Integrating RIS/PACS: The Web-based Solution at University Hospital of Ribeirão Preto, Brazil

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Integration of a Radiology Information System (RIS) and a Picture Archiving and Communication System (PACS) reduces the risk of inconsistent data by reducing interfaces among databases that contain largely redundant information. Furthermore, RIS/PACS integration is the basis for a filmless radiology facility. Web technology is based on international standards and supplies the main features for the RIS/PACS integration task based on a client/server model. This article presents a web-based system developed to manage and distribute images and diagnostic information within the University Hospital of Ribeirão Preto (HCRP) at the University of São Paulo.

KEY WORDS: PACS, RIS, filmless radiology, web technology

INFORMATION SYSTEMS for managing medical images and data first appeared in the late 1980s, when digital acquisition procedures began to be used in large hospitals. At that time each procedure was considered an isolated system, simply connected to the display station and a dedicated printer.¹ The potential of these early systems, along with the growth of digital information distribution procedures, produced the need to standardize the format of medical imaging and communication. In response to this need, the National Electronic Manufacturers Association (NEMA) and the American College of Radiology (ACR), with the support of the Radiology Society of North America (RSNA) and a number of radiological equipment companies and universities, created the DICOM (Digital Imaging and Communication in Medicine) standard. Originally named the ACR-NEMA standard, DICOM was introduced to the public for the first time at the 1993 RSNA meeting.^{1,2}

Standardization through DICOM was essential for the development and implementation of the Picture Archiving and Communication System (PACS). PACS has been rapidly evolving into the best technological option for tasks such as medical image transmission, archiving, and display, thus forming, along with the Radiology Information System (RIS) and the Hospital Information System (HIS), a basis for a filmless radiology service.

Filmless radiology uses a high-bandwidth network that transports digital images among electronic systems that acquire, archive, communicate, and display these images. The goal of implementing a filmless radiology service is to provide enhancements such as greater accessibility, integration of images and reports, application of new techniques for the development of new acquisition protocols, and new methods for processing and displaying images. It should also create an economic impact by reducing the expenses associated with storage and handling of conventional radiographs and eliminate any waste and additional radiation dose associated with repeating exams. According to specialized literature, most medical services will probably

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have performed the transition to filmless radiology within the next 10–20 years.³

In a filmless environment, the RIS/PACS integration is the basis for a successful electronic radiology practice, preventing data inconsistency and assuring the integrity of information among the involved databases. Web technology is one way of achieving this integration since it is based on international standards and can provide information distribution. Since these technologies are being incorporated into many aspects of life, there is a very fast learning curve for the end user. In addition, web technology is an appropriate basis for integrating systems based on a client/server model. In this model, a server machine handles all complex processing, and communication with the client machine is carried out using a standard protocol. Additionally, the interface for data and image display can be standardized and used throughout an enterprise using a web browser. Thus, client and server machines can be managed independently and data transmission is controlled by an operational system, providing better guarantees in terms of efficiency and stability.¹

The Science of Image and Medical Physics Center (CCIFM) of the School of Medicine of Ribeirão Preto (FMRP-USP) has been working toward transitioning the radiodiagnosis service of the University Hospital of the School of Medicine of Ribeirão Preto (HCRP) to a filmless environment. This process began in 1998, with the proposal to develop and implement RIS⁴ followed by the introduction of a PACS. Implementation began in 1999 and is still in progress. The RIS has been operational since August 1999 and RIS/PACS integration was done in late 2002. This article describes the current status of the project named Filmless-HCRP, as well as some of the applications that are currently being developed. Outcomes of the preliminary experiences using the implemented systems are also presented here.

MATERIALS AND METHODS

The Filmless-HCRP had an initial goal of creating the base systems for a filmless service, leading consequently to the creation of both RIS and PACS-HCRP. These systems were developed separately because of their complexity and the need of making arrangements to solve the urgent

requirements of the University Hospital (HCRP). This resulted in a number of heterogeneous systems that perform specific tasks ranging from patient registration to image generation. The information, although perhaps relating to the same patient, was distributed among the systems' databases and needed a linking key to assure referential integrity. For that reason, a new system needed to be implemented to integrate all the data and link examination reports with their respective images.

