Integrating the Healthcare Enterprise: A Primer

Part 1. Introduction[1]

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Does the subject of this series of articles intrigue you but you're not sure if the topics covered really apply to you and your practice? Before you read another word, go to the end of this introduction and seriously try to answer the questions posed there. If you answer "yes" to questions 1, 4, 5, 6, and 7, you need to read these articles.

And they said, "Go to, let us build a city and a tower, whose top may reach unto heaven; and let us make us a name, lest we be scattered abroad upon the face of the whole earth." And the Lord came down to see the city and the tower, which the children of men builded. And the Lord said, "Behold, the people is one, and they have all one language; and this they begin to do: and now nothing will be restrained from them, which they have imagined to do. Go to, let us go down, and there confound their language, that they may not understand one another's speech." So the Lord scattered them abroad from thence upon the face of the earth: and they left off to build the city. Therefore is the name of it called Babel; because the Lord did there confound the language of all the earth: and from thence did the Lord scatter them abroad upon the face of all the earth.—Genesis 11:4–9

Introduction

With the arrival of the new millennium, we find ourselves well into the "information age" with respect to healthcare delivery. Improving the delivery of healthcare both in a quantitative and qualitative sense will depend on improving management of digital information within and among healthcare institutions. Currently, within a given healthcare setting, there are typically dozens of information systems that each perform specific functions. There might be, for example, a billing system, an admission/discharge/transfer (ADT) system that registers patients, as well as numerous departmental systems (eg, radiology information system and picture archiving and communication system [PACS]). To optimize "information efficiency," these systems need to intercommunicate such that end-users of the system have the information they need to make their decisions and get their work done, when and where they need to do so. Historically, many of these information systems developed as monolithic, stand-alone systems without significant interfaces to other systems. Fortunately, the advent of medical information systems standards such as HL7 (Health Level 7) (1)

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and DICOM (Digital Imaging and Communications in Medicine) (2) have created a mechanism to share patient data and optimize work flow.

These and other standards, however, are necessary but not sufficient for the successful integration of heterogeneous information systems. Consider, for example, the case of the light bulb. Very early in the evolution of the light bulb, there were numerous, vendor-specific types of bulb bases. This multiplicity of design caused great havoc among lamp manufacturers and consumers until a limited set of bulb base designs became industry standards. Now consider the situation if a lamp were used for signaling. The sender and receiver can both choose from a number of different vendors of signaling lamps. Both sender and receiver units can use any number of standard light bulbs, wiring systems, and sources of electricity. If, however, the sender and receiver do not agree on the framework for how they are going to blink the links, then the standards they have implemented (bulbs, wiring, electricity) will not succeed in fostering the desired communication.

Similarly, the typical healthcare enterprise continues to suffer with a situation analogous to the biblical "tower of Babel," whereby each hospital information system utilizes HL7, DICOM, and other standards in a wide variety of ways as to practically preclude communication of information from one to another. Consequently, these systems often operate almost completely independently, with a paper printout typically serving as the only means of communication. This lack of consensus by various hospital and radiology information systems, PACS, and modality vendors on how to use existing standards has thwarted our efforts to automate processes such as physician order entry, patient and examination registration (especially for the challenging "John Doe" patient), and the creation and review of imaging reports. The failure to automate these processes has resulted in a very inefficient work flow, despite the use of electronic information systems.

The Integrating the Healthcare Enterprise (IHE) initiative defines such a consensus effort and framework (3) for integrating information systems in a healthcare environment. A joint effort of the Radiological Society of North America (RSNA) and the Healthcare Information and Management Systems Society (HIMSS), the IHE initiative began in 1998 as an effort to more clearly define how existing standards, notably DICOM and HL7, should be used to resolve common information system communication tasks in radiology. The IHE technical framework defines, precisely, a common information model and a common vocabulary for systems to use in communicating medical information. It then specifies, precisely, how DICOM and HL7 (so far) are to be used by information systems to complete a set of well-defined transactions that accomplish a particular task. At the same time, the framework provides a common human vocabulary that professionals and vendors can use to discuss further problems of this nature.

Modality and medical information system vendors have rapidly become strong supporters and architects of the IHE effort. Vendors came together to demonstrate the way in which actual products could support this next level of integration. The first demonstration was held at the RSNA annual meeting in 1999 and again at the 2000 annual meeting of HIMSS. The initiative was expanded in its second year and shown at RSNA 2000 and HIMSS 2001. The Year 3 efforts will be on display at this year's RSNA meeting and at next year's HIMSS convention.

The following two articles are the first two parts of a four-part primer designed to further explain the IHE initiative. The first article will detail the seven "integration profiles" that are currently defined in the IHE technical framework. This piece will define the common language of the framework that allows professionals and vendors to describe the problems and their solutions. More detailed descriptions of common problems in radiology and how the specific integration profiles address these specific scenarios are presented. Again, non-radiology healthcare information system users and providers will be able to identify analogous problems within their domains and subsequently be equipped to formulate their solution in terms that the IHE community can act on.

The second article attempts to explain what IHE does for each of the different users of medical information systems, currently aimed at radiology processes and procedures. Other healthcare information system users and vendors will, we believe, see in these descriptions analogous problems and scenarios that arise in their domains. They will also discover that the IHE initiative is an extensible vehicle that can and will be expanded to meet the challenge of these needs in other medical domains besides radiology. Users (through their professional organizations), vendors, and standards organizations are invited to participate fully in the IHE initiative and are encouraged to contact the IHE project offices at the RSNA or HIMSS headquarters.

The third and fourth articles will be published in the November 2001 issue of *RadioGraphics*. The third piece will detail the role of existing standards in the IHE initiative. IHE is not a standard nor is the initiative a standards body. IHE is not a certifying authority. The IHE community of vendors and users makes use of existing standards, notably DICOM and HL7, to achieve the integration goals of IHE. This third article will detail some of the newer components of DICOM and how they relate to IHE. It will also examine how HL7 is evolving to meet the challenge of more complex information system integration demands.

The fourth and last article will explain the future of IHE. The Year 3 (2001/2002) demonstration will be described in more detail. This article will include practical aspects of how to include IHE requirements in contracts and requests for proposals. Future directions of the IHE initiative and mechanisms by which other users, vendors, and organizations can participate will be described. It is only through this further participation by users and vendors that the IHE initiative can grow and flourish. The plans for expansion of the initiative outside radiology will be presented.

In addition to this primer series, more information about the initiative, including the latest version of the IHE Technical Framework, can be found at the IHE web site: *www.rsna.org/IHE.*

Questions for Consideration

1. Do you have communication problems in your work flow and between your information systems that you think IHE could help you resolve?

2. Does the Scheduled Work Flow integration profile adequately represent or codify the way you perform radiologic procedures? If no, how is it lacking?

3. Are the distinctions between Order, Requested Procedure, Scheduled Procedure Step, and Performed Procedure Step clear to you? Does this hierarchy adequately capture the complexity of performing radiologic procedures?

4. Is the performance of grouped procedures a significant problem for you? Does the Presentation of Grouped Procedures integration profile address this scenario adequately? If no, how is it lacking?

5. Do you have significant clinical or operational problems related to making images appear similar on film and on workstations? If yes, do you use the DICOM (part 14) gray-scale display function standard to calibrate your equipment? Does the Consistent Presentation of Images integration profile adequately address this issue? If no, how is it lacking?

6. Do you have significant problems managing paperwork (requisitions, notes, patient history, etc) in addition to films and images? If yes, does the Key Image Note integration profile address these needs? If no, how is it lacking?

7. Do you have significant management problems in reconciling unknown patients, performing procedures on trauma patients, or performing procedures when one or more information systems are unavailable? If yes, does the Patient Information Reconciliation integration profile address these scenarios adequately? If no, how is it lacking?

8. What other aspects of radiology work flow could benefit from IHE type integration profiles?

9. Are there any related topics that you would like to see discussed or clarified in future articles or presentations?

References

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3. Radiological Society of North America/Healthcare Information and Management Systems Society. IHE technical framework, year 3, version 4.6. Oak Brook, Ill: RSNA March 2001.

Editor's note.—*Please visit the online version of this article in the Education Resources pages of RSNA Link (www.rsna.org) and answer the questions posed above. We are very interested in your opinions on these articles.*

Integrating the Healthcare Enterprise: A Primer

Part 2. Seven Brides for Seven Brothers: The IHE Integration Profiles[1]

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ONLINE-ONLY CME

See www.rsna .org/education /rg_cme.html.

LEARNING OBJECTIVES

After reading this article and taking the test, the reader will be able to:

- Understand common work flow and information system problems that occur in radiology departments.
- Understand what the IHE initiative from RSNA and HIMSS is.
- Understand the IHE information model.
- Understand the seven integration profiles of the IHE and the specific problems they address.

Introduction

This article describes at a high level the IHE information model and the seven integration profiles that make use of this model to accomplish a number of important, common, core processes in radiology. Although the technical details of IHE can be left to the boffins and experts, radiologists will need to understand, at a high level, the information model and work flow derived from this model. This will allow them to understand why the information systems to which they are increasingly exposed do not currently perform as they would desire or expect. More important, they will then understand the importance of the IHE initiative in offering the hope that future information systems, which will adhere to the IHE framework, will be able to function in a more integrated fashion, thereby solving some common problems of today's medical information systems. It is hoped that nonradiologist readers will see similarities with problems in their information model and work flow and will be encouraged to participate in the expansion of the IHE initiative into other subspecialty areas.

IHE is not a standard nor a certifying authority. IHE is more than a standard. IHE defines a common language to assist humans in unambiguously discussing how to integrate heterogeneous information systems. IHE has defined, in a technical framework document (1), a view of the radiology world. This is not to say that there is only one possible view of radiology, nor does this imply that it is the best view of radiology. It is merely one view of radiology, about which a large group of IHE participants could come to consensus. As the IHE initiative expands, so too will its view of the world.

Abbreviations: ADT admission/discharge/transfer, DICOM = Digital Imaging and Communications in Medicine, HL7 = Health Level 7, PACS = picture archiving and communication systems, RIS = radiology information systems, DICOM S/R = DICOM Structured Reporting

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Within this world, there are a number of tasks that must be accomplished to deliver radiology services to patients. Again, these are not all the tasks that must be accomplished to provide complete radiology services, but they are a fundamental subset of the necessary core processes. The IHE precisely defines these tasks. More tasks will be defined for more processes in future years as part of the expansion of IHE both within radiology and in other subspecialty healthcare areas.

Lastly, IHE defines the information model that specifies the bits and pieces of data that must be created, managed, manipulated, and exchanged to accomplish these tasks successfully. This information model is an integration of subsets of HL7 (Health Level 7) (2) and the DICOM (Digital Imaging and Communications in Medicine) model of the real world (3). Most important, all the pieces of information and their meanings required for the IHE defined processes are fully specified in the IHE technical framework. Thus, vendors and their information systems, who agree to abide by and implement the IHE framework, now have a common, fully defined, mutually agreed-on context in which to interact to perform radiology processes successfully.

