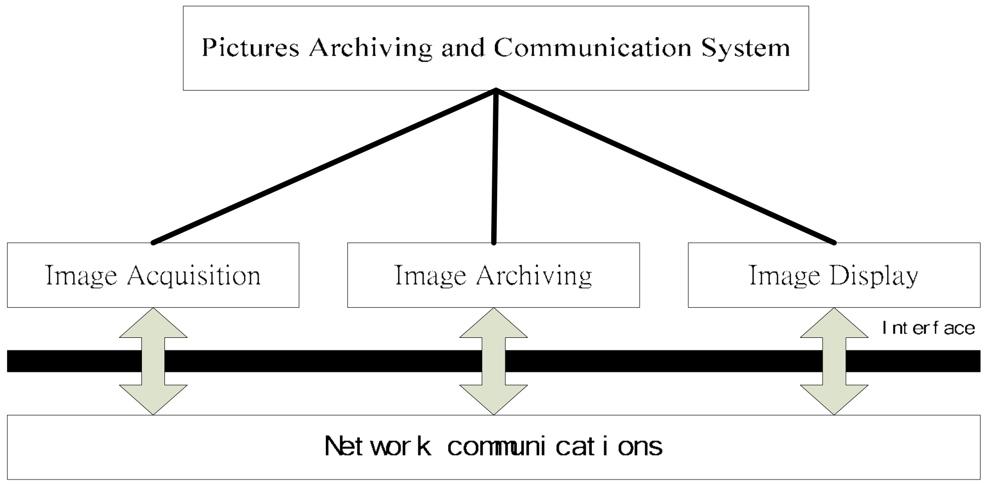

Figure 1. Structure of medical imaging systems
(source: Computer and Communication Magazine Issue 53, page 41)

3. System Structure

Here is an example of some problems that may arise from paper-based files. Hospital A, due to different needs from different departments, set up multiple filing systems from different companies leading to a lack of consistency. When doctors wish to see cross-departmental patients, the multiple systems become a hindrance. Additional personnel are needed for system management, which also adds to financial burden. However, after installing PACS with DICOM technology, the paper-based records could be digitalized by simply running through the scanner and transferred into DICOM format through Non-DICOM Gateway digitalization. After all relevant records are in PACS, doctors may access the information safely, conveniently and consistently (as shown in Figure 2).

Using a computer workstation and a scanner connected with a USB port, test the system to see that it is working normally after installation. Afterwards, install the software needed to transfer files into DICOM format then test again and complete the setups required before testing the connection between the HIS system and the DICOM server. Open the software for DICOM format transfer, access patient information through HIS system, scan the paper records to reformat, then send all digitalized DICOM records to the DICOM server to complete for future doctors to not have to go through human processing to have access to records needed (shown in Figures 3).

This study provides a computer plus scanner device to turn paper files to images before going through 11, 12, 12, 14, 16, 17 to reach 20.

A filing system digitalization to DICOM device can scan paper materials into image files, then turn them into DICOM standard format to be saved onto a PACS, including:

A filing system digitalization to DICOM device can scan paper materials into image files, then turn them into DICOM standard format to be saved onto a PACS, including:

1. A medical information processor that connects with the workstation to receive commands such as file order;
2. A numbering processor to number text structurally based on information sent from the

information processor;

3. A DICOM formatting device to transform text information into DICOM values after the numbering processor is connected to allow for image management;

4. A image transmitter connected to the scanner to transmit the images;

5. An image encoder and compressor that connects input from DICOM to the format values and shows a column of values to represent the information and images sent and after checking the VR and kept strings, the machine will do a thorough check of patient information before digitalizing to fit DICOM requirements. After the input of patient information, the scanner together with the encoder digitalizes the file to DICOM format before determining whether compression is needed. A final check is made to ensure consistency before editing to the patient file may be made, as shown in Figure 4;

6. A document maker combines text and images into DICOM format and can transfer required files through broadband to a delegated DICOM server. This cycle is shown in Figure 5.

