Part II: Preparing and Assessing First-Year Radiology Resident On-Call Readiness.

Technical Implementation[1]

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Rationale and Objectives. The effectiveness of using a Digital Imaging and Communications in Medicine (DICOM)-based interactive examination system in evaluating the readiness of first year radiology residents before taking overnight call in the emergency department (ED) was reported in part I of this article. This report describes technical aspects for the design and implementation of this system.

Materials and Methods. The examination system consists of two modules: Data Collection and Image Viewing. The Data Collection module was a personal computer (PC)-based DICOM storage server based on a free public domain software package, the Mallinckrodt Central Test Node. The Image Viewing module was a Java-based DICOM viewer created using another freeware package: zDicom ActiveX component.

Results. The examination takes place once a year at the end of the first 6-month rotation. Cases selected for the examination were actual clinical cases according to the American Society of Emergency Radiology core curriculum. In the 3-hour timed examination, each resident was required to read the cases and provide clinical findings and recommendations. Upper-level residents also participated in the examination to serve as a control. Answers were scored by two staff radiologists.

Conclusion. We have been using this examination system successfully in our institution since 2003 to evaluate the readiness of the first-year residents before they take overnight call in the ED. This report describes a step-by-step procedure for implementing this system into a PC-based platform. This DICOM viewing software is available as freeware to other academic radiology institutions. The total cost for implementing this system is approximately $2000.

It is essential to evaluate the basic reading and interpretive skills of first-year residents before they begin taking overnight call in the emergency department (ED) without direct attending supervision. Depending on individual radiologists, subspecialties, and academic settings, forms and styles for such evaluations may vary. In the past, before the implementation of a picture archive and communication system (PACS), using hard copies of preselected images along with multiple choice questions was the most popular and cost-effective approach. Although this traditional "view-image-and-pick-answer" approach has been used widely in radiology learning and still is commonplace in many Web-based teaching files (1,2), it does not necessarily reflect the individual's interpretive skill or actual hands-on proficiency in executing basic PACS functions (eg, window and leveling). Insufficient or lack of confidence in these interpretive and hands-on skills may result in missed findings, wrong impressions, and failed communications. This confidence is particularly crucial for first-year residents before taking overnight call in the ED. We identified the need to develop an objective, meaningful, and easy-to-implement system for first-year resident on-call readiness.

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In a previous article, we described the effectiveness of administering an interactive examination by using a Digital Imaging and Communications in Medicine (DICOM)-based system along with a month-long Emergency Radiology Core Curriculum ED lecture series (3). Results obtained from this examination were used as an unbiased index for assessing the readiness of our first-year radiology residents before taking overnight call in the ED. This system has been used in our institution on an annual basis since 2003. This current article describes the detailed technical aspects for the design and implementation of this examination system.

MATERIALS AND METHODS

System Design

The basic objective is to develop an examination system that can be used to evaluate not only the essential interpretive skills, but also the hands-on capability of using basic PACS functions. As mentioned, the major advantage of this examination system compared with the traditional testing approach is the use of an interactive PACS viewing simulator with actual series of clinical cases. Although at the beginning of the design period, consideration was given to our existing PACS for this purpose, the associated software and hardware costs and potential Health Insurance Portability and Accountability Act (HIPAA) issues drove our decision to develop a stand-alone system. Based on the primary objectives, existing network constraints, and resources appropriated to this project, the following hardware and software requirements were identified.

Hardware Requirements

The system must:

- Be able to collect DICOM images by using a standard DICOM protocol
- Allow online sharing of DICOM images during the examination
- Be able to store examination cases for up to 10 years
- Be configured with self-backup capability
- Be configured using industrial standards
- Be supported by our information system
- Be low cost (<$5000)

Software Requirements

- The DICOM connectivity must allow automation
- The DICOM Viewer should provide basic viewing functions
- The DICOM Viewer should accommodate multiple users simultaneously
- The software must be HIPAA compliant
- Any software packages used must be compatible for future system updates

