Development of a Fax-Based System for Incorporating Nondigital Paper-Based Data into DICOM Imaging Examinations

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We describe the development of software that allows and automates the routine inclusion of nondigital paper-based data directly into DICOM examinations. No human intervention is required. The software works by allowing the direct faxing of nondigital paper-based patient data directly into DICOM imaging examinations and is added as the first series in the examination. The software is effective in any typical PACS/DICOM server environment.

KEY WORDS: DICOM conversion, DICOM server, image to DICOM conversion, TIFF to DICOM, JPEG to DICOM, DICOM barcode, DICOM workflow

INTRODUCTION

Contemporary medical imaging uses the Digital Imaging and Communications in Medicine (DICOM) image format¹ for the transport and storage of medical images such as CT, MRI, and X-rays. DICOM has become the de-facto standard as the format used for moving images from one place to another and has found particular use in the area of Picture Archiving and Retrieval Systems (PACS) and teleradiology (the practice of reading medical images at a remote location from where the examination was actually performed or acquired). Radiologists, the physicians who interpret these images, often encounter a key challenge in the interpretation of these remotely acquired images: patient imaging examinations cannot be interpreted in a vacuum without ancillary clinical information regarding the patient whose examination is being interpreted.² Specifically, accurate interpretations require the radiologist to be aware of all patient information submitted by the referring physician, the patient, and the written notes by the technologist who performs the imaging exam-

ination. Additionally, it is often helpful to have the referring physician's address, telephone, email, and fax information readily available for use when communicating urgent findings. The DICOM format does allow the entry of brief patient histories, usually by the technologist, in order to provide the patient history and doctor information to the reading radiologist. However, in practice, these options are not often used as they were intended to be. The reasons for this are many: equipment vendors may charge a premium to include DICOM options for imaging equipment, often inflating the cost of already expensive imaging equipment. Moreover, busy technologists and administrative personnel may skip what they perceive as time consuming data entry tasks, rationalizing that the reading radiologist always has access to the patient's chart if more information is required. This is not always an accurate assumption, since with current PACS and teleradiology systems, the patient's chart may be located hundreds or thousands of miles from where

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the examination is actually being interpreted. To date, solutions to the clinical information issue have for the most part taken the form of faxing the handwritten clinical data (paperwork) directly to the teleradiologist, or scanning the paperwork with a sheet-fed paper scanner to be uploaded to an ftp site where they end up available to the interpreting radiologist as an entry in some type of ancillary folder. These methods can work, but may prove to be cumbersome and untenable once more than a few patients are involved.

Some software vendors have incorporated some type of capture software in their PACS or teleradiology software packages that allows the scanning and capture of scanned materials into the imaging examination. With certain exceptions, these capture applications are typically designed for capturing secondary medical images, not paperwork. Also, the software can be cumbersome to use, with many steps involved, and always involves human intervention to physically match the paperwork to the proper examination in some manner. Moreover, many teleradiologists prefer the simultaneous viewing of this ancillary handwritten paper data at the same time as the medical images are viewed, not before or after. Ideally, the viewing of this clinical material and the actual images by the radiologist should be done as a one-step process, not requiring matching or any other

steps or mouse clicks. To date, little has been done to meet this challenge by designers and developers of teleradiology and PACS viewing software. In the teleradiology practice of one of us (AR) numerous existing solutions were tried, but none was found to be satisfactory. Consequently, we developed software specifically designed to address the problem of the incorporation of paperwork/handwritten clinical patient information into DICOM image examinations.

METHOD

A growing teleradiology practice with no efficient way to automate the transmission of analog clinical paperwork to our interpreting radiologists produced the impetus to develop our software application. The first step in development was to assess the workflow and configuration of our teleradiology practice. We determined that our teleradiology practice model best fits a “spoke-wheel” configuration (Fig. 1): we maintain a central server and patient examinations are sent to our server from various client centers that subscribe to our teleradiology reading service. Our client centers vary extensively with regard to the computer and technical abilities of their employees, so we determined the most typical client

Fig 1. Configuration of Complete Radiology Reading Services, PLLC.