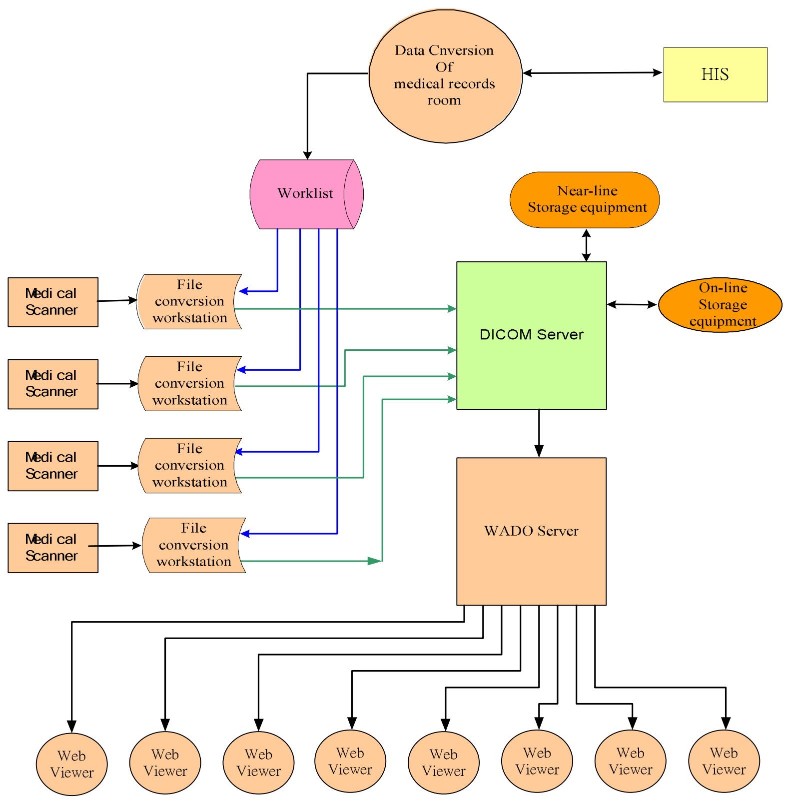

Figure 2. Diagram of DICOM electrical records management system

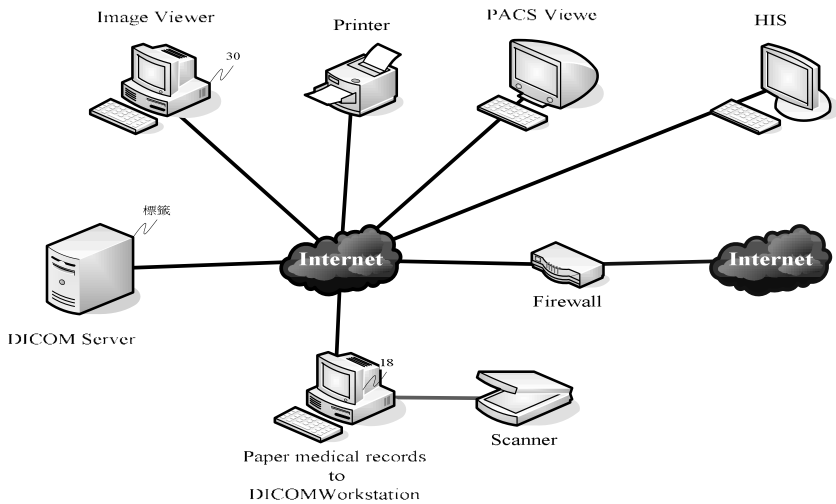

Figure 3. Structure of DICOM electrical medical records management systems

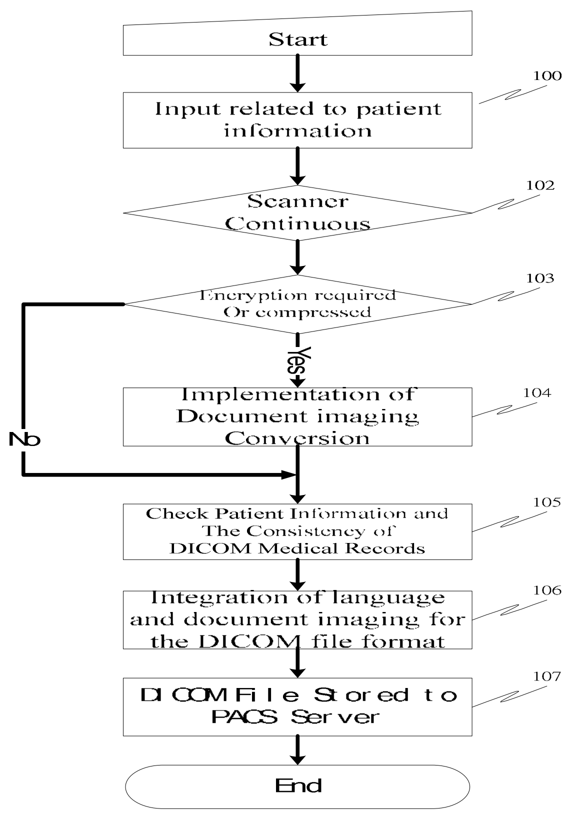

Figure 4. Flow chart of paper-based and DICOM medical records