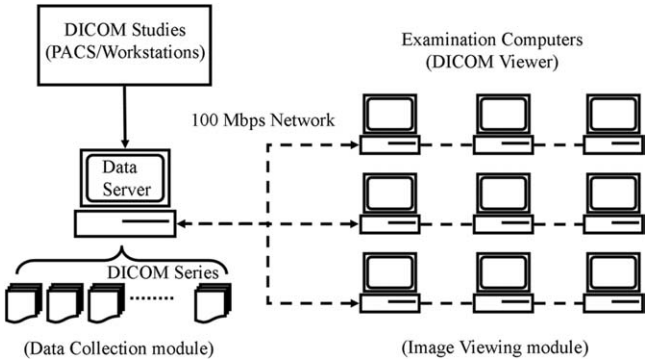

Figure 1. System schematic of the DICOM-based examination system consists of two modules: Data Collection and Image Viewing. The Data Collection module consists of a data server for storing DICOM images sent from other DICOM modalities, such as PACS and workstations, using the CTN DICOM storage application. The Image Viewing module consists of a PC-based DICOM Viewer developed using the eZDicom ActiveX component.

System Implementation

Based on the identified hardware and software requirements, a personal computer (PC)-based system and two public domain freeware DICOM packages, Central Test Node software (CTN; Mallinckrodt Institute of Radiology) and eZDicom, were selected for our implementation (4,5). The examination system consists of two modules: Data Collection and Image Viewing.

Data Collection Module

The Data Collection module is a data server for storing DICOM studies and distributing images during the examination (Figure 1). This server is a PC-based system (Optiplex GX400; Dell, Round Rock, Texas) running Windows 2000 Professional operating system (Microsoft Windows; Microsoft Crp, Redmond, WA) with two 320-GB hard drives. The two hard drives are configured as Redundant Array of Inexpensive Disks (RAID) format using an internal RAID adapter (SATA 1200Al; Adaptec, Foothill, California). With this RAID-1 configuration, disk space is available for storing a large number of DICOM studies. Up to 1000 clinical cases can be stored in this server based on the assumption of 600 computed tomographic images per case (or an equivalent data set of 300 MB for other modalities). The hardware is configured by using standard computer parts with support

warranty provided by the manufacturer. Currently, this system is installed in our PACS network with standard backup power supply. Other system maintenance, such as Windows Updates and Security Patches (Microsoft), are supported and performed by our information system. The total equipment cost for this system was $1950.

For the purposes of this system, the data server requires only the basic DICOM transfer function (ie, storage capability). Therefore, we chose to use a public domain DICOM package, CTN (4). CTN currently is a standard for DICOM development and is being supported by the Radiological Society of North America. Although this package provides many other sophisticated DICOM utilities, only two were being used: simplestorage.exe and dcm_modify_elements.exe. The first application (simplestorage.exe) is for receiving DICOM images, and the second (dcm_modify_elements.exe) is for removing patient name, medical record number, and other protected information for HIPAA compliance. These two applications are precompiled DOS-based applications without any installation requirement. The operations of these two DICOM applications are automated using the built-in Windows Startup function provided by the operating system.

DICOM images are transferred directly from our PACS and workstations. As a standard procedure, DICOM parameters (ie, IP address, Port number, and AE Title) for the data server were configured at the sending machines (eg, a workstation) by our onsite PACS engineer. DICOM images are automatically processed and stored in simple folder systems using the accession numbers. During the examination, selected DICOM images are moved to a shared location for data access by the Image Viewing software.

Image Viewing Module

The Image Viewing module is a basic DICOM Image viewer with functions for viewing and manipulating series of DICOM images. Although there are many freeware toolkits and commercial products appropriate for our project (6), we chose the freeware eZDicom (ActiveX component). This ActiveX component is compatible with most desktop programming languages, including C++, Delphi, Basic, and Java. Because this component is a stand-alone ready-to-use DICOM module, no DICOM programming skill is required. The eZDicom package also contains sample applications and source codes. In our implementation, we developed an Image Viewer based on this ActiveX component using Java language (Sun Microsystems, Santa Clara, California). Although the viewer we developed is a simple application, it contains all the essential viewing functions available in our PACS workstations, including image scrolling, window and level adjustment, pan and zoom functions, and linear measurement (Figure 2). Currently, we provide this DICOM Viewer as freeware for other academic institutions. It is available through email request to the corresponding author.