The RIS-HCRP (Radiology Information System of the University Hospital of Ribeirão Preto) was developed to work under a client server model, with a relational data model and friendly graphic user interface providing acceptance by the end user. Currently, all RIS and HIS data are stored in an Oracle database (version 8.1.7.0.0), and front-end interfaces are implemented using Delphi 5 (a Visual programming language). Main RIS modules are patient report generation, patient report search, and management. Access to these modules is defined by the rights assigned to each user, who must be registered in the system with a user name and a password. Once the system is initialized, both username and password are requested, thus providing access only to modules for which they have received permission, according to their function in the service activity workflow. When there is a request for an exam, a label with a barcode is generated by the HIS; it contains the patient's registration number and the clinic that submitted the exam requisition. When the exam is performed, the technologist generates an electronic record in the exam generation module by reading this barcode which generates an automatic insertion of information concerning the type of exam, anatomic region, and applied technique. When the exam is over, the images are forwarded to the reading room in order to be assessed and registered. Reports are initially done by resident physicians and later verified by faculty physicians. A report initially receives a status of temporary in the system, not accessible on the HCRP web until the reviewer (physician) has checked it and released it as definitive. After revision, the definitive report can be accessed by any HCRP station through the intranet search module and can also be printed directly in the Medical Archiving System (MAS), in which it is attached to the patient's report. Detail about RIS can be found in a previous article.⁴

PACS-HCRP (Picture Archiving and Communication System of the University Hospital of Ribeirão Preto) is composed of software and hardware that form a system supporting several services such as a DICOM server, the DICOM (storage) server for image archiving, the integration interface with the RIS/HIS server, and the webserver (Fig. 1). The DICOM server used in this study was the CTN (Central Test Node) (<http://www.erl.wustl.edu/DICOM/ctn.html>), which is open-source software developed by the Mallinckrodt Institute of Radiology, Electronic Radiology Laboratory, to demonstrate the efficacy of the DICOM standard. It uses a relational database to store its configuration and data concerning the acquired images. In its configuration structure contains the registration of a table called "Application Entity" all equipment that interact in the image communication process. It is important to note that the CTN can support only TCP/IP communications. Besides its tables that store data with the configuration for

Fig 1. PACS-HCRP structure.
Flow A: acquisition and storage of DICOM images. **Flow B:** exhibition of electronic radiology reports and associated images.

image communication, CTN also supplies services or programs that run on both the server's and the clients' side in order to assure accurate communication. The main service, which handles the acquisition and storage of DICOM images, is the archive server. It receives all the DICOM messages, reads the header of the file (message) it is receiving, and saves the relevant data in the database tables. These data consist of information about the patient, the exam, and a pointer to the location where the original DICOM file is archived on the server.

The main CTN tables are "patient level" — patient information such as identification, name, date of birth, sex, etc; "study level" — information concerning exam studies which are defined during the exam acquisition [it is in this table that the tag accession number information is archived through the "acnum" (accession number) column]; "series level" — information regarding exam series; "image level" — specific image information; "instance table" — it is in this table that the pointer indicates where the original DICOM file is stored on the server. It is important to note that this table structure is extremely important and must maintain synchronization and linking of all data between the RIS and PACS databases.

Considering that DICOM files can be quite large depending on the type of exam, a large archiving area in the server must be available. For this reason, another 200-GB server was incorporated in to the PACS structure with the goal of storing these images, thus allowing online consultation.

The PACS-HCRP system is a continuation of the whole process of assisting patients for image diagnostic exams. After having generated the exam in the RIS, the technician types the patient identification and information about and exam into the equipment's interface, where the images will be generated (e.g., magnetic resonance, ultrasound, computerized tomography). At this time, the accession number is inserted into its group and element position in the DI-

COM header. Images are generated with the patient's information in the DICOM message, compacting everything in one file (DICOM), which will be sent to a DICOM server through the HCRP ethernet. In this study, this function is performed by the CTN, which establishes the communication with its clients through a specific communication and waits for the sending of new files (exams). When the CTN receives the files, it extracts patient and exam information and archives it in its database tables. The acquired original file containing all this information and exam images is archived in a specific folder that is created in the archiving server under the accession number. Patient and exam information is shared on the system basis, allowing data integrity and consistency in the RIS/PACS system and assuring reliability to the link of demographic information with the generated images.

After performing these preliminary steps, it is possible to effectively complete the RIS/PACS integration. In order to do this, web technology is used, with access and distribution of these systems' information by means of a HTML (Hyper Text Markup Language) and ASP (Active Server Pages) application, running on a IIS (Internet Information Server) and connected to two databases via ADO (ActiveX Data Objects).