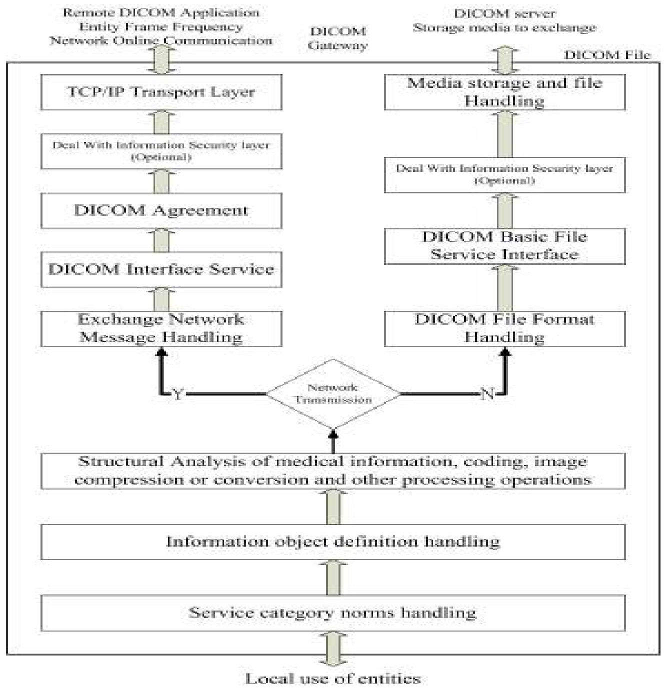

Figure 5. Flow chart of transmission through the DICOM network

3.1 System Test Environment

As shown in Figure 6, PC-01, PC-02 and PC-03 transmitted 10, 20 and 30 DICOM medical records hrough 1000Mbps cable network. Speed of transmission was calculated through the SCU and SCP records and file size.