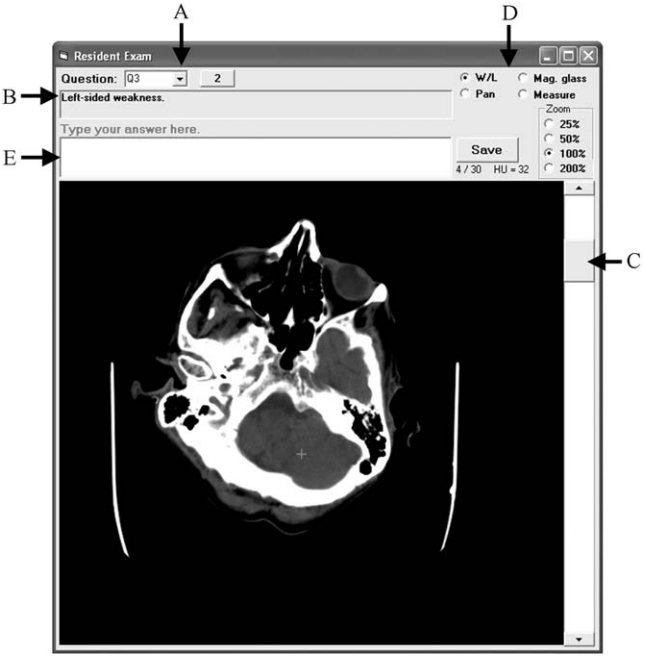

Figure 2. Screen capture of the DICOM Viewer application shows the functions for loading and viewing DICOM images for the examination. **(a)** Drop-down menu for selecting cases, **(b)** patient history, **(c)** interactive button for scrolling images, **(d)** basic viewing functions, and **(e)** textbox for entering answer.

RESULTS

This DICOM-based examination system was developed and first used in 2003 for evaluating the readiness of the first-year residents before taking overnight call in the ED. Based on feedback from examinees, the DICOM Viewer was modified in 2004 and 2005 to improve viewing features and image loading speed. The current version of the software allows loading of a large number of images (eg, 1000 computed tomographic images). Step-by-step procedures for administering one of our actual first-year resident examinations (Examination 2006) are provided in the following subsections.

Demonstration (Examination 2006)

[Step 1] Delivering ED lecture series.—At the end of the first 6-month rotation, a month-long ED lecture series

was given to the first-year residents by our staff radiologists. Contents of this lecture series were based on American Society of Emergency Radiology core curriculum (3).

[Step 2] Case preparation.—At the conclusion of the lecture series, clinical cases (n = 20) were selected by two ED-trained staff radiologists based on the contents of the lecture series. Accession numbers for these cases were given to the data server administrator. Corresponding DICOM image folders were then moved to the shared location within the server.

[Step 3] Viewer preparation.—Nine standard PC-based computers were prepared in three nearby locations for the examination. To avoid conflicts in regular clinical schedules, the examination was administered in four consecutive sessions with nine residents each. DICOM images were transferred or copied from the network-shared location to these computers the day before the examination.

[Step 4] Examination setup.—During each of the four examination sessions (two sessions per day at 7:00 AM and 12:00 noon), examinees were given individual access codes for identification. A staff radiologist was assigned to proctor each session.

[Step 5] Case viewing.—Each examinee was given 3 hours to read the cases using the DICOM Viewer and to provide clinical findings and recommendations (Figure 3). The viewer provides basic PACS functions, such as window and level adjustment, image scrolling and zooming, and linear measurement. Answers provided by the examinees were collected at the data server. A backup copy of the answers was stored on the local examination computers (n = 9) until the end of each session.

[Step 6] Scoring.—The answers were spot checked by the examination proctor at the end of each session. The DICOM Viewer was then reset to remove all answers from the previous session. The answers were then scored independently by two staff radiologists who were blinded to the residents' identities. Although the system was designed primarily for assessing the readiness of the first-year residents, upper-level residents also participated in the examination. The detailed mechanism for scoring and judging the readiness of the first-year residents is described in part 1 of this two-part series article (3).

DISCUSSION

The interactive DICOM-based examination system we developed is a more meaningful approach to assess the readiness of first-year residents before taking overnight call compared with traditional testing methods of using static and preselected images. Implementation of this system is detailed in this article. The DICOM viewing software we developed is available as freeware for other academic radiology institutions.

Figure 3. Photographs from an actual examination (Examination 2006) show multiple residents taking the examination simultaneously in nearby locations.

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