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Reviewing Images From Portable Media: An Ongoing Challenge

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INTRODUCTION AND STATEMENT OF THE PROBLEM

Distributing imaging data on portable media has become a common practice. Imaging centers frequently copy imaging examinations to portable media such as CDs (or DVDs) for patients and referring physicians. When patients present for their care at other institutions, physicians or their information technology personnel may import the data from these CDs into the organizations' picture archiving and communication systems (PACS) to use the familiar PACS user interface to view the images. Alternatively, physicians may choose to review the images directly from the outside CDs using PCs.

When there is no mechanism to incorporate the examination into a PACS or when a PACS is not used, such as in an outpatient private office, image-viewing software is needed. This software may accompany the images on a CD and may be designed to launch automatically when the CD is loaded into a PC. Some physicians choose to use third-party software products. The ease of use will vary by vendor and by operators' familiarity with the software.

Although portable media such as CDs provide convenient storage for imaging data sets, access to those media outside of originating facilities may be problematic. In practice, the exchange of medical images and accompanying information on storage media still has problems that frustrate many medical specialists [1]. A receiving institution may need to register a patient in its information system (hospital information system, radiology information system, or both), import the images into a temporary archive, and reconcile the patient and order IDs before importing the images into the local PACS. In addition, nonstandard formatting of storage media and saved data sets poses a significant barrier to a seamless exchange of medical imaging data through portable media.

Because many physicians have experienced difficulty viewing and navigating through imaging examinations from CDs that patients bring for clinical consultations, the American Medical Association (AMA) passed Resolution 539 (A-06), "Development of Standards for MRI Equipment and Interpretation to Improve Patient Safety" [2]. The AMA has convened a series of meetings with representatives from imaging equipment manufacturers, radiology and other interested medical specialties, and imaging facilities, with the goals of

(1) agreeing to standards in electronic imaging formats (e.g., left to right, axial, coronal, sagittal); (2) developing standards of data manipulation and localization consistent throughout all units for best interpretation of the data; and (3) ensuring that each electronic format is equipped with the capability of loading and launching its contained images on the physician's computer. [3]

The AMA is looking to the imaging community to help propose solutions to help clinicians efficiently view patients' imaging data. Because the incorrect identification of image features such as laterality could result in serious adverse events, the AMA has raised concerns of patient safety and has called for "standards" to address this issue.

EXISTING STANDARDS

The Digital Imaging and Communications in Medicine (DICOM) standard is the most widely implemented and supported communications standard for medical imaging data [4]. The ACR and the National Electrical Manufacturers Association founded an effort in 1983 to create a standard method for transmitting medical images and associated information through a standardized terminology and structure for information exchange. The DICOM standard has grown to become international in scope and to incorporate numerous specialties that generate and use medical images, such as pathology, gastroenterology, and surgery.

The DICOM standard does not define a particular PACS architecture. Rather, DICOM specifies the protocols and services that allow imaging systems, including PACS, to communicate. The DICOM standard ensures interoperability between imaging devices and PACS. Under the DICOM standard, image data and associated information are organized into objects so that examinations can be communicated as a precisely organized set of data elements.

To prevent incompatibility between different imaging equipment, the DICOM standard has a highly structured format for images

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and related information. One of DICOM's most important features that has enabled its success is an open standards development process. That process encourages the involvement and consensus of both vendors and users. The DICOM standard has allowed improvements in image quality by achieving consistency in the presentation of images on film and on different display monitors, independent of the brand, type, and characteristics of the media. This quality initiative was achieved through the creation of a "gold standard" to which every monitor and hard-copy device could adhere. Since 1999, DICOM has operated a joint working group with Health Level 7, the organization that sets standards for messaging among clinical information systems. The DICOM standard has a strong relationship with the Integrating the Healthcare Enterprise (IHE) initiative, in which profiles of standards are defined as solutions for health care workflow and enterprise integration challenges. The IHE initiative is not a standard per se but a set of profiles that use and endorse standards such as DICOM and Health Level 7 [5].

Almost all image acquisition modalities, such as computed tomography, magnetic resonance imaging, and ultrasound, provide a DICOM interface to transmit images across networks. Also, modern PACS provide DICOM interfaces to import images. Exporting imaging data from a PACS to CDs usually also involves saving data in DICOM format. Therefore, image-viewing applications that are able to read DICOM images can be used to review imaging examinations on CDs. Although DICOM specifies a format for the exchange of imaging data using portable media such as CDs, vendors may not comply fully with the standard. As a result, one vendor's image viewer may not be able to render an imaging examination written to a CD by another vendor's equipment, and for the same reason (ie, DICOM noncompliance), these images cannot be imported into the PACS.

Only a few PACS vendors do not support the DICOM standard. Instead, those vendors store images in proprietary formats. When distributing images on CDs, most vendors package copies of their viewers on the same CDs with the patient imaging data. Images on CDs from those vendors with non-DICOM-conformant image formats may be accessible only through the vendor-specific image viewing clients, which are not always intuitive to navigate.

There are 3 main problems with this approach. First, whenever an executable file such as image-viewing software is exchanged, there is a heightened chance of spreading a virus. Many institutions have very strict guidelines that prevent running nonvalidated software on their PCs and would not allow opening such viewers. Second, this approach does not allow proprietary images to be imported into users' PACS for comparison with other examinations. Third, images cannot be viewed using physicians' familiar software and cannot be analyzed for 3-D or other postprocessing. Even if a vendor claims to store images in DICOM format, the standard may not be followed completely. Compliance with DICOM is not an all-or-none phenomenon; the ability exists for partial compliance and the creation and support of private extensions. These customizations to DICOM are becoming less frequent as the standard is updated and newer objects with more mandatory attributes become available. So it is also important to support new objects in computed tomography and magnetic resonance imaging to garner these interoperability benefits.