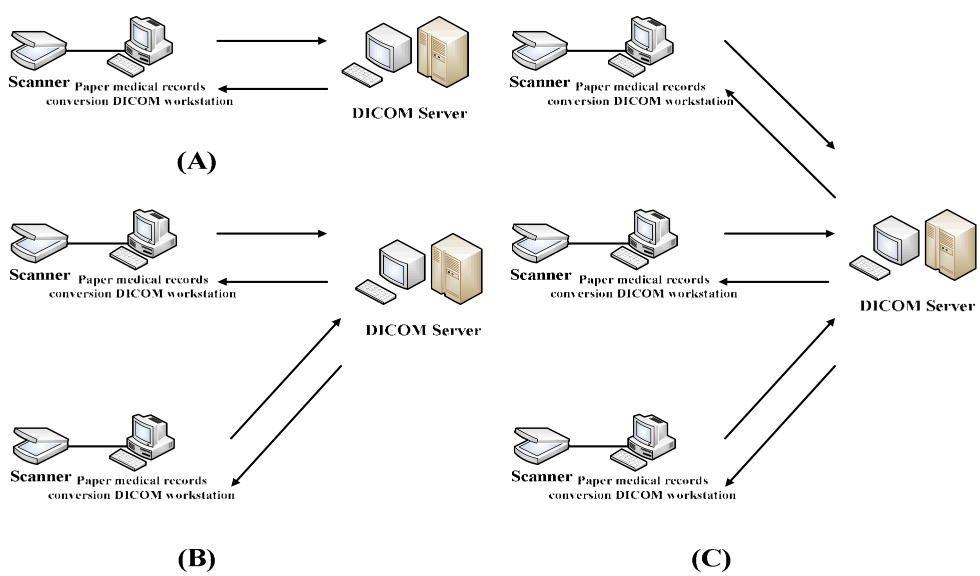

Figure 6. Diagram of computer SCU and server SCP testing

3.2 DICOM Network Transmission

3.2.1. To Save：The DICOM network consists of two parts—the SCU (Service Class User) that makes the request, and the SCP (Service Class Provider) that receives the file. This study is designed according to DICOM standards. In principle, PACS systems are equiped for network transmissions. In Figure 7, the SCU and SCP link saving and exchange of information of the sub-systems. As shown below, each computer is matched through SCU and SCP to transfer data to a medical digital image transmission server.

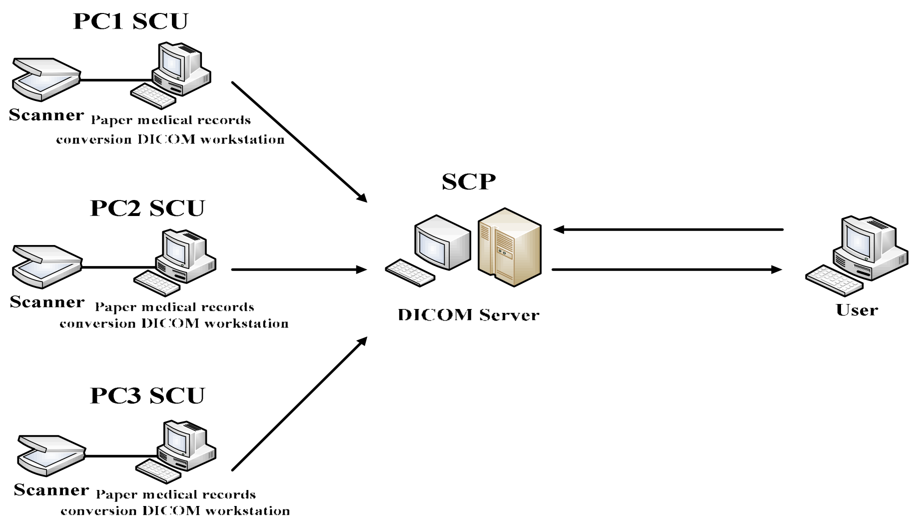

Figure 7. Diagram of computer SCU and server SCP transmission

3.2.2.**Query / Retrieve**：The user uses workstations in the clinic or the nurses station and searches for information through the sub-systems to display the data on the workstation for clinical reference, as shown in Figure 8.