The link between exam reports and images is done in real time by the INTRANET-HCRP web system. During the web report search process, a window with a user-friendly interface is opened for the physician who wishes to visualize a specific patient's exam; the window requests the physician's username and password. The system offers a few options, for example, the electronic report search. By selecting this option, a new window is opened in which the user may enter a patient's register number or ask to recover all exams of a specific kind within a certain period. Once the patient and exam are selected, a new window is open, showing the exam report and information regarding the radiologists who interpreted the exam. The system then

performs a link with the RIS/PACS and checks if there are any online images for this exam in the CTN databases. If so, a link at the bottom of the report window allows the user to retrieve the images and opens a new window initializing a Java applet for the display of the DICOM images (Fig. 2). This Java applet, named Dicom Viewer, is open-source software developed and offered by Nagoya Institute of Technology, Iwata Laboratory, Japan (<http://mars.el-com.nitech.ac.jp/dicom/index-e.html>) with the goal of visualizing DICOM images by means of a web browser.

RESULTS

The RIS was initially implemented in the magnetic resonance and computed tomography (MR and CT) sectors of the HCRP. This choice was made because of the smaller volume of exams made in these sectors compared with that of others, such as conventional radiology, and also because technologists were familiar with computers, which are inherent to these modalities. In addition, the MR and CT equipment was DICOM compliant and this allowed optimization of the interfacing prior to implementing the radiodiagnosis service. After an initial period of use and adjustments, the system was extended to the other sectors of the radiodiagnosis service. Now, all radiological exams currently performed in the HCRP are generated and reported using the RIS environment with images available for browser searches in any computer connected to the hospital's intranet. The system is still being tested and improved but has already shown efficiency for its purpose and has allowed the integration of electronic report systems with a filmless focus in other hospital areas such as gynecology and obstetrics and digestive endoscopy.

The web application allows the search for exam reports by stating name, last name, HC patient register number, or type of exam within a certain period. When a patient is selected, a new window is open displaying all exams that match the requested parameters. The physician can then select the exam of interest, opening a patient's exam report in another window. This report contains the report description and the names of the reading and reviewing physicians. If there are any available images, the user may see them in another window by activating the display button that appears at the bottom corner of the report window. This button starts the

DICOM image display, allowing the user to see the images and make use of functions such as zooming, brightness control, and side-by-side viewing of different images of a selected study. The available images are referred to as online. As images age, they are removed and stored on a CD and receive an offline status in the system. The current online images' archiving period is approximately five months. If there is a need to recover an offline image, it is possible to perform a search on the RIS and acquire the identification of the CD that contains the images of the required exam. Then, the physician has to ask the radiodiagnosis service to load the specific CD.

The accession number is the only criterion used at this moment to associate images to an examination. Images sent to archive without the accession number are accepted by the archive but stored in a special collection of unknown objects. Authorized persons later can associate these unknown objects to the correct examination. If the technologist types in wrong information concerning the accession number, the link between reports and images will not be possible and the information must then be corrected manually. In the same way, any other detected inconsistent data concerning patient identification and exam must be corrected manually.

DISCUSSION

The main goal of the development and implementation of a RIS in the radiodiagnosis service of the HCRP was to optimize the process of report search and communication through the hospital's ethernet. Before RIS implementation, reports were entered manually, checked by specialists, forwarded for typing, then printed, corrected, reprinted, signed, and forwarded to the Medical Archive Service (MAS). This process had an average turnaround time of 2–3 days, which made the search for reports that were still unavailable in the MAS rather long. With RIS implementation turnaround time was reduced considerably because once the report was reviewed, it was made available for online search. In addition to this, the definitive report was now sent directly to the MAS using electronic signatures, which made

Fig 2. Screen sequence for radiology electronic reports and associated images exhibition. (a) The hospital intranet page with the user login and password on the upper-right corner. (b) RIS database exams search based on patient ID. (c) RIS database search result for the specified patient. (d) Electronic radiology report of a selected MR exam. (e) MR image visualization with the DICOM Viewer.

the distribution process much faster. Although the main goal of RIS implementation was report search, its potential in assisting management and quality control of the exam generation process is extremely great. Since a report of the whole process performed in the system's environment is archived, it is possible to recover statistical information regarding the exams performed and the losses and repetitions that might have taken place; this helps detect critical points (technical as well as managerial) in the service's workflow.

Concerning the PACS, structuring a filmless radiology environment at the HCRP radiodiagnosis service has been one of the goals for the Science of Image and Medical Physics Center. Through the fellowship established with the HCRP Analyses and Information Center (AIC), the implementation of a DICOM server and a web application was made possible for the linking and communication of images and associated reports. Initially, only magnetic resonance exam images were made available, but the developed structure is generic and will be extended to other modalities. A new, customized DICOM server version is also under evaluation, with the intent of saving offline images in CDs and DVDs with greater RIS integration. In the current structure, the exam's accession number is manually inserted into the DICOM header by the technologist; forwarding of ima-

ges to the server is also done manually. However, a new RIS version is being developed in the AIC/HCRP that will implement scheduling and the generation of worklists, as well as the automatic forwarding of data to modalities and images to the server. Another important aspect of the new RIS will be the implementation of structured models for reports based on the Index for Radiological Diagnosis of the American College of Radiology.⁵