The IHE Portable Data for Imaging (PDI) integration profile has been specified to address how images and related information can be exchanged among imaging and viewing devices using DICOM-conformant CDs [6]. The IHE PDI profile describes the use of DICOM to store a complete set of uncompressed images from any modality on CDs. These images can and should be of full fidelity and identical to those used by radiologists for primary interpretations and hence suitable for diagnostic use and clinical decision making.

The IHE PDI profile contains more than just a reference to and further constraints on the DICOM interchange media standard. It also specifies how so-called Web content can optionally be included on CDs in a defined manner, to include images in a Web-friendly format such as that of the Joint Photographic Experts Group (JPEG). Many vendors have been producing CDs containing images in Web-friendly formats for patients or other physicians who do not necessarily have access to viewers that can accommodate DICOM-encoded images and other objects. The IHE PDI profile does not prohibit storing DICOM viewer software applications on CDs, but it does warn of the security risks. The IHE PDI profile also allows for, but does not standardize the format of, diagnostic imaging reports that may also be included on CDs.

The PDI integration profile has the potential to make a major impact by stopping the proliferation of CDs that are potentially incompatible or contain data that might be substandard. However, to allow transparent integration across systems, equipment manufacturers and imaging centers must comply

with the IHE PDI profile. Compliance with the IHE PDI profile by vendors will dramatically reduce the technology barrier to importing outside examinations and facilitate user-preferred DICOM viewers. Thus, a user may choose a certain preferred viewer to navigate images from different facilities and obviate contending with trying to understand multiple different varieties of viewers.

IMAGE DISPLAY REQUIREMENTS

As mentioned, imaging data on CDs can be accessed by many software applications that are able to "read" DICOM data. Image quality will depend not only on the source images (eg, DICOM, JPEG) but also on the characteristics of the display hardware (ie, the computer and monitor resolution) and the software used to view images. There are several good reviews of monitor performance issues highlighting recommendations for diagnostic quality monitors, such as in digital mammography [7]. Note that observer performance is determined by multiple factors, including monitor and viewing conditions [8].

Viewing software requirements will vary by user and purpose (diagnosis, patient education, surgical planning, etc). Several key features include panning, zooming, rotating, linking, and cross-referencing. A minimal number of manipulations ("clicks") should be required to perform the most common tasks and logical or useful combinations such as panning and zooming. Monitor calibration and the use of a standardized grayscale display function is important for the uniform rendering of grayscale contrast across different types of viewing devices and media (cathode ray tubes, liquid-crystal displays, film, paper). A standardized presentation layout may also be useful and in some ways can be more challenging to implement, because series descriptors differ across institutions, vendors, and modalities. Advanced processing tools such as on-the-fly multiplanar reconstructions and computed tomographic/positron emission tomographic image fusion are becoming more available on the embedded viewers included on CDs. Other key determinants to usability are not just the functionality but the uniformity and simplicity of the user interface. The lack of an intuitive navigational model has been one source of frustration for many providers. Regulatory issues may need to be considered, but these are beyond the scope of this article.

SHORT-TERM AND LONG-TERM SOLUTIONS

In the short term,

- referring physicians need to demand that their imaging institutions only provide IHE PDI–compliant DICOM media;
- vendors need to review their current CD formats to ensure IHE PDI and DICOM compliance and to especially address the "frequently made mistakes" documented in the IHE specification;
- imaging centers that create CDs, both hospital institutions and ambulatory practices, need to demand IHE PDI and DICOM compliance during the purchase and upgrade of PACS and modalities, and in the interim, they should obtain and use third-party CD-authoring devices that produce compliant media; and
- imaging centers and hospitals receiving media for import for consultation, review, or prior comparison also need to demand that only IHE PDI–compliant DICOM media be provided and contact offending sites when media cannot be read.

Referring physicians may wish to avail themselves of the opportunity to obtain and learn to use their own dedicated commercial, free, or open-source DICOM CD-viewing software to avoid dependence on different on-board viewers and learn how to disable the on-board viewers when CDs are inserted (registry setting or holding the shift key). Imaging centers can assist their referring physicians in this regard, to the extent permissible under the Stark legislation.

In the near future, medical imaging studies may be distributed via networking, and there will be less need for portable media. However, the accessibility of images online still needs to be defined in a standard that is widely accepted. The current bottleneck needs to be addressed as we look into the future and design user interfaces for image viewing. The AMA community has proposed the development of a standard graphical user interface that would be intuitive to all users, regardless of their medical specialty, and would facilitate effective and user-friendly access to medical images.

However, imposing a common user interface for image viewing may not be beneficial overall, for several reasons:

- Different medical specialties have different needs for postprocessing.
- Individual user preferences differ significantly.
- Software upgrades evolve along with the technology advancements.
- The costs of development, maintenance, support, accreditation, and policing are high.
- Such requirements may stifle innovation and are potentially anticompetitive.

Certainly, there is an issue with how electronic medical images are being viewed from portable media in non-PACS environments. The radiologic and imaging sciences communities need to be proactive in the development and reinforcement of standards for imaging data exchange.

The ACR Committee on DICOM Standards strongly advocates that all imaging centers ensure that their systems are fully compliant with the DICOM standard and use the IHE PDI integration profile. The committee is working with the AMA to address issues of a "common image browser" and is following closely the efforts of the Deutsche Roentgengesellschaft (German Radiological Society) to establish a certification system for vendors of producers and readers of CDs [9]. Also under consideration is a process of accreditation for sites that produce media.

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