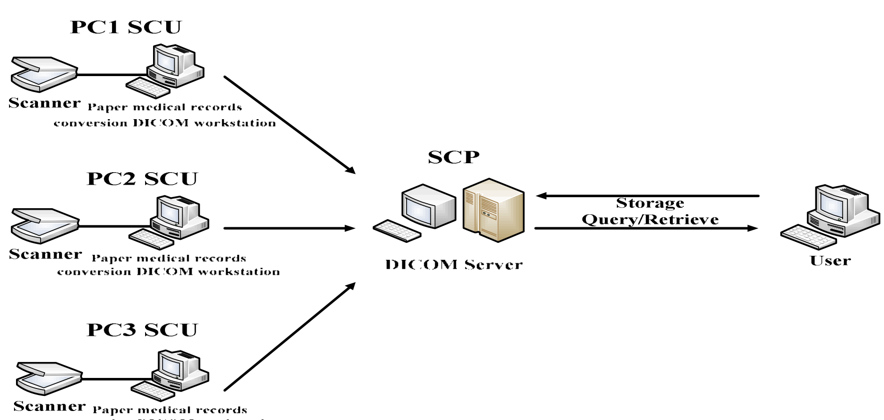

Figure 8. Diagram of user using query / retrieve on server

4. System Test Project

DICOM Transmission Service Module Test

Through testing of a DICOM archive service, evaluation of the speed and duration of one-to-one versus one-to-many computer transmissions was made. The model was of one to many computers digitalizing medical images through DICOM formatting at the same time.

Our researchers acted as users of the DICOM transfer interface. The number of files was kept the same—10 or 20 images from the clinic—to be transferred at the same time to test efficiency and determine the number of working computers for maximum sever transmission.

4.1 Query / Retrieve Testing

As shown below, TPC1, TPC2 and TPC3 engaged in server query / retrieve through a 1000 Mbps network. Five queries were made for patient data, study data and series data, and five retrieves were made for study retrieve and series retrieve to understand system efficiency in a network environment. The structure of the server query / retrieve made is shown is Figure 9.

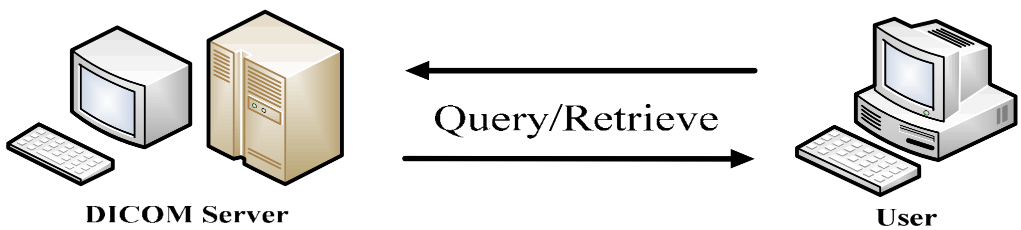

Figure 9. Diagram of user making server query / retrieve at workstation

4.2. System Testing Results-Results of DICOM Transmission Model Testing

The transmission program splits data into SCU and the listening and receiving SCP. Before a transfer, SCU will verify the correctness of the data to be transferred before messaging with SCP to send data through the network..

The chart shows that PC3 only tested the data transfer of the SCU and SCP. PC2 transferred all the data between SCU and SCP while all the sub-systems were running five times (n=5). Each time, 10, 20 and 30 pages of medical records were transferred, as shown in chart 1 and figure 10.

Chart 1. Results of transmission efficiency testing between computer SCU and server **SCP**

A

Exp	Image Type	Size（MB）	Time（sec）	N
1PC-User	10 Page（10MB）	10.1MB	35.3	5
	20 Page（22MB）	22.3MB	53.4	5
	30 Page（31MB）	31.2MB	194.1	5

B

Exp	Image Type	Size（MB）	Time（sec）	N
1PC-User	10 Page（10MB）	10.1MB	36.1	5
	20 Page（22MB）	22.3MB	57.7	5
	30 Page（31MB）	31.2MB	201.3	5
2PC-User	10 Page（10MB）	10.1MB	36.4	5
	20 Page（22MB）	22.3MB	58.3	5
	30 Page（31MB）	31.2MB	201.4	5