The IHE technical framework is process oriented. It defines a set of actors that must interact with each other to complete a given process successfully. The actors interact by means of well-defined transactions that are based (currently) on DICOM and HL7 messages. The framework intentionally avoids assigning roles to specific products (eg, hospital information systems, radiology information systems [RIS], picture archiving and communication systems [PACS], or imaging modalities), even though specific products have traditionally performed some of the transactions. The goal is to define the interactions among functional components of the healthcare information system environment. Vendors and users of the various information systems that make up this environment can then decide which products implement which roles in a specific department.

IHE has defined seven integration profiles, each of which groups a set of actors and transactions together with a common vocabulary to accomplish a specific, typical work flow task. These integration profiles—(*a*) Scheduled Work Flow, (*b*) Patient Information Reconciliation, (*c*) Consistent Presentation of Images, (*d*) Presentation of Grouped Procedures, (*e*) Access to Radiology Information, (*f*) Key Image Note, and (*g*) Simple Image and Numeric Reports—are the core processes addressed by the IHE technical framework at this time.

Before we discuss the seven integration profiles, let us examine in more detail the model of the real world used by the IHE framework. It is important to define clearly the terms used in this model because some of the terms have been used ambiguously in the past. By precisely defining the terms of the model, we will be better able to understand the integration profiles and the problems they address.

In the IHE model, a patient is the subject of an order for radiology service placed on behalf of an ordering physician by an *Order Placer* actor. One can imagine that the Order Placer actor is often part of a hospital information system or a clinical information system, but the framework does not force this decision.

This order is fulfilled by an imaging service request that will be managed by the Department System Scheduler or *Order Filler* actor (for simplicity, hereinafter referred to as the Order Filler). Again, traditionally, the Order Filler in radiology would be the RIS, although this is not specified in the framework. What is required is that some information system must take responsibility for managing the imaging service request by implementing the Order Filler actor. It is at this point that the Order Filler assigns the accession number to the imaging service request.

A single imaging service request is satisfied by engendering one or more requested procedures. Requested procedures are the unit of work for the radiologist. A *requested procedure* is the smallest unit of work that can be codified and billed and which causes a radiology report to be generated. *Requested procedure identifiers* identify requested procedures. It is important to note that requested procedure identifiers are not the same as accession numbers. Recall that the accession number is assigned by the Order Filler at the level of the imaging service request. An imaging service request can lead to one or more requested procedures, and each requested procedure is a unit of codified, billable, reportable work. Thus, two requested procedures created in response to the same imaging service request could share the same accession number. Outside the IHE world, the term accession number is used by some vendors to represent imaging service requests and by other vendors to mean requested procedures. IHE removes this ambiguity by clearly specifying that *accession numbers* shall be defined at the level of the imaging service request (created by the Order Filler) to satisfy the Order Placer. For similar reasons, we avoid the terms "study" and "examination" because these terms are also used ambiguously.

The requested procedures are in turn composed of scheduled procedure steps. Scheduled procedure steps drive work flow. Scheduled procedure steps are work that is anticipated to be performed by technologists (and radiologists) at the modality. Thus, *scheduled procedure steps* are the fundamental unit of work for a modality and thus are the elements that should appear in modality work lists. It is important to recognize that during a particular procedure a scheduled procedure step may not be performed, since not all scheduled work is necessarily appropriate in all situations. Scheduled procedure steps become performed procedure steps as the technologist at the modality workstation completes the work.

Let us consider a series of examples. In a simple case, a referring physician orders “radiographic evaluation of the right hand.” This order causes the creation of a single imaging service request that is assigned an accession number. This particular imaging service request generates a single requested procedure, “computed radiography, right hand, two views,” which is associated with a single CPT code (73130). This requested procedure could, depending on the particular vendor’s implementation, be accomplished as one or more scheduled procedure steps. In other words, each view could be a separate scheduled step or both views could be incorporated into the same scheduled procedure step. At this point, the technologist images the patient and the scheduled procedure step becomes a performed procedure step. The radiologist generates a report for the requested procedure, and the Order Filler actor notifies the Order Placer that the imaging service request has been satisfied.

In a more complex example, a referring physician orders a “ventilation perfusion scan for pulmonary embolus.” Again, this order would cause the creation of a single imaging service request that is assigned an accession number by the Order Filler. This imaging service request, however, generates two requested procedures—“lung scan ventilation” (CPT 78593) and “lung scan perfusion” (CPT 78580)—but they share the same accession number. Each requested procedure in this case consists of a single scheduled procedure step, which becomes a performed procedure step as the work is completed. The radiologist can now dictate separate reports for each requested procedure or, as is done at some institutions, dictate a single report that applies to both requested procedures. In either case, the two requested procedures are fulfilled, and the Order Placer is notified that the imaging service request has been fulfilled.

Keeping this information model in mind, we will now examine the seven integration profiles and the problems that they address.

Scheduled Work Flow

The Scheduled Work Flow integration profile fills in all the necessary details to perform the typical work flow previously described. The significance of this profile should not be underestimated. This integration profile was the first to be developed in year 1 of the IHE initiative (1998) and remains the underpinning of the information model. More important, the lack of tight integration of scheduled work flow between heterogeneous hospital and departmental information systems can have a significant deleterious effect on hospital and departmental operations. In the worst scenario, there may be no transfer of information from one system to another other than through a paper report and repeat, manual data entry. Every time there is a manual handoff of information there is risk of error and introduction of inefficiency.

Even in the presence of simple (non-IHE) integration between systems, there is often just a minimum set of messages exchanged and integration is said to be “loose.” Typically, these interfaces are point-to-point between two information systems. When extended to a large institution, “loose” integration entails management of many of these point-to-point interfaces. This management rapidly becomes a complex, expensive task. Overall, the effect is that while routine operations proceed, there are few mechanisms for proactively preventing and managing error or exception cases, and significant manual intervention is required to keep the systems coordinated. For example, with loose integration, the status of procedures in one system may not exactly match the status in another system because one system may not signal every state transition. Occasionally, one information system may attempt to cancel a procedure that has already occurred or one or more information systems are temporarily unavailable and manual reconciliation must occur. From a vendor viewpoint, without the IHE Scheduled Work Flow integration profile, each system installation becomes a custom integration project with the associated cost and complexity that custom work entails.

The Scheduled Work Flow profile makes use of nine actors and over 40 transactions to ensure a rich collaboration between the components of the information system environment. In addition to Order Placer, Order Filler, and Acquisition Modality introduced above, this profile introduces the *ADT* (admission/discharge/transfer) *Patient Registration*, the *Image Manager*, *Image Archive*, *Performed Procedure Step Manager*, *Image Display*, and *Image Creator* actors. Recall that the one information system can implement many more than one actor. In fact, the framework requires the grouping of the Image Manager, Image Archive, and Performed Procedure Step Manager as well as other actor groupings (troupes), which significantly reduces the potential number of involved information systems in any one implementation.

In introducing the Performed Procedure Step Manager and defining the usage of DICOM Modality Performed Procedure Step, the Scheduled Work Flow profile ensures that all the information systems can be appropriately notified as (image-based) work is performed and completed. The performed procedure step–in progress transaction occurs as the work is started on the modality workstation. The performed procedure step–complete message is important because it ensures the link between the scheduled procedure step (and the requested procedure it is part of) and the exact list of images constituting the performed procedure step. This message provides the Image Manager with two critical pieces of information: (*a*) the precise list of images to expect and (*b*) the signal that the acquisition step is completed. The message avoids errors in reporting incomplete studies and simplifies the technologist task that would otherwise have to be performed through a RIS and a PACS terminal. The Image Manager or Order Filler actors can also use this knowledge to perform related tasks (eg, long-term archive, prepare the study for review). The Order Filler also sends an order status update message to inform the Order Placer that the imaging service request has been satisfied. If an Image Display actor is then available, the images may then be displayed, presumably to the ordering physician.

Patient Information Reconciliation

The Patient Information Reconciliation integration profile is used to support the clinical situation when the patient is unknown to the enterprise and yet imaging must proceed. This situation most frequently occurs in the setting of trauma, but the IHE framework also identifies several other scenarios in which this can occur. For example, the ADT Patient Registration actor may register an unidentified patient (John Doe) and the Order Placer actor may place an order. Subsequently, the patient is identified and the ADT Patient Registration actor sends update/merge messages to both the Order Placer and Order Filler. The Order Filler then notifies the Image Manager.

In a similar scenario, an unidentified patient may be registered (John Doe) at the ADT Patient Registration actor but in this case the order is generated at the Order Filler in the eventuality that the Order Placer is unavailable. Again, reconciliation occurs as the update messages flow through the profile. The same logic applies in the case of an unidentified patient who is registered and imaged at a modality before an order is entered. This integration profile also supports situations in which information is incompletely propagated; for example, the wrong patient record is used in ordering/scheduling due to communications failures or information is mistyped at a modality workstation in the absence of a modality work list.

These are all common scenarios. In a loosely integrated world, in the absence of IHE, these cases engender angst that errors will not be caught, and significant manual effort must be expended to detect and correct these events.

Consistent Presentation of Images

The Consistent Presentation of Images profile is at the core of the service provided by the radiology department. In defining precisely how to make use of the DICOM Gray-scale Standard Display Function (also known as DICOM part 14 or GSDF) and the relatively new DICOM Gray-scale Soft-copy Presentation State, this profile ensures that images are displayed as similarly as is physically possible on different display devices, including both soft-copy display and film. Thus, images viewed on film on a viewbox, on a diagnostic quality workstation, or on a personal computer should be perceived similarly, given the physical limitations of the display device hardware and the ergonomics of the viewing environment.

Consistent presentation of images has great clinical significance when healthcare providers may be discussing electronically rendered images at a distance. It is crucial for image features to be rendered as equally perceptible as possible between what may be very different devices and conditions. Similarly, it is important to be able to specify precisely how an image was displayed and to be able to reproduce a specific presentation of an image. One can imagine numerous medicolegal scenarios in which it may be critical to reproduce these image presentations.

The importance of accomplishing this particular integration profile cannot be understated. First, as evidenced by DICOM part 14 itself, this is an immensely complicated task that is the result of years of collaborative scientific research between industry and academia. In addition to its clinical and medicolegal implications, this profile has a significant impact on work flow operations in the department. This profile plays a key role in the Presentation of Grouped Procedures profile described below. More important, it can be used to introduce a number of efficiencies in the department. Consider the example of routine magnetic resonance imaging. The technologist, in finishing a study, typically zooms, pans, and sets windows or levels for each of the images in a series to make the images suitable for filming or viewing. Zooming and panning the image can usually be performed once for the first image in a series and then propagated to the remainder of the images in the series because the field-of-view and other image parameters typically do not change between images in a given series. Setting windows or levels, on the other hand, is typically performed image by image because signal strength typically varies across images in a series. Until the advent of the DICOM Gray-scale Softcopy Presentation State and this integration profile, there was no way to capture and transmit this information from one device to another. Typically, there is no way to capture this information even on a given device. Postprocessing would, thus, traditionally, have to be repeated by the radiologist viewing the study on a workstation and even by the technologist when a subsequent print request appears. This repetition can be very costly in terms of both radiologist and technologist throughput.