employee profiles we encounter. For example, Site 1 employees (Fig. 1) may feel comfortable with computers and have no problem using a sheet-fed paper scanner in conjunction with some type of scanning software in order to scan paperwork into their PACS system for later transmission to our servers with the imaging examination. Regrettably, Site 1 represents our ideal client subscriber. More often, we encounter imaging a client employee profile like those of site 2, who may have extremely limited knowledge of computers and software and perhaps also have great difficulty operating any type of software application correctly. Yet, another typical client profile is represented by Site 3. Site 3 has only one employee who is fairly technically competent and feels completely comfortable with any type of software application and paper scanner. Unfortunately, Site 3 operates on a shoestring budget utilizing used imaging equipment and no PACS system. Needless to say, our Site 3 subscriber also very likely has no funds

to invest in paper scanners and scanning software. Sites 1–3 (Fig. 2) are all examples of typical subscriber situations we see in practice. Other client subscriber site employees often represent some hybrid combination of the characteristics described for employees at sites 1–3.

Consequently, knowledge and understanding of the technological and financial resource limitations of our client subscribers in a very real sense served as a blueprint for the design of our software and its workflow requirements. We had to make our application usable with ubiquitous and inexpensive equipment that could be found in the front office of any imaging center. We also had to design our software to be workable by the lowest common denominator of computer or software knowledge of a client imaging center employee such as site 2. As a result, these most common scenarios and their permutations directly provided the model for the design of our software application. Our software application requires only a working fax machine at

Fig 2. Workflow of DICOMfaxadder.

62507-STECA

FAX COVER SHEET FOR 644 Medical Imaging MRI

PATIENT NAME: CAROLE...

DATE OF EXAMINATION: 20081003

TYPE OF EXAMINATION: MR

BODY PART EXAMINED: SHOULDER

Instructions: please place this sheet in front of the paperwork corresponding to the above patient and examination. If possible, set your fax machine for 'fine' resolution. Fax the cover sheet and paperwork to the fax number that has been provided to you as soon as possible.

THE ABOVE EXAMINATION CANNOT BE INTERPRETED WITHOUT THIS FAX.
PLEASE FAX THIS COVER SHEET WITH THE PAPERWORK AS SOON AS POSSIBLE.
THIS WILL ENSURE PROMPT INTERPRETATION OF THE PATIENT S EXAMINATION.
THANK YOU.

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Fig 3. Example of bar-coded fax cover sheet produced by DFA.

the sending client site and the knowledge of how to use it. It *allows the direct faxing of any number of paper sheets containing clinical data directly into the PACSDICOM imaging examination* for any patient examination present on our central server. We named our software application the DICOM fax adder (DFA).^{3,4}

SOFTWARE WORKFLOW

The DFA consists of two separate software applications that work in tandem with each other: we call them DICOMQUERY (DQ) and AUTO-SEND (AS). The key concept in our development of the DFA was the realization that we had to send

some type of *returnable* information to the client site where the patient examination originates from *before* the clinical paperwork was sent back to us. This returnable information must somehow be keyed to the examination that had originated from the facility sending the examination to us. Once we realized this, the next step was to decide upon the best media to use and the best way to send it to the

Table 1. Some Methods of Producing Image Files to be Processed by DFA

Fax machine
TWAIN paper scanner
Graphics print driver
Screen capture

Table 2. Some Methods of Transmitting Image Files to DFA

Fax machine
Secure FTP
Password-protected web folder
Password protected Email

originating facility and then back to us. We determined that using the fax machine to accomplish both of these tasks was the most obvious solution.

The software work cycle is initiated by the arrival of an imaging examination on our central DICOM server (Fig. 2). The DICOM server is monitored by DQ. When a new examination is detected on the server, DQ stores the DICOM header information from the examination in a database for later retrieval by AS. DQ also generates a bar-coded⁵ fax cover sheet (Fig. 3) which is automatically delivered within minutes to the fax machine at the site from which the examination originated, via fax delivery. The actual sheet is produced as a PDF file⁶ by DQ and submitted to our fax server for faxing to the client site. The bar-coded cover sheet also clearly indicates the patient, examination, and body part that it is associated with and the telephone number to fax both the cover sheet and paperwork to (Fig. 3). The client site employee simply matches the cover sheet with the proper patient paperwork and faxes it back to our fax server where it is processed by AS. The fax (multipage TIFF) file travels from our fax server on our internal network as an email attachment to an internal email address assigned to AS on our email server. AS automat-