C

Exp	Image Type	Size（MB）	Time（sec）	n
1PC-User	10 Page（10MB）	10.1MB	36.5	5
	20 Page（22MB）	22.3MB	58.7	5
	30 Page（31MB）	31.2MB	201.6	5
2PC-User	10 Page（10MB）	10.1MB	36.2	5
	20 Page（22MB）	22.3MB	57.9	5
	30 Page（31MB）	31.2MB	202.8	5
3PC-User	10 Page（10MB）	10.1MB	36.4	5
	20 Page（22MB）	22.3MB	58.5	5
	30 Page（31MB）	31.2MB	202.1	5

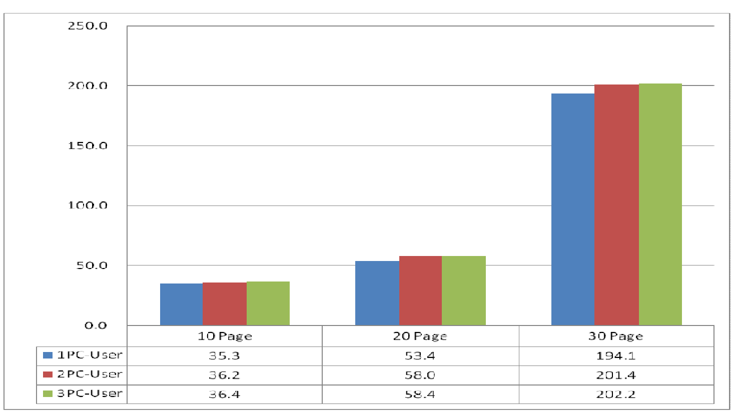

Figure 10. Transmission time difference between multiple SCUs and SCP

He user made query / retrieve to the digitalization server to search for and retrieve the data needed. After retrieving the image from the archive, it is displayed through a sub-system at the workstation. The testing was repeated five times (n=5), and each time the records retrieves were 10, 10 and 30 pages, as shown in chart 2 and figure 11.

Chart 2. Test results of query / retrieve network testing

A

Exp	Image Type	Size（MB）	Time（sec）	N
1PC-User	10 Page（10MB）	10.1MB	12.5	5
	20 Page（22MB）	22.3MB	16.8	5
	30 Page（31MB）	31.2MB	24.9	5

B

Exp	Image Type	Size（MB）	Time（sec）	N
1PC-User	10 Page（10MB）	10.1MB	13.5	5
	20 Page（22MB）	22.3MB	17.3	5
	30 Page（31MB）	31.2MB	25.0	5
2PC-User	10 Page（10MB）	10.1MB	13.3	5
	20 Page（22MB）	22.3MB	17.3	5
	30 Page（31MB）	31.2MB	25.3	5

C

Exp	Image Type	Size（MB）	Time（sec）	N
1PC-User	10 Page（10MB）	10.1MB	13.6	5
	20 Page（22MB）	22.3MB	17.1	5
	30 Page（31MB）	31.2MB	25.6	5
2PC-User	10 Page（10MB）	10.1MB	13.9	5
	20 Page（22MB）	22.3MB	17.3	5
	30 Page（31MB）	31.2MB	25.7	5
3PC-User	10 Page（10MB）	10.1MB	13.7	5
	20 Page（22MB）	22.3MB	17.3	5
	30 Page（31MB）	31.2MB	26.5	5