There are more nefarious scenarios in which this profile can be critical to good patient care. Consider the case of direct coronal computed tomography (CT) of the sinuses. For this examination, the patient is placed prone on the CT table and the neck is hyperextended. The CT gantry is then tilted such that the angle of the gantry matches that of the hyperextended neck. This positioning allows for axial imaging (with maximum spatial resolution) of what is an anatomically coronal plane. The CT scanner, however, still believes that it is performing axial imaging. Thus, although the DICOM orientation vectors and the image labeling are correct, the images are typically displayed upside down and flipped left to right compared with the traditional presentation of a coronal image. Again, the images are correctly labeled, but they are not displayed in a traditional format (eg, patient's right to image left). Physicians, thinking the images are displayed "traditionally" could make drastically wrong treatment decisions unless they take the time to carefully check the DICOM orientation labeling. Many scanners can "automatically" flip these images before filming so this has not typically been a problem in the film-based world. In a soft-copy environment, however, there has been no way to communicate the correct presentation of the images to a remote image display (such as a PACS) until the advent of DICOM Gray-scale Soft-copy Presentation State and this integration profile. This scenario is a good example of a bad thing: an information system introducing a new opportunity for human error. The Consistent Presentation of Images integration profile closes the door to this opportunity.

The phenomenon of filmless imaging in radiology also removes a critical quality assurance step when hard copy is generated. Specifically, in a traditional film environment, radiologists perform important quality assurance steps in that they determine which images are of sufficient quality to release from the department. In a filmless environment, in which the radiologists themselves do not see the actual film, poor quality images may be printed and distributed outside the department. The Consistent Presentation of Images profile ensures that images appear as closely as possible to those viewed in the soft-copy environment.

The Consistent Presentation of Images profile accomplishes its goal by specifying that all Image Display and Print Composer actors must be calibrated to the DICOM part 14 Gray-scale Standard Display Function. They, along with their colleagues Acquisition Modality, Image Manager, Image Archive, Image Creator and Print Server, must support the creation, storage, and transmission of the appropriate DICOM Gray-scale Soft-copy Presentation States. Print Composer and Print Server support this integration profile by means of the "print request with presentation look-up table" transaction.

Presentation of Grouped Procedures

This integration profile solves the very difficult problem of "linked procedures." This refers to procedures that are related to each other by the fact that they are derivatives of the same physical acquisition of data. The role of the Presentation of Grouped Procedures integration profile in solving this very difficult problem has been previously detailed (3). In this article, we merely summarize the importance of this problem and highlight the role of this integration profile in resolving this issue.

In a grouped procedure, we receive an order from a physician for, for example, "CT of the chest, abdomen, and pelvis for abscess." This image service request would (depending on a site's protocol) first expand the order into three requested procedures; "CT chest, enhanced," "CT abdomen, no additional contrast," and "CT pelvis, no additional contrast." Note that the first requested procedure would engender two scheduled procedure steps; "contrast injection, CT," followed by "CT chest." The second and third requested procedures each engender a single scheduled procedure step, "CT abdomen," and "CT pelvis," respectively. Each requested procedure would be reported separately, resulting in three reports each corresponding to separately billable, CPT codes. In addition, many institutions interpret these steps independently for a number of reasons. First, some institutions may have the chest images interpreted by a thoracic radiologist, whereas the abdominal and pelvic images may go to other radiologists. Second, some institutions generate separate physical reports for each requested procedure billed. In any event, however, the protocol on a typical, multidetector, helical CT scanner calls for performing a single helical data acquisition from the thoracic inlet through to the inferior pubic rami. The problem here is that we want to reprocess the chest images with the lung reconstruction kernel, set the lung window levels, and then split the single physical data set between the requested procedures. This causes two new problems. The first is how to group the lung window images and the mediastinum window images of the chest with the requested procedure, "CT chest, enhanced." The second problem is how to indicate that other portions of the same helical acquisition are to be associated with other requested procedures without transmitting or storing the data set more than once.

In a film-based environment, this "split" of the data is handled by the same work flow, specifically generating multiple sets of films postprocessed at different window values. In an electronic environment, however, the same work flow does not work successfully. We do not want to send the data set to the PACS multiple times, once for each requested procedure. We also do not want to send a portion of the data set to one study and a second portion to the second study, since there are situations in which a single viewer might want to view the entire data acquisition at one time without jumping from study to study. There may also be overlap between points in the data set, and a given image would need to appear in two or more requested procedures. It should be noted that this scenario is quite common in CT, where it might occur up to 30% of the time (Channin, unpublished data, 2000), depending on the service population of the institution. There are numerous other imaging situations where this occurs.

The Presentation of Grouped Procedures profile solves this problem. The Acquisition Modality actor allows the technologist to perform the procedure step and acquire a data set. These images are stored to the Image Archive as is commonly done today with DICOM storage. The technologist then creates one or more Gray-scale Softcopy Presentation States that associate subsets of the images (and the image manipulations that are appropriate for those images as described above) with the appropriate requested procedure. This ensures that the value added by the technologist in establishing the structure and presentation of the combined image sets can be fully used by the Image Manager to automate the reading of the same image set, which has been properly split and presented depending on the requested procedure.

Access to Radiology Information

The Access to Radiology Information integration profile provides a well-defined means for delivering radiologic information to non–RIS and the users of those systems. This profile and the Simple Image and Numeric Reports integration profile begin to make use of DICOM Structured Reporting (DICOM S/R) (4). DICOM S/R is a complex, sophisticated part of the DICOM standard designed to address most, if not all, of radiologic and other medical reporting requirements. IHE, in accordance with its strategy of making use of existing standards (notably DICOM and HL7), defined these integration profiles to solve real-world work flow process problems with well-defined subsets of DICOM S/R. A textbook describing DICOM S/R in detail is now available (5).

The Access to Radiology Information profile introduces the Report Reader, Report Repository, and External Report Repository Access actors. In the IHE model, a Report Creator actor sends a radiologic interpretation as a DICOM S/R object to a Report Manager. The Report Manager is responsible for maintaining versions of the report and the state of the report (eg, is it authenticated?). At any time, the Report Manager can send a report to the Report Repository, and the Report Manager can make this report (eg, a preliminary report) available for query and retrieval according to the definitions in the Access to Radiology Information integration profile. At a minimum, the Report Manager must send a final report to the Report Repository. The Report Repository provides permanent storage of the DICOM S/R reports and responds to report query and retrieve messages from any Report Reader in the institution. The External Report Repository Access provides a similar query and retrieve functionality but acts as a gateway that translates external reports from other information systems into the IHE model by using DICOM S/R.

The Access to Radiology Information integration profile also precisely specifies the details to be used by Image Display actors to query and retrieve images and presentation states. Thus, this profile provides the critical link between RIS, which may be in the process of conversion to an IHE model architecture, and legacy systems, which would like to provide their users access to radiologic information, notably reports, images, and presentation states.

Key Image Notes

The Key Image Note integration profile describes a mechanism by which technologists, radiologists, and others involved in the performance of radiologic procedures can flag images as significant and attach a comment to those images. The analogy in the real world is to all the scraps of paper, especially yellow Post-it™ notes, that tend to get associated with a radiologic procedure yet are not integrated into the formal, final report nor ever completely managed as part of the patient's medical record. This integration profile makes use of a new DICOM object, the Key Object Selection Document (DICOM supplement 59). Users of the Image Creator or Acquisition Modality actors can create these objects and send them to the Image Manager and Image Archive for storage as part of the procedure. Image Display actors can then retrieve these objects from there for eventual display to the user. Important points in the definition of this profile include (*a*) one key image note can be associated with many images, (*b*) multiple key image notes can be associated with a single image, and (*c*) key image notes can reference specific presentation states thus ensuring that a comment addressed to a visible feature will likely be perceivable when the note is read.

This key image note mechanism can be used for many purposes. Technologists, nurses, and others can use key image notes to document incidents that occur during the procedure. These incidents can be clinical (eg, the patient had a reaction), technical (eg, "at this point in the procedure the power failed"), or quality control related (eg, "these images have artifact due to patient motion and respiration"). Radiologists can use the key image note mechanism to indicate rapidly to clinicians which images contain the most significant findings. Similarly, radiologists can tag images that contain teaching findings or other technical issues that need to be documented.

Simple Image and Numeric Reports

This last integration profile begins to address the diagnostic reporting work flow that occurs in all radiology departments. Acknowledging the complexity of diagnostic reporting in general, the related complexity of the DICOM Structured Reporting standard, as well as a host of reporting issues that are currently outside the scope of the IHE initiative, IHE defined a modest integration profile to allow the creation, transmission, storage, and display of reports based on a subset of DICOM S/R. The simple image and numeric reports profile can meet many, but not all, routine reporting needs. Enhancement of reporting profiles will surely follow in the future of IHE.

The IHE model for simple image and numeric reports is based on DICOM templates defined as DICOM content mapping resources (DICOM supplement 53). These templates specify the structure of the document to be used for a specific purpose, in this case, this IHE integration profile. This does not mean that other templates cannot and will not be used in reporting, but merely that a specific template, namely the "basic image diagnostic report template" (TID 2000) is to be used at this time in IHE transactions. This template and therefore the IHE model states that a simple image and numeric report shall have a title and contains one or more sections. Each section has a title and can contain report text, measurements, image references, and coded entries (eg, diagnosis or pathology codes). Report text and coded entries can also document further image references and measurements from which they are inferred. One can easily see that "simple" is in the eye of the beholder and that the IHE model and integration profile can manage reports that can be quite sophisticated.

The previously introduced Report Creator, Report Reader, Report Manager, Report Repository and External Report Repository Access actors submit, query, and retrieve these DICOM S/R reports. In IHE year 3, a new actor, the Enterprise Report Repository, is identified as the recipient of a new structured report export transaction, such that legacy hospital information systems can receive straight text (ASCII) versions of these simple image and numeric reports via an HL7 message. Again, this allows a mechanism by which an institution can slowly transition to an IHE architecture while maintaining functionality in existing information systems.

Conclusions

We have described the IHE model of radiology work flow and seven integration profiles that use this model to successfully perform complex processes in the radiology department. Radiologists cannot ignore the information model and work flow that surrounds them as they do their work. In a film-based world, radiologists by virtue of their training and experience have a very good understanding of the physical processes required to provide accurate, high-quality, radiologic images and interpretations. In shifting to an electronic paradigm of radiology, radiologists must now understand, at least at a high level, the new information model and work flows that surround them, occasionally without a physical presence. For better or worse, as information systems become integrated, whether to reduce the opportunity for error or to introduce efficiencies, we must all realize that we are now smaller parts of a larger machine, and we must keep in the back of our minds a picture, painted with broad brush strokes, of the model that binds us together and to the information systems that support us.