As part of the filmless environment project, a report workstation is under development, with the goal of allowing radiologists to work without the need to print films (Fig 3). Besides the basic functions of image manipulation, report stations will allow a selection of key images to be linked to the respective reports. Images for browser searches will be the key images selected by the radiologist and made available in JPEG format by a webserver. Access to DICOM files will then be restricted to report stations. Hence, it will be possible to keep an exam file online for a longer period, 3–4 years for example. DICOM images will be available online for 1–2 months and then stored offline in CDs or DVDs. If DICOM files are necessary, they may be requested from the radiodiagnosis service.

No systemic problems or standard failures in sending or receiving images were found regarding communication between modalities and the DICOM server, thus confirming that

Fig 3. PACS-HCRP structure for filmless environment.

DICOM serves all the stated goals for managing and distributing images within the HCRP radiodiagnosis service. It was also observed that the HCRP ethernet is nearly adequate for a filmless system, but it requires more bandwidth. Therefore, structural improvements are being made in order to increase HCRP's net bandwidth to 1 Gbit/s.

Finally, a content-based image retrieval (CBIR) facility will be included in the PACS. It uses automatic extraction and comparison of pictorial attributes for query and retrieval (Fig 4). Research for the development of the CBIR system has begun and is being conducted under a fellowship with the Data Base and Image Research Group (GBdl) (<http://www.gbdi.icm-c.usp.br/index.eng.html>) from the Computer Science and Statistics Department of the University of São Paulo at São Carlos, Brazil.

CONCLUSION

The University Hospital of the School of Medicine of Ribeirão Preto at University of São Paulo (HCRP) is one of the largest teaching hospitals in Brazil. It has 817 beds with approximately 22,000 inpatients and 590,000 outpatients treated per year. Around 184,000 radiological exams are performed per year, where 3.6% are magnetic resonance, 8% are computed tomography, 9.4% are ultrasound, and 79% are conventional radiography. The radiology facility of HCRP is located in two different buildings: one is in a general hospital at the University of São Paulo campus, and the

other is at an emergency unit hospital in the downtown São Paulo. Initially, RIS/PACS were introduced as information management systems aimed at improving the efficiency of radiology practice and making images and associated radiology reports available through the use of network protocols. Although time reductions and efficiency improvements have not been quantified yet, the information interchange has been very helpful for the integration of physicians located at the general hospital and at the emergency unit, which is especially important for a teaching hospital.

An important part of implementing RIS/PACS is the necessity of a good model of data organization, classification, and retrieval. The data consist of a wide range of data types from simple text and numbers to audio, images, and video recordings. Because of the overwhelming increase in the volume of images, it is necessary to use more efficient and sophisticated methods to organize such data. There are two approaches for searching images in an image database. The first attaches a textual description to each image and the search process finds the required images using this text. This is not the optimal solution for two reasons: it cannot be automated and the retrieval depends on the objective description from the operator describing the image (as when a radiology report is generated), which may be different from the description used when the query is issued. The second approach uses a set of image processing algorithms to automatically extract characteristics (features) from the images, and

Fig 4. Example of content-based image retrieval application. The interface allows the selection of a query image either into the PACS database or through an external media and retrieves images with similar histograms based on a k -nearest-neighbor approach. The query image is shown on the left upper corner and the user can choose a retrieved image to see the respective electronic radiology report.

those characteristics are then indexed together with the image. In this approach, the image retrieval operation processes the image features instead of the images. This approach is independent of human subjectivity and is the core of the CBIR system. The PACS with content-based image retrieval resources, called cbPACS,⁶ answers similarity queries, taking advantage of a metric access method embedded into the image database manager. The cbPACS implementation has been an arduous task. It is necessary to find specific features for each anatomy structure, imaged by each modality. Furthermore, it will be necessary to recognize normal and pathologic patterns and, perhaps,

to identify different types of pathology. Currently, the system works on features based on gray level distribution of images,⁷ but cbPACS is prepared to integrate new image features based on texture and shape of the main objects in the image.

The RIS/PACS implementation was the initial step of a project intended to build a filmless environment with an integrated CBIR facility. Besides, other services at HCRP have had their information systems upgraded following a schedule for Electronic Patient Record (EPR) implementation and images and hospital EPR integration. Although in an initial version cbPACS tests have shown a good potential for

hospital application, a more complete version will be made available for public utilization in the next 4–5 years.

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