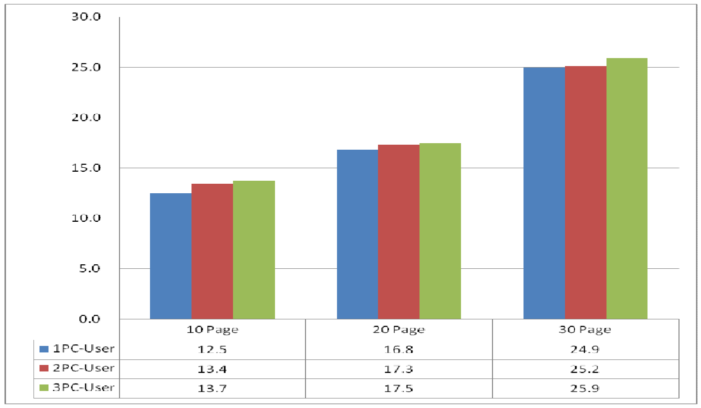

Figure 11. Time differences between multiple query / retrieve network transmissions

5. Conclusion

Therefore, digitalizing records to fit DICOM format includes network application and file management. Its difference to other formats is that it includes all the information in the same data. DICOM files are standardized and free plus a string of images. A single DICOM document is only an image, but the image may contain many sets of images in order to save images in motion and other complex data. The images may also be compressed and used in other formats including JPEG, JPEG Lossless, JPEG 2000, LZW and Run-Length Encoding（RLE）.

From the patient's point of view, a DICOM structured hospital may largely reduce waiting time. What previously may need several trips to the hospital to complete (visitation, photography then reports,) now only takes one. In a modern society that desires speed and efficiency above all else, this is a great appeal to all. For doctors, DICOM may also reduce consultation time so that doctors may have more time to engage in research. The DICOM archive also makes it easy to access data for statistic or research references.

Patient files will increase indefinitely. With speed and accuracy stressed with the retrieval of each file, a perfected computer system is needed for quality control. Thus, the system needs to be carefully monitored and disease-sorting functions should also be subject to change and updates as needed to increase the level of management.

Once all data in the hospital is computerized, IT convenience may be enjoyed. With the eradication of paper files, system stability may be improved as well as patient safely and various decision-making devices to ensure quality with timely information. A good, paper-free hospital must take into consideration how to please its users, its system stability, the accuracy of its patient records, the security of record retrieval and provide a patient-based service. All these are issues that need to be faced in the face of putting a paper-free hospital into practice.

Management of paper records is no easy feat, and at the present, no standard exists for all systems to coordinate management, so the digitalization of paper files is a technology that can reduce budget used to construct system hardware and improve system usability. The rules for electronic medical records as of now are:

1. Information standard format: for information exchange to exist, a standardized format

must be had by both parties to understand the content and meaning of the data. With the medical information promoted by the HL7, DICOM, LOINC and SNOMED, a standardized international medical information format is starting to appear—the DICOM standard format.

2. Anytime, anywhere: with the development of the Internet and computers, dispersed electronic patient files allow “anytime, anywhere” to be much more than just a slogan. In the future, even customized user interfaces may surface. Customized websites are already a reality, so a customized medical file system must not be far behind.

The digitalization of medical files into DICOM images and saved onto the hospital DICOM server through coordination with PACS provide all personnel inside the hospital and out to browse medical images and intensify patient care. Mass labor for passing files around could also be saved along with storage space, as shown in chart 3.

Chart 3. Comparison between this study and traditional paper records

Item	Traditional paper medical files	System reviewed in this study
New soft/hardware	Unnecessary	A large investment is needed initially. Follow-ups needed for upgrades.
Techs for the care and repair of soft/hardware	Unnecessary	Good communication and cooperation with relevant companies are needed.
Operating process	n/a; manual labor needed	Computer run; little chance of error
Access to records	Only available to those who borrow the files	The same file/image may be accessed by different people in different locations.
Misplacement	Very likely	Computerized images are less likely to be misplaced.
Archive space	High requirements	Low requirements
Storage conditions	High requirements	Low requirements
Accessing and archiving	Done manually; restricted by time and space available	No manual procedures needed, but cannot be brought to places without a workstation.

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