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Integrating the Healthcare Enterprise: A Primer

Part 3. What Does IHE Do for ME?[1]

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Introduction

The Integrating the Healthcare Enterprise (IHE) initiative brings together users and developers of medical information systems to advance data integration. Each of these stakeholders in the healthcare delivery process is vital to successfully caring for patients in an expert, efficient, and cost-effective manner. Each of the different members of this community has a slightly different perspective on why IHE is important and how IHE can (positively) affect their role in delivering healthcare.

In this article, we present eight differing perspectives. Readers are referred to the second article in this primer series (1) for a more detailed explanation of these integration profiles. Readers from other (nonradiology) segments of the healthcare enterprise and industry should see in this collection of user perspectives kindred spirits with vested interests in addressing analogous problems from their domains.

The Departmental Chief or Chairman

As a radiology departmental chief, I have the ultimate responsibility to provide the highest possible quality of care for our patients in addition to prompt, reliable, and responsive consultation for our clinical colleagues in as cost-effective a manner as is practical. I am accountable for analyzing and optimizing departmental work flow and productivity and for creating a vision and road map for the future direction of the department. Selection, procurement, and integration of imaging equipment and information systems are integral parts of my job.

Abbreviations: DICOM = Digital Imaging and Communications in Medicine, HL7 = Health Level 7, PACS = picture archiving and communication system, RIS = radiology information system

Index terms: Information management • Picture archiving and communication system • Radiology and radiologists, departmental management • Radiology reporting systems

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In 1989, a work flow analysis of our radiology department was performed, which, to our surprise, demonstrated that 59 steps and a dozen people were required to produce a routine chest radiograph of an inpatient. With the transition to the use of computers alone, there would have been very little reduction in the number of steps or the time required for them without integration of the various information systems and modalities within the entire healthcare enterprise. During the past 10 years, we have subsequently redesigned our work flow and have been forced to create custom interfaces with our vendors by using DICOM (Digital Imaging and Communications in Medicine) (2) and HL7 (Health Level 7) (3) interfaces. These efforts have drastically decreased the number of work flow steps to less than 10 and have similarly reduced our departmental turnaround times. Unfortunately, these custom interfaces were often slow and unreliable (especially the initial ones) and, in many cases, quite expensive. Today, fortunately, most of these work flow enhancements can be obtained by using the IHE integration profiles.

During the past several years, I have often felt like Charlie Brown from the comic strip *Peanuts*, after he has once again charged down the field at the football held enticingly in place by Lucy only to have it snatched away at the last possible moment. In one of the comic strips that has been archived in the American History Museum, Lucy even gives Charlie Brown a signed document "proving" she won't pull away the football and she still manages to yank it away just before he's able to kick it. This scenario has been repeated in our department for the past 10 years, as we've been promised by earnest and presumably well-meaning vendors that our brand new modality or information system will "plug and play" virtually seamlessly with our existing systems by using DICOM and HL7, without any need for any significant customization. The consistent need for major "customization" of our new modality or information system after delivery has typically resulted in problems. These difficulties have ranged from the need to perform additional manual work flow steps to "temporarily work around" the problems to major delays in our ability to use the equipment and major additional unbudgeted expenses to attempt to provide the promised full functionality of the system. These idiosyncratic interfaces also add to the complexity of the system, which has resulted in increased equipment down time especially when software upgrades are installed on our modalities or information systems, which need to be further modified to continue to function properly.

As departmental chief, it is important for me to have the flexibility to purchase equipment that is "best of breed" rather than staying with a single vendor or a short list of vendors that happen to have a custom or "approved" interface to my existing systems. Universal adoption of the IHE integration profiles will make it much easier for me to have the flexibility to purchase what I want rather than settle for second best. Similarly, I do not want to feel constrained to utilize my information technology staff's choice of a hospital information system provider for my radiology information system (RIS) or radiology picture archiving and communication system (PACS) but would rather know that by conforming to IHE integration profiles, my own choices will be likely to integrate seamlessly with the hospital systems.

In today's job market in which there are severe shortages of qualified radiology personnel, I need to make sure that I provide an optimized work flow process and adequate tools for my departmental administrator, technologists, and radiologists to get their jobs done as effectively as possible with a minimum of frustrations. I also need to ensure that the unique requirements of our clinicians, information technology staff, and vendors are addressed as well. I have been impressed with the IHE progress thus far and remain optimistic that it will continue to evolve to serve the needs of my department, staff, and associates.

The Department Manager or Administrator

As the department of radiology administrator, I am focused on providing superlative service to our patients and our referring physicians in as cost-effective a fashion as possible. I am struggling against tighter budgets, rising costs, increasing procedure volumes, and an extremely tight technical labor pool.

As I walk through my department, I want to see patients moving through the system comfortably and efficiently. I do not want to see idle, expensive modality devices when I know that we have backlogs of outpatients waiting for procedures. I do not want to see technologists jumping from one information system to another to complete routine tasks. I want to see more procedures done per technologist per modality device. I want my electronic environment to reduce the number of steps we take in any given process. I do not want to add work flow steps because of information systems. I do not want to see technologists "sneaker-netting" paper around the department where once we ran films.

Since we are now in a filmless environment, I want to be confident that studies are performed according to protocol, manipulated by the technologists appropriately, stored correctly and permanently into the PACS, and ready for viewing on both workstations and, as necessary, film.

I want to make sure that our referring physicians can access radiology information—images and reports—from the information systems they use. When they access this information, I want to be confident that they are getting the images they expect in a format that is displayed correctly. Although I understand that the return on investment from information systems comes from more than film cost reductions, I still want to minimize not only my film costs, but also the costs associated with managing these requests for radiology information. Authorized users of radiology information should be able to query and retrieve the information they need for patient care from my systems so that I do not have to manage pushing this information to them.

I want to reduce the opportunity for errors by the technologists, because these errors are not only dangerous to the patient but very labor intensive and therefore expensive to correct. In the days of film, when modalities were islands of functionality, a stick-on label and a pen could correct an error. Now, modalities are intertwined with the RIS, PACS, and other information systems, and errors on one device have significant upstream and downstream repercussions on other information systems.

I understand fully that the return on investment from my information systems comes from increasing these efficiencies and reducing tangible and intangible costs, not from reducing film costs. I believe that the IHE initiative will foster these efficiencies.

The Technologist

As a technologist, I am focused on performing the highest quality possible radiologic procedures on my patients. I want my patients to be as comfortable as possible, wait the least amount of time, and move through our department as quickly as possible.

I know how to perform a procedure on my modality. I know how to problem solve to get the procedure done, and I know when to get help in problem solving. Yet, as the department has added more and more information systems, I have had to learn how to use all these different systems. I have no clear mental picture of how these systems interact. Each information system refers to parts of the radiologic procedure and the steps involved in the radiologic process differently, and each system has different means for modifying information and correcting mistakes. Figuring out what to do next in any given scenario or in the case of an exception is getting more and more complicated not simpler.

I often find myself repeating steps in my work flow unnecessarily. For example, if I zoom, pan, and select window levels once to film a study or to send it to PACS, I may have to repeat these steps over and over for a given procedure. Worse yet, if I do some image manipulations, another user of a different information system may have to repeat the work I have already done. Either I should be able to do the work once or they should be able to do this step once, but both of us should not have to reproduce each other's work.

Although we are now in a mostly filmless environment, we are still generating and manipulating too much paper. We get orders on paper, electronic orders printed on paper, requisitions, protocol sheets, flow sheets, quality assurance sheets, and patient history sheets. We have manual logbooks and protocol notebooks. I have no choice but to put my comments and questions on all these sheets of paper. I am constantly on the phone clarifying orders, rendering generic orders more specific, and manually scheduling inpatients and outpatients into the system. Even so, I must still spend time interrupting the radiologists for more clarifications. This reduces my efficiency and their efficiency.

When I complete a procedure on my modality workstation, I want to be assured that the images are permanently stored and that they will be presented for viewing as I have manipulated them. I take responsibility for the appearance of my images, and I want to know that my time and effort is not being wasted.

I want to receive fewer requests for radiology images and reports from outside sources. Once I hand off the images to PACS, I want users to query and retrieve the images from the PACS. I do not want to spend my time pushing images to various three-dimensional postprocessing, surgical, or research workstations.

My job is to perform high-quality radiologic procedures on sick patients. I hope that the IHE initiative can foster information systems that help me and my equipment do just that.

The Radiologist

As a radiologist, I am focused on providing the highest possible quality of care for my patients and the highest level of service to the referring physicians who entrust me with the care of their patients. I am struggling to do this in the face of increasing bureaucracy, increasing regulation of my practice, and decreasing reimbursements, all within the context of a very competitive market that includes a very tight technical and professional labor pool. I must continually work harder and smarter to keep up.

I routinely use a number of departmental information systems, including RIS and PACS. At my institution, 95% of the 250,000 procedures we perform per year are acquired, stored, transmitted, and interpreted from a PACS. I now spend the majority of my clinical time in front of one or more workstations. On occasion, I use a small number of other terminals and personal computers to access other hospital information systems located outside my department. In between clinical responsibilities, I use the RIS to edit and sign reports. I then coordinate with our practice manager to make sure that the professional billing information gets entered correctly into our practice's billing system. Although these information systems are adequate for getting my work done, my frustration lies in the fact that they do not work better together to facilitate my work flow and make me more efficient.

Consider the routine scheduled work flow. When a technologist finishes a study, he or she places the requisition, which is stapled to numerous associated pieces of paper, in a pile in a letter tray. Although we are filmless in our department, we are far from being paperless. Currently, there is no way to electronically annotate the study. I want to capture electronically what are now scribbles in the margins of the various papers. I also want my residents to be able to annotate images.

Every few minutes, I retrieve a stack of requisitions and return to my PACS workstation. By virtue of the accession number printed on the requisition, I can usually identify the study that needs to be interpreted. On occasion, a study is listed as "unspecified" because the image information received by the PACS from the modality workstation does not match the order information received by the PACS from the RIS. This happens frequently for trauma patients and other "John Does," but also when the hospital's admission/discharge/transfer system is down. For either of these scenarios, I must wait for the RIS administrator to manually enter the order and the PACS administrator to manually merge the image information with the order information once it arrives in the PACS. This not only delays me in interpreting the study, but I worry that the referring physician will not be able to find the imaging study in a timely fashion when clinically needed.

Because of our reliance on paper requisitions, it is also very difficult for us to distribute work efficiently among the available radiologists. We are bound to the paper requisition. We must also be in proximity to the technologists so that we can confirm exactly what was done, when, and why. The scheduling and specification of imaging protocols for work to be done is very inefficient. My residents and I are constantly being interrupted to schedule and specify protocols for studies.

On occasion, the image folder on my PACS workstation is empty because, for example, images from a computed tomographic (CT) examination of the abdomen are stored with CT images of the chest, since the images were all acquired in one data acquisition. I can almost always find the correct images, but it does slow me down. Again, I worry if my clinical colleagues will find the images in a timely fashion.