Table 3. Enhancements and Ancillary Functions of DFA

GUI email address database of client sites for emailing encoded cover sheets
GUI Fax number database of client sites for faxing encoded cover sheets
Auto-rotates encoded coversheets faxed tilted or upside-down from the client site
Contains solution for interpreting disrupted barcodes on cover sheet sent from dirt or defective fax machine at client site
Client user can stack multiple patients at once separated by different patient cover sheets
Automatically produces and e-mails/faxes a daily log back to each client site containing patient names and examinations received by our server during the preceding 24 h including a column indicating whether or not paperwork was faxed back to our server for each patient examination or if paperwork is missing (Fig. 4)

GUI graphical user interface

ically processes this file. Image files can also be submitted to AS via direct email using an encrypted password-protected pdf attachment. Since AS can be configured to look for new files sent to any windows folder, any secure method of producing (Table 1) and transmitting the image file to the windows folder "watched" by AS will work satisfactorily (Table 2).

Processing by AS consists of decoding the barcode and transformation from TIFF (fax) format into DICOM format. Following barcode decoding, the corresponding DICOM header information for that patient is retrieved from the database (Fig. 2). All paperwork associated with the coded fax cover sheet is then transformed into DICOM format and sent to the DICOM server with DICOM SCU storage service as series 0,

CRRS HAS RECEIVED THE FOLLOWING EXAMINATIONS FROM:
 MEDICAL IMAGING MRI on 10/04/08
 PLEASE COMPARE THIS LIST TO YOUR FACILITY LOGS.
 IF AN EXAMINATION IS NOT ON THIS LIST WE DID NOT RECEIVE IT.

644 Medical Imaging MRI						
Patient_Name	Images	Mod.	Type	St_Date	Received	Paperwork
MATTHEW...	87	MR	L-SPINE	10/03	10/03 15:41	10/03 15:55
RANDY...	133	MR	RIGHT KNEE	10/03	10/03 12:59	10/03 13:14
CYNTHIA...	91	MR	L-SPINE	10/03	10/03 16:22	10/03 17:10
STEPHANIE...	110	MR	MRA/CAROTIDS	10/03	10/03 14:20	10/03 14:33
STEPHANIE...	175	MR	MRA/COW	10/03	10/03 14:21	10/03 14:44
MICHAEL...	188	MR	S.T. NECK WW	10/03	10/03 18:29	10/03 18:51
CAROLE...	113	MR	RIGHT SHOULDE	10/03	10/03 19:11	10/03 19:39

Fig 4. Example of daily transmission log produced by DFA.

where it is treated as simply another series belonging to the patient's examination. More specifically, within 5–10 min, the faxed information sent from the client site becomes the first series in the appropriate patient's imaging examination. When the teleradiologist opens the case for interpretation in his/her image viewer, the first images seen are the clinical paperwork followed by the actual imaging examination. We have fine-tuned DFA over a period of years and have added several ancillary but related functions to it in order to enhance its function, and our teleradiology practice (Fig. 4 and Table 3).

DISCUSSION

The DFA is currently running on one of our servers, and has been successfully handling over 500 imaging examinations per daily cycle for several years, attaching an average of three paper sheets to each examination. We have found it to be a significant value-added enhancement to the reading services we provide to our subscribers, allowing our radiologist associates to practice teleradiology in an appropriate manner by allowing the evaluation of all of the patient's pertinent clinical data at the same time as the images are interpreted. Moreover, the DFA can be advantageous to teleradiology practices in terms of allowing more parsimonious delegation of non-physician employees who no longer need to be delegated to matching and sorting faxes and pdf files to the appropriate DICOM examination for radiologists. The initial analog paperwork to graphic image format conversion can occur in several ways and from the following sources: (1)

sheet-fed paper scanner, (2) fax machine, (3) graphics print drivers or graphics software scanning programs, and (4) screen capture applications.

The DFA is capable of processing many image file formats (GIF, JPEG, TIFF, Fax) produced by any the above methods (Table 1), and we have employed all of them successfully at one time or another. Nonetheless, we have found that the ubiquitous and inexpensive fax machine that is always present at the client subscriber site, in conjunction with the DFA on our side, is the easiest configuration to employ with most of our teleradiology client subscriber sites. The DFA greatly enhances our teleradiology practice. It produces a quick, easy, and inexpensive way for our client subscribers to transmit the critical patient paperwork to our interpreting radiologists.

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