More important, images are often not presented to me as I wish to see them. In the good old days, the technologists would adjust the images on the modality workstation before filming them. Now, even when they do make adjustments to the images for an occasional hard copy, those changes don't show up on my PACS workstation and I must redo the manipulations. This duplicated effort, again, slows down the technologists and slows me down.

Since I no longer interpret studies from film and therefore do not see filmed images before they are released from the department, I am concerned that the quality of filmed images sent from the department may be suboptimal.

Worse still, there are scenarios in which our clinical colleagues must manipulate images to ensure that they are viewed correctly. Images may be technically labeled correctly, but they are not displayed conventionally. For example, we find that they often must be flipped manually horizontally or vertically. Because these manipulations are not sent from the modality workstation to the PACS, they must be performed again on the PACS. This needs to be done very quickly, as I worry that clinicians may not notice that the images, although labeled correctly, are not displayed as expected. This could lead to disastrous patient outcomes.

I need to be able to quickly identify and mark images that are important to the clinicians. I need better reporting tools. I need to record measurements and comments and to have them integrated into a consistent model for reporting radiologic findings.

IHE has addressed a number of common, problematic scenarios that crop up in my electronic world. For me, the solutions embodied in the IHE technical framework cannot be implemented fast enough. Waiting for them to become realized in the products and systems I use daily makes me feel like a chained dog faced with a steak just out of reach.

The Nonradiologist Clinician

As a clinician, I am focused on providing the best healthcare possible to my patients. I must provide this superlative care to more and more patients, and I must juggle more and more patient needs. I do so in the context of an ever-changing healthcare environment with rising bureaucracy, increasing administrative chores, decreasing reimbursement, and more and more information systems. These information systems are supposed to make my life easier and more efficient. Instead, they add steps to my work flow and reduce my efficiency, exactly the opposite of what they are supposed to do. I must have all the information I need to support my decision-making process when and where I need it. I spend too much of my time hunting and gathering information, and this strains the time I have available to digest the information and see my patients.

When I place a request for a procedure, I want to know when the procedure has or is going to be started, and I want to know when the study is completed. I want to see my patient's images when I need to see them. This might be 2 minutes after they leave the procedure room or 2 years after they leave the institution. I want to see the images and reports in my office, at home, in the clinic, and in the operating room.

When I access the images, I do not want to manipulate the images to highlight image features and findings. The technologists should have done this, and this is part of the value added by the radiologist. I rely on the radiologists more than I am willing to admit. I need their report, but it must be available in a timely fashion. I can't sift through 100 or 1,000 CT or magnetic resonance images looking for key findings. I need and trust the radiologists to filter and consolidate this vast amount of information for me. I need them to make annotations and comments that I can see when I am looking at the images.

My institution is now filmless, which has pros and cons. I greatly appreciate the positive impact of PACS on our institution. I especially appreciate no longer having to wait for films in the film file room. I appreciate that studies are almost never lost now. However, I still need film on occasion, and although I understand that the radiologists no longer check each film, I need to have good-quality hard copies available when I call for them.

When I access the images on a workstation, I don't want to spend time looking for images in folders. I don't care if the chest, abdominal, and pelvic CT images are acquired in one spiral, one helix, or one "double helix": I want look at the chest when I need to see the chest and I want to look at the abdomen when I need to see the abdomen. When I need to look at today's abdominal CT images, I don't want to wade through a bunch of neck and chest images from the previous examination before I get to the abdominal images. I can't afford to waste precious time surfing the PACS looking for the images. Similarly, when my patients come in as John or Jane Doe or change their names or need to have their identity protected, I don't want to waste time looking for their images.

I am looking for the IHE initiative to make the information systems with which I interact perform more cohesively such that I can work more efficiently, not less efficiently, in an electronic environment.

The Chief Information Officer

As the chief information officer, I am responsible for protecting and serving the data of the patients of our institution. As the steward of this information, I am responsible for the oversight and management of dozens if not a hundred or more information systems. I face this responsibility in the context of increasing internal policies and procedures for information management that are themselves a reflection of growing local, state, and federal regulations. I am also facing this information management challenge in the context of tighter budgets, rapid technology growth and the associated rapid obsolescence curve, increasing personnel costs, and a very tight technical labor market.

In the good old days, I was less concerned with information system purchases in departments such as radiology. We understood that there were information systems buried in the modalities, but at the time they didn't communicate with other information systems. Now, as the modalities and departmental information systems become more sophisticated and need to interact with other departmental and hospital information systems, the level of complexity has gone through the roof. I now have to understand how work flow is processed in each department, and I need to define the points of contact between these information systems.

I want to deploy best-of-breed computer systems to best support my clinical, research, educational, and management user communities. I love information systems standards. When standards work as intended, I can buy best-of-breed systems. Standards also encourage a healthy competition between my vendors to improve performance and service. Unfortunately, standards don't completely address all of my needs. Until they do, I can no longer afford to develop, test, and manage more point-to-point interfaces between systems. I must, therefore, consolidate to fewer information systems, even though this means occasionally giving up best-of-breed end user functionality. I know that I will never be able to consolidate to one system from one vendor, and so I look to the IHE initiative to define a framework that I can ask my vendors to implement to help me consolidate to a handful of systems that act in concert to process work flow in my institution.

The Imaging Information System Vendor

"Connectivity" of imaging acquisition systems is a nonnegotiable customer expectation. Providers transmit images from their modality workstations to a variety of imaging information systems, which include stand-alone analysis or review workstations, cluster archiving systems, hardcopy film and paper output devices, and an increasing number of PACS. The level of connectivity expected by our customers now reaches well beyond point-to-point image transfer, taking into account increasingly sophisticated work flow processes.

Many customers wonder why radiology requires more than what DICOM delivers for imaging. It is widely known that DICOM development has been a challenge; however, over the last 8 years, we in industry have optimized DICOM to provide good interoperability between radiology systems.

Now the "bar of clinical information integration" has been raised. New demands, such as linking images to radiology documents, accessing RIS and other clinical information systems, and communicating these data beyond the walls of the radiology department, require a broader level of connectivity. And this leads to the challenge of the new decade: increase efficiency and comfort of patient care and decrease the risk of medical errors. To achieve these goals, the imaging industry needs to reach out to healthcare information vendors to develop a complementary range of connectivity standards, among which HL7 plays a central role.

Through the IHE initiative, industry reaches practical agreements on the best use of information technologies and standards to solve real-world clinical problems. This is good for customers who desire flexibility to select best-of-breed imaging systems. In addition, for vendors it greatly simplifies the design and installation of new equipment and the process of upgrading previously installed equipment.

IHE is about teamwork, and not only teamwork between vendors, but also that between users and vendors. This is a novel approach to the complex problems of healthcare information systems integration that now has reached maturity in its definition. The capabilities of IHE have been proved through several multivendor demonstrations at RSNA 1999 and 2000 and at HIMSS 2000 and 2001. In addition, since any integration effort is difficult to test in the field, the IHE "connect-a-thon" which precedes these demonstrations is an extremely beneficial forum in which to test integration in a neutral environment.

To exploit the benefits of the IHE efforts to date, two specific actions need to be taken. First, vendors need to enhance and align DICOM and HL7 capabilities of their imaging and nonimaging products with the IHE initiative. Second, customers who plan to leverage the benefits of IHE by purchasing new products or upgrading existing scanners need to demand IHE participation from their vendors.

Although IHE takes a rather extensive perspective at specifying how each of the seven integrated work flow processes (or integration profiles) can be implemented in the institution, it does not require that the user upgrade all information systems at once. Each work flow process can be implemented in incremental steps, preferably starting with the Scheduled Work Flow integration profile. For example, users may elect to integrate one or two modalities with the RIS or PACS (or both) to support the Scheduled Work Flow integration profile. Overall, IHE is a key element in reducing the risk of encountering integration roadblocks. IHE significantly increases the level of the confidence in planning and executing these projects in a successful manner. This benefits both the customer and the vendor.

IHE also is an opportunity for vendors to maintain a simpler dialogue with customers in understanding their integration requirements. In addition, it provides a common framework for vendors to reach agreement on solving provider problems. For example, the IHE Consistent Presentation of Images integration profile ensures that images are consistently displayed on any display system within the institution (film or soft copy). This benefits both the user and the vendor in that images will appear consistent across all calibrated display systems. Users no longer will have to call their local service person to "tweak" the image to make it look like their films. Vendors benefit from reduced service calls.

The Nonimaging Information System Vendor

The mission of many imaging and nonimaging medical information systems vendors is to transform healthcare delivery by helping customers improve efficiency and provide consistent quality care to patients. In making this transformation, it is challenging to overcome the barriers to access information across system boundaries. Yet, there is a better approach than the "interface engine" method of data integration, which adds undue complexity, poor maintainability, and higher costs to the institution.

Each individual information system is highly dependent on work flow information from other systems in keeping the provision of radiology services responsive to the entire healthcare institution. In the past, custom ad-hoc integration solutions were viewed as insurance policies against losing customers. In reality, they have resulted in limited market growth while stifling technologic evolution. IHE provides a better solution.

In the radiology department, for example, three major forces are converging, which makes IHE a timely initiative. First, the "image factory" is becoming completely digital, which opens the door to higher efficiencies and quality of care.

The second force emerged from the dawn of the schizophrenic period when image information had to be separated strictly from the clinical and administrative information. Now the rapid adoption of PACS, its linkage to the RIS, as well as the Internet distribution of images and reports, are reinforcing the need for nonimaging and imaging product vendors to work together. With stronger linkages, the lines of RIS and PACS are being blurred, evolving into a new generation of information systems. These new systems are compelling radiology leadership to team up with the chief information officer.

Finally, the third force is the need to improve efficiency, cost effectiveness, and quality of care while concomitantly reducing medical errors. With this force, the "bar of patient information integration" has been raised. In the paper and film era, links between patient information and the acquired images were a manual process, which was both error-prone and time consuming. In this new era, patient information management becomes an integrated capability of the prescription, acquisition, review and diagnosis of a study.

Vendors view IHE as a mechanism to enable consistent exchange of clinical information and to allow healthcare providers to select best-of-breed information systems.

There is no question among vendors that the IHE initiative will lead to improved patient care and improved information accessibility for the healthcare provider. Yet vendors also look for growth, profit, customer satisfaction, and employee opportunity to fulfill their mission. Meeting the goals of IHE helps us make good on our corporate missions.

As an information system vendor, we need to ensure the future viability of our products. Through our involvement with IHE, we have gained insight and knowledge in enterprise information distribution. This insight has facilitated our ability to turn our vision of enterprise radiology into reality. IHE is helping to drive the future functionality of our products, and we believe this helps to secure our position in the future.

IHE gives us a forum to address our initiatives and priorities. Those initiatives are evaluated objectively along with the initiatives of other vendors. The end result is a solution that meets everybody's needs, thus reducing turf battles between vendors. Healthcare providers are the driving force behind IHE. Our involvement has allowed us to create and maintain a close relationship with these users. Not only do we gain understanding of our users' issues, but users also gain a better understanding of issues within the industry. This mutual understanding lends itself to a closer relationship.

In addition, our involvement has given us exposure to new users who share their ideas and experiences and may also become potential new customers. To move forward, we need the support of not only users but that of other vendors as well. Our involvement with IHE has advanced the quality of our relationships with other vendors, which has improved our ability to better serve the needs of our joint customers. Our involvement with IHE has given us insight into the various issues and challenges in the imaging world. This knowledge has been invaluable as we expand our product line.

Because of our IHE involvement, integration efforts with other vendors can be completed in less time. Even integration efforts with non-IHE compliant vendors are easier because we have a framework on which to build. With standard integration models, our customers are easier to support.

Our involvement in IHE has allowed our employees to expand their knowledge outside the radiology arena. This exposure to the healthcare industry makes our employees more valuable.

The bottom line is that IHE is good for business. Our involvement is helping us meet our objectives to deliver on our vision of the future. The truly remarkable thing about IHE is the fact that it's good for the patient, it's good for the healthcare provider, and it's good for all information systems vendors. IHE has created an environment where everybody wins.

Conclusions

Numerous stakeholders in the healthcare delivery process share common problems, at least some of which are addressed by the IHE initiative. Most important, the IHE initiative provides a forum and a framework in which all these stakeholders can come together and work to resolve these problems. The model established by this initiative can and will be extended vertically within radiology, to other departmental areas, and horizontally across the healthcare enterprise.

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Integrating the Healthcare Enterprise: A Primer

Part 4. The Role of Existing Standards in IHE[1]

Michael Henderson • Fred M. Behlen, PhD • Charles Parisot • Eliot L. Siegel, MD • David S. Channin, MD

Introduction

Integrating the Healthcare Enterprise (IHE) is not a standard. IHE is an initiative and a movement that has produced numerous deliverables. First and foremost, IHE has produced a milieu for open discussion among medical information system vendors, users, and other interested parties (eg, standards bodies, professional societies) on how to better integrate heterogeneous computer information systems with the goal of improving patient care. The initiative also provides vendors with a "connect-a-thon," which allows them to confirm that their systems can successfully connect to and communicate with each other. From the perspective of practical value to the user, the most important output of the IHE initiative is the technical framework (1). This document describes, as unambiguously as possible, the transactions that must occur to solve seven real-world problems, or *integration profiles* in IHE terms.

If the IHE and its technical framework are not standards, what are they? The technical framework serves as a consensus document of how to think about, discuss, and successfully overcome medical information system integration problems by using existing standards and tools.

The following analogy may clarify further that one *conforms* to standards, whereas one *complies* with consensus documents such as the IHE technical framework. Consider hammers, nails, screwdrivers, and screws. There are many different hammers—cheap ones, expensive ones, manual, air-driven, and so on-but most hammers consist of a handle on one end and a shaped piece of hard material on the other. The same applies to screwdrivers. There are standards for hammers and standards for nails. There are even more technical standards for screws, since they are a more modern device. The standards for hammers might stipulate, for example, that the hammer head cannot fragment into dangerous shrapnel when a force of less than *n* newtons is applied to it. A standard, however, would probably not prohibit you from driving a

Abbreviations: ADT = admission/discharge/transfer, CDA = clinical document architecture, DICOM = Digital Imaging and Communications in Medicine, HL7 = Health Level Seven, IHE = Integrating the Healthcare Enterprise, PACS = picture archiving and communication system, RIM = reference information model, XML = extended markup language

Index terms: Information management • Picture archiving and communication system • Radiology and radiologists, departmental management • Radiology reporting systems

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screw with a hammer, and, in fact, numerous people probably do drive screws with hammers. One could imagine a group of prospective homeowners and a group of builders getting together and coming to a consensus that if a builder wants to participate in a project that he or she will agree to drive nails with only hammers and to drive screws with only screwdrivers since those methods yield the best result, that is, a safe, strong structure with a good look and feel. The consensus could also state that a certain kind of nail should be used in one situation and that another kind of nail should be used in another situation, without specifying a standard for how those nails should be manufactured.

To extend the analogy further, the homeowner (or even appropriate governing authorities) might require the builder to conform to certain standards, such as local electrical codes. The homeowner, however, could also require the builder to adhere to other consensus documents that might otherwise be optional for the builder. The builder complies to meet a customer requirement, and by doing so, the builder's construction company can participate in a larger arena where cooperation among builders is required. It might also lower their construction costs due to a reduction in the number of different kinds of nails and screws required.

The Digital Imaging and Communications in Medicine (DICOM) (2) standard from the American College of Radiology (ACR) and the National Electrical Manufacturers' Association (NEMA) and the Health Level Seven (HL7) standard (3) from same organizations are the tools—the hammer and screwdriver—currently used in the IHE technical framework. The data elements used by these standards and precisely defined by the IHE framework are the nails and screws.

As the IHE initiative expands into other medical arenas outside radiology and as it addresses other healthcare enterprise–wide processes, other tools (standards) will be added, as appropriate, to the IHE toolbox. For now, however, understanding the role of HL7 and DICOM in IHE is sufficient, and this article is intended to clarify how the IHE community of vendors and users employ the existing standards of HL7 and DICOM to achieve the integration goals of IHE. The article also examines how HL7 is evolving to meet the challenge of more complex information system integration demands and details some of the newer components of DICOM and how they relate to IHE.

Health Level Seven

HL7 is a standard for electronic data interchange in healthcare environments. Originally developed in 1987 by a group of large healthcare providers who met at the University of Pennsylvania, the standard at first emphasized point-to-point transmission of patient-oriented admission/discharge/transfer (ADT), order, and results information in inpatient environments. Today, HL7 prescribes formats for the interchange of information concerning all aspects of the healthcare enterprise, including billing, clinical pathways, care guidelines, referrals, and information about practitioners and support staff.

The "seven" in HL7 is a reference to the position of the standard atop the seventh layer of the Open System Interconnection (OSI) series of protocols from the International Organization for Standardization (ISO) (4). From its inception, HL7 has emphasized the data to be carried, rather than the formatting of messages or the configuration of endpoint systems. By its own description, HL7 "does not try to assume a particular architecture with respect to the placement of data within applications but is designed to support a central patient care system as well as a more distributed environment where data resides in departmental systems. Instead, HL7 serves as a way for inherently disparate applications and data architectures operating in a heterogeneous system environment to communicate with each other" (3).

Data in an HL7 message are transmitted in fields of well-defined data types. Fields are grouped into segments of related information. Messages may be formatted by using Encoding Rules/7, which treat segments of a message as recordlike entities and set off fields and subfield elements by using common delimiters such as a vertical bar (|) and caret (∧). Alternatively, HL7 messages may be transmitted by using external protocols such as the extended markup language (XML) (5).

HL7 provides widely adaptable specifications for the transmission of such data as patient identifiers and addresses, as well as the encoding of clinical information, by using well-known systems such as the Common Procedure Terminology (CPT) from the American Medical Association (6), the International Classification of Diseases (ICD) (7), and Logical Observation Identifier Names and Codes (LOINC) (8).

This "widely adaptable" capacity of HL7 is a great weakness as well as a strength. "Widely adaptable" means that different vendors can implement the HL7 standard in a variety of ways.

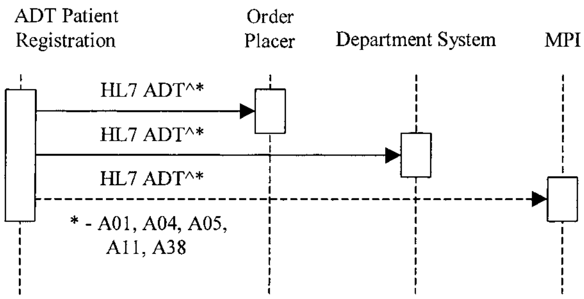

Figure. Interaction diagram shows how patient information flows from the registration system to interested endpoint systems by means of ADT messages. *A01*, *A04*, *A05*, *A11*, and *A38* represent the specific trigger events that cause the transmission of messages: admission, registration, preadmission, admission or registration cancellation, and preadmission cancellation. Each of these events triggers the generation of an event-specific message to the Order Placer, department, and master patient index (*MPI*) systems.

This lack of uniformity makes HL7 interfaces expensive and complicated for both vendors and customers because each of the many different systems from many different vendors may have used a different interpretation of HL7. The IHE technical framework comes to the rescue by specifying *how* to use HL7, which reduces the variability in implementation. This consensus makes it easier for users and vendors to interface their systems, which creates a potential for substantially reducing costs.

Utility of HL7 in the Clinical Service Environment

The HL7 standard prescribes messages for the transmission of patient demographic and registration information, as well as for the communication of clinical orders, observations, and results data. The standard is thus well suited for transmitting data between integrated clinical information systems and systems dedicated to the support of specific clinical services, such as laboratory and radiology.

Messages in HL7 are initiated through the occurrence of trigger events, such as "patient is admitted" or "new order is placed." The event-driven nature of the HL7 environment makes it a relatively simple matter to produce case illustrations and interaction diagrams that precisely define the participants in a dialogue, their roles and responsibilities, and the nature of the communications between them. A sample interaction diagram from section 6.1.4 of the IHE technical framework document (1) illustrates how the ability of HL7 to model real-world events fits into IHE (Fig).

HL7 Use in IHE

In the IHE technical framework, several sets of HL7 transactions are defined for communicating three broad categories of information: patient, order, and results information. These transactions operate between the ADT and order entry systems on the requesting side and between the Department System Scheduler and Image Manager systems on the performing side.

Patient Information.—HL7 ADT messages provide for the communication of demographic and registration information in response to over 60 discrete trigger events. The IHE technical framework specifies Patient Registration and Patient Update transactions in which this information will be communicated, and cites 13 trigger events from the HL7 standard that will cause the generation of messages within the IHE model.

Order Information.—Within HL7, a general-purpose order management (ORM) message allows communication of order and status data between Order Placer and Order Filler systems. The IHE technical framework specifies Placer Order Management, Filler Order Management, Procedure Scheduled, and Procedure Update transactions that use HL7 ORM messages and order responses (ORR) to coordinate the transmission of this information.

Results Information.—Although most IHE transactions dealing with reports use the DICOM standard, IHE uses the HL7 observation results unsolicited (ORU) message to transmit ASCII text report information between a report manager and a repository.

Patient Information Messages

As shown in the Figure, patient information originates in all cases from the ADT system and flows to the systems that need patient data to correctly attach orders and results to the correct patient. HL7 messages are used to transmit demographic information, visit data, and such vital statistics as height and weight.

The IHE technical framework document specifies a Patient Registration transaction by using the trigger events shown in the interaction diagram. In addition, a Patient Update transaction is defined by transfer, discharge, and class update events (and their cancellations, where applicable); demographic data updates; and duplicate patient record merges.

IHE also provides for the entry of order information for unidentified patients directly into the Order Placer or Order Filler systems. In this way, the provision of care is not impeded by the lack of available demographic information or by the unavailability of system resources. Reconciliation of patient data among systems is accomplished subsequent to the placement or execution of the order.

Order Information Messages

IHE uses the HL7 general-purpose order management message to communicate information about the patient for whom the order is being placed, the time for which the procedure is scheduled, and the specific activities to be performed. In contrast to ADT messages, which are distinguished by their trigger events, order messages use an order control code to communicate state transitions (eg, new order, number assigned, order discontinued).

In the IHE model, orders may be initiated on either a placer (order entry) or filler (Department System Scheduler) system. The filler system is responsible for determining the specific procedures and steps required to fill the order and for transmitting all order information, including patient demographics, to the Image Manager.

Four HL7 order transactions are specified in IHE: (*a*) placer order management, in which new orders and cancellations are transmitted from an order entry system; (*b*) filler order management, which provides for communication of new orders, order updates, and cancellations from the Department System Scheduler or Order Filler; (*c*) procedure scheduled, in which order information is transmitted from the Order Filler system to the Image Manager; and (*d*) procedure update, in which the Order Filler communicates changes to procedure and schedule information to the Image Manager.

Results Information Messages

The IHE technical framework facilitates the transmission of DICOM structured reports to an enterprise report repository. To accommodate the widest number of possible endpoints, reports are specified as simple ASCII text; the use of special formatting characters within the report is discouraged.

Results received through DICOM structured reports must be mapped to the HL7 standard. In a number of cases, the data types and field widths vary between the DICOM and HL7 standards. IHE provides a complete mapping of the fields common to both formats.

Future Developments in HL7

Although HL7 has been a successful standard by any measure, the implementation of each HL7 interface involves substantial customization at considerable cost. In large measure, this customization is the price for the flexibility that HL7 provides. HL7 has evolved to meet the need for the many point-to-point connections present in the healthcare enterprise. Like DICOM, HL7 does not dictate the internal organization of applications, but only the meaning and format of communications between those systems. But unlike DICOM, which operates in a much more limited domain, HL7 has no explicit information model that defines the relationships between the concepts in the various types of messages. There is an information model that is implied by the messages, just as there is in natural language, but as in natural language there is considerable latitude for interpretation. The Version 3 project, which began in 1996, has undertaken to develop an explicit information model common to all HL7 messages: the reference information model (RIM). It is important to understand that the RIM does not model all of healthcare, but only the aspects that are common to the various application domains and need to be communicated. But even so, the scope of this modeling effort is immense.

The lack of a common information model invites questions such as, "If I can fax a result to a referring physician, why can't I fax a result to a patient?" (Answer: Because a fax number is an attribute of a physician, not of a patient.) The RIM recognizes that physicians and patients are both people, albeit in different roles, and that both may possess a fax number. Because they are derived from a common information model, the various Version 3 messages will have a greater degree of consistency. This greater consistency will serve the aim of reducing the variability that necessitates extensive customization of present HL7 interfaces. Further standardized compatibility will ensue as internal data models of systems evolve to become more compatible with the RIM and with Version 3 messaging (a natural result as designers adopt standard data models to simplify interfacing). This process will take many years, but its fruits will justify the years of development of Version 3.

In addition, Version 3 defines a development framework that specifies how messages are developed from the RIM. Automated tools are being devised to make this process less arduous and error prone.

The adoption of XML as the encoding syntax for HL7 Version 3 has attracted much attention.

It is important to understand that XML is a tool for tagging text information and for working with tagged data, but it does not define the tags nor their meaning. HL7 provides these definitions and uses XML as a tool for encoding them. XML encoding will facilitate the communication and processing of HL7 messages with widely available software tools. A fair share of the HL7 development effort has gone into the adoption of XML, but that effort is dwarfed by the collective effort of reconciling all messages to a common information model, the RIM.

Clinical Document Architecture

Another major development in HL7 is the clinical document architecture (CDA). The CDA provides an exchange model for clinical documents, which may include narratives, such as discharge summaries, and structured consultation reports. The CDA employs the HL7 RIM, coded vocabularies, and XML to make documents that are legible to both humans and machines. These documents can be parsed and processed electronically and can still be retrieved and displayed by using XML-capable Web browsers.

The CDA is called an architecture because it specifies common characteristics of families of documents rather than a specification based on a single document schema. Implementation of CDA occurs at three "levels."

Level 1 of the CDA defines a document header that identifies the document, its version, its author, whom it is about, and the clinical context (eg, encounter, location). Everything in the CDA header is derived from the RIM. The body of the document contains basic text structures such as sections, paragraphs, lists, and tables, but no RIM-derived content is specified (ie, the body content is not standardized).

Level 2 assigns codes to document types and to structures within the document body, enabling, for example, an insurance claim processor to extract the diagnosis section from a report.

Level 3, which is expected to be completed in 2002, will define the encoding of any RIM content in a CDA document. Level 3 will specify the markup of clinical content to the extent that it can be expressed in the RIM. Thus, anything that can be expressed in Version 3 messages can be encoded in Level 3 CDA documents, although CDA documents may still contain text content that is not modeled in the RIM.

A key distinction of the CDA, as opposed to HL7 messaging, is its treatment of persistence and paradigms for data management. Messages are used to update databases, and of course databases can be designed and operated so as to provide persistent long-term storage, but the foundation on which databases operate is the maintenance of up-to-date information. Document management encapsulates information into persistent objects, which are archived until they are discarded. A document may be superseded by a later version, but it cannot be changed. As such, document management is more focused on maintaining a collection of permanent records.

Clearly, both approaches have a role in health information management. Persistent objects facilitate the management of permanent records, whereas messages are better for updating dynamic variables. The addition of the CDA to the traditional HL7 messaging standards allows HL7 to serve both needs.

Digital Imaging and Communications in Medicine

There is probably not a radiologist in the world who does not know of DICOM. Many would say that DICOM is a standard to communicate radiologic images from acquisition devices to workstations or a picture archiving and communication system (PACS). This purpose was indeed the prime objective of DICOM in the late 20th century, but this is no longer the case.

DICOM at the Close of the 20th Century

DICOM image transfer from a computed tomography, magnetic resonance imaging, computed radiography, radiofluoroscopy, angiography, ultrasonography, nuclear medicine imaging, or positron emission tomography device was a reality by the mid-1990s. This image transfer was the first dimension of DICOM. It made the DICOM standard universally accepted in the radiologic community and allowed the standard to extend rapidly to include cardiology and radiation therapy. It is now poised to address the needs of other medical imaging arenas such as microscopy, pathology, and ophthalmology. DICOM should no longer be viewed as a radiology-specific standard. DICOM now includes, for example, specifications for a variety of commonly used one-dimensional waveforms, such as those used in cardiology or electrophysiology.

The second dimension of DICOM, which is also widely accepted, addresses the network connection of print devices that produce film and other print media. Commonly called DICOM

Print, it is an important productivity tool that allows film and paper printers and other hard-copy imaging to be connected to a hospital network, not only within the radiology department but also in remote clinical areas.

The third dimension of DICOM concerns the interchange of images on storage media such as magneto-optical and CD-ROM disks. The DICOM CD-R was particularly successful. First introduced in angiography and cardiology as a cost-effective and full-fidelity recording media to replace traditional cine films, it is now increasingly used as an effective way to give patients their images for transfer between healthcare providers. With a simple DICOM viewer on the CD, any referring physician or even the patient can view the images on any personal computer. (Many free public domain DICOM image viewers exist; for example, see *www.psychology.nottingham.ac.uk/staff/cr1/dicom.html*.)

The fourth dimension of DICOM arose from the recognition that the network integration needs of the imaging department required more than the electronic exchange of medical images. Imaging and work-flow management require that nonimage information be exchanged between the imaging devices and the information systems in the department, notably the radiology information system (ie, Department System Scheduler or Order Filler in IHE terminology) and increasingly the PACS (the IHE Image Manager or Image Archive). The first of these functionalities to be standardized was the *Modality Worklist* service class. This transaction transmits to the image acquisition device a variety of information such as patient demographics, requested procedure, and scheduling information. This transfer of data allows a technologist at a modality to select the patient or study information from a list of choices and therefore reduces the chance of making a typographic error in manually entering the same information (however, errors in patient or study selection can still occur). The Modality Worklist is now in broad use, and no enterprise of significant size can afford to operate in a digital environment without it.

The DICOM *Storage Commitment* service class followed the DICOM Modality Worklist closely. Storage Commitment can be used to guarantee that images will not be deleted from an acquisition device unless another device (typically an archive) takes ownership and responsibility for the long-time care of the images.

DICOM in the 21st Century

More recently, DICOM introduced the *Performed Procedure Step* service class that signals to the Department System Scheduler, Image Manager, and Image Archive that a scheduled step in the work flow has been completed. The signal includes key tracking information for the Image Manager or Image Archive and Department System Scheduler, such as the list of images concerned and dose information. IHE has been instrumental in ensuring that these three image management services (Modality Worklist, Storage Commitment, and Performed Procedure Step) become broadly supported on modality workstations, PACS, and radiology information systems via the Schedule Work Flow integration profile (9).

The fifth dimension of DICOM brings us back to images and their consistent display. In an environment of local, physical image production (either film-screen radiography or film printing), the imaging department can control image quality. In an electronic environment in which images are printed remotely or reviewed on far-flung workstations, the consistency of gray-scale rendering becomes an important issue. The techniques previously used by the imaging department, notably the cross-calibration of every image-rendering device against every image-generating source, cannot be extended to any significant size because of the cost and complexity of such a task.

DICOM provides a solution with the standardization of a gray-scale display function based on the physiologic perception of luminance by the human eye (10). As a consequence of this standardization, as soon as each sending or receiving device is independently calibrated against this DICOM Gray-scale Display Function, pixel values representing the actual gray-scale levels can be perceived in a consistent manner independent of the luminance characteristics of the rendering device.

DICOM has extended the notion of gray-scale calibration to include other manipulations, such as flip, rotate, or zoom transformations and textual or graphic annotations, such that a complete documentation of how the image was presented may be made. DICOM (and therefore IHE) terms this a *Gray-scale Presentation State*, and these states have been adopted as formal DICOM objects.

There are a number of important scenarios for which precisely defined presentation states might be useful; for example, to make a record of the viewing conditions of an image at a specific point in time, to transfer manipulations made on one device to another device, and to ensure display consistency between a print composer and printer (although the latter uses an extension to DICOM Print called *Print Presentation Look-up Table*). In addition, the Gray-scale Presentation State provides a mechanism for optimizing the use of new DICOM objects for direct radiography and digital mammography, both of which require that all sending and receiving systems to be calibrated. IHE has adopted these presentation services in the IHE Consistent Presentation of Images integration profile.

The sixth dimension of DICOM addresses reporting and measurement collection, including links to the DICOM images from which these reports and measurements are made. Called the DICOM *Structured Reporting* service class, this DICOM component introduces a pragmatic and progressive approach to coding and structure in reports. DICOM Structured Reporting objects, like the DICOM image objects, have the possibility of being extremely complex. This potential for complexity is necessary to cover the wide range of reporting applications. Just as the use of DICOM formatted images has taken a few years to address all types of images, we expect DICOM Structured Reporting to be adopted in stages.

DICOM Structured Reporting addresses the need to electronically record measurements either directly at modality workstations or when the measurements are integrated with viewing, analysis, and even computer-assisted diagnosis applications. These DICOM reporting objects can also be used to capture informal notes that today are scribbled on tiny scraps of paper or image jackets. As tools to manage reporting codes and automatic reporting techniques, such as text templates, become more prevalent, DICOM Structured Reporting should become a valuable format to support more general radiology reporting, especially as it becomes more common to maintain links with key images and data mining applications. IHE begins the process of exploiting DICOM Structured Reporting in the IHE Simple Image and Numeric Report integration profile.

The HL7-DICOM Common Working Group

DICOM and HL7 are working together through a common working group, recognized by HL7 as the Imaging Integration Special Interest Group and by DICOM as Working Group 20. The group monitors the IHE initiative and can supply recommendations for changes in standards to the appropriate body, when changes are found necessary. The memberships of the Imaging Integration Special Interest Group and Working Group 20 also overlap with the membership of the IHE Technical Committee.

Summary

IHE is not a standard. It is an initiative that has produced a consensus document that serves as a technical framework within which medical information systems can be designed to interact successfully to accomplish real-world tasks. IHE uses existing standards as tools to achieve integration. Today, these tools are DICOM and HL7, which are sufficient for the tasks described in the current IHE integration profiles. As more integration profiles and tasks are defined in other areas, other standards will be added as necessary.

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Integrating the Healthcare Enterprise: A Primer

Part 5. The Future of IHE[1]

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Introduction

The future of Integrating the Healthcare Enterprise (IHE) is you. All who are interested in advancing integration of healthcare information to improve patient care are welcome to participate in the IHE initiative. In particular, the stakeholders identified in a previous primer article (1)—the department chief or chairman, department manager or administrator, technologist, radiologist, nonradiologist clinician, chief information officer, imaging information system vendor, and nonimaging information system vendor—should actively participate in IHE efforts. In this article, we review the structure of the IHE initiative, educational opportunities, the Year 3 demonstration, and how to specify and purchase IHE functionality. We also suggest other ways for the stakeholders in medical informatics to participate.

Structure of the IHE Initiative

The IHE initiative is organized into a set of committees, each of which has been given a specific role to play in making the initiative a success. The initiative is directed by an executive committee made up of senior members and senior staff members of the two (to date) sponsoring professional societies of the IHE, namely the Radiological Society of North America (RSNA) and the Healthcare Information and Management Systems Society (HIMSS).

If you are a member or senior staff member of a professional healthcare-related society, you should be lobbying your society to become a sponsoring society of the IHE. Although there is a small financial burden to becoming a sponsoring society, there is a potential for a tremendous return on investment as the IHE expands to meet the particular needs of your society and its membership. Studying the lessons learned from the radiology examples and experience documented in these primer articles (1), as well as other reports, should help you identify analogous problem areas in your domain that could be addressed by expansion of the IHE initiative.

The IHE Executive Committee directs the Strategic Development Committee. This recently constituted committee consists of clinical and clinical informatics experts from radiology, pathology, nursing, and internal medicine. There are also tech-

Abbreviations: DICOM = Digital Imaging and Communications in Medicine, HIMSS = Healthcare Information and Management Systems Society, HL7 = Health Level Seven, IHE = Integrating the Healthcare Enterprise

Index terms: Information management • Radiology and radiologists, departmental management

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nical representatives from the Electronic Communications Committee of the RSNA and the IHE Special Interest Group. The latter represents chief information officers of major healthcare institutions. The emeritus chairs of the IHE planning committee are also included. Staff from the RSNA and HIMSS round out the committee. The committee is charged with identifying steps in patient care work flow, recommending priorities of clinical and operational domains for IHE consideration, identifying integration needs and barriers (problems and solutions) within and across domains, and lastly, helping to populate the domain planning committees.

The domain planning committees (of which there is currently one [radiology] with others in formation) are responsible for filtering the problem and solution sets from the Strategic Development Committee down to those sets that can realistically be addressed by IHE. These committees consist of vendors and domain experts (eg, system users, administrators, hospital information system experts), and they direct parallel technical committees to develop the solutions identified.

The technical committees are typically, although not exclusively, made up of vendor experts. These experts are the unsung heroes of the IHE effort. These individuals spend (and their companies generously sponsor) an inordinate amount of time delving into the nitty-gritty detail of the integration to ensure that it works.

Last, and certainly not least, the IHE initiative has a technical project manager, Dr Steven Moore of the Mallinckrodt Institute of Radiology at Washington University in St Louis, Missouri. Dr Moore and his team, working under subcontract from the RSNA and HIMSS, develop the test software used by participants in the IHE connect-a-thon and demonstrations and manage these events. The software for the current year is available to only current participants in the connect-a-thon and demonstration. The small charge to participate is typically trivial in comparison to the value of the knowledge gained by the vendor, the value of participation in the connect-a-thon, and the value to the vendor's products in complying with the IHE technical framework. The software used in previous years' demonstrations is available at no charge to the general public from the IHE Web site, *www.rsna.org/IHE.*

Educational Resources

There are numerous IHE educational resources. In addition to the demonstrations and workshops at the annual meetings of both RSNA and HIMSS, there are presentations and sessions on IHE-related topics at many medical and medical informatics meetings held throughout the year.

In addition to the current *RadioGraphics* series of primer articles (in the September-October 2001 and November-December 2001 issues), the IHE Web site (*www.rsna.org/IHE*) has numerous other documents and PowerPoint presentations that can be used as educational materials. This Web site is also home to the latest revision of the IHE technical framework (2), although some might consider the framework to be graduate-level educational material. An IHE presentation is available through the HIMSS Web University at *www.himss.org.* In addition, an IHE monograph of relevant articles describing IHE functionality, solutions, and future directions will be published by HIMSS in early 2002.

Year 3 Demonstration: RSNA 2001 and HIMSS 2002

After participating in the connect-a-thon in early fall 2001, vendors will gather for public demonstrations of IHE integration at both the annual meeting of the RSNA (November 25–30, 2001) and the annual meeting of HIMSS (January 27–31, 2002). After 2 years of rapidly expanding integration capabilities, the IHE committees designated Year 3 as a consolidation period: a time to educate users about the solutions that IHE has made available to improve patient care, while these enhancements simultaneously become broadly available in commercial products. For Year 3, the vendor demonstrations were redesigned to communicate the clinical benefits available through IHE and how to obtain them. The demonstration groupings will be organized by the seven IHE integration profiles (3): Scheduled Work Flow, Patient Information Reconciliation, Consistent Presentation of Images, Presentation of Grouped Procedures, Access to Radiology Information, Key Image Note, and Simple Image and Numeric Reports. These integration profiles are discrete blocks of integration capability that provide specific enhancements to clinical practice. Attendees at the demonstrations will be guided through the full sequence of integration profiles.

The demonstrations will be supplemented with educational workshops targeted to the specific need of clinicians, information technology and radiology administrators, systems implementers, and technical support staff. Of particular interest will be sessions on clinical problems and solutions, with use of IHE to acquire integrated systems, and on user perspectives from clinicians and administrators whose institutions have implemented IHE functionality. A kiosk that features an interactive video highlighting the IHE initiative will also be available.

A full schedule of the demonstrations and educational workshops at the RSNA annual meeting can be found at *www.rsna.org/IHE/ihedemo2001/*. A similar schedule for the IHE demonstration and related events at the HIMSS annual meeting can be found at *www.himss.org*.

Professional societies and other organizations interested in incorporating components of the demonstrations, workshops, and other presentations into their societal events should contact representatives of the IHE initiative (see below). A miniature speaker's bureau is available, and there are numerous IHE experts available to speak at other meetings.

How to Specify and Purchase IHE Functionality

Anyone involved in making information system purchasing decisions at healthcare institutions should be well aware of the IHE initiative, the IHE information model, and the integration profiles. A specific document, "IHE Profiles: Guidelines for Buyers," is available from the RSNA Web site.

The IHE technical framework is a revision-controlled document that can be incorporated by reference into legal contracts. Although typically a purchase contract requires that equipment or services conform to standards, the contract can also specify compliance with the IHE technical framework. Thus, one can specify conformance to the HL7 and DICOM standards and additionally require compliance with the IHE technical framework.

The role of radiology executives, radiology department administrators, and senior management in advancing the efforts of IHE by specifying IHE compliance (and DICOM and HL7 conformance) in purchase contracts cannot be underestimated. Although altruistic to a point, most healthcare information system vendors are driven by marketing and sales organizations. Vendor engineering groups typically receive significant direction and guidance from these groups. If IHE compliance and adherence to standards is not **loudly** and **clearly** communicated as being of great importance to the user community, future IHE engineering efforts may be diluted by perceived need to develop other functionality.

Vendors, on the other hand, will be thrilled to receive uniform, loud and clear feedback from their customers, especially when it leads to significant overall improvement in their products; lowers the complexity (and therefore cost) of their interface development, deployment, and support; and allows them to operate in a larger arena of integrated heterogeneous systems.

An important note to buyers: Beware the notion of purchasing a system that conforms to standards (notably DICOM) and complies with IHE, yet in which these functionalities are not "turned on" or in which "turning on" these functionalities requires an additional cost. IHE, DICOM, and HL7 functionality should be on and running when the system is installed and should be included in the base price of the system.

Future Directions

The IHE Strategic Development Committee is, as charged, expanding the model of integrated, scheduled work flow to include more patient care work flow processes. As new areas of integration problems between information systems are identified, the committee will use the concept of integration profiles to address them. The committee is currently looking at pathology work flow, and at such enterprise-wide integration frustrations as desktop integration, security (in light of forthcoming HIPAA [Health Insurance Portability and Accountability Act] requirements), and electronic master patient index issues. Other suggestions for future directions of IHE efforts are welcome.

How to Contact the IHE

To learn more about IHE, please visit the IHE Web site at *www.rsna.org/IHE* or search for the term IHE at *www.himss.org*. To participate in IHE at any level, you should contact either Joyce Sensmeier, Director of Professional Services, IHE Coordinator, Healthcare Information and Management Systems Society (HIMSS), 230 E Ohio St, Suite 500, Chicago, IL 60611-3269, or Christopher Carr, Director of Informatics, IHE Coordinator, Radiological Society of North America (RSNA), 820 Jorie Blvd, Oak Brook, IL 60523.

Comments, questions, concerns, and ideas can be sent to the addresses above or electronically to *IHE@rsna.org*.

Call to Action

Anyone interested in realizing the dream of having all relevant patient information available to all care providers on demand at the point of care while concomitantly reducing errors, reducing costs, and increasing efficiency should be interested in the IHE initiative and its future.

Chairmen should be studying the work flow in their departments and identifying new ways that IHE can assist them in improving these work flows by better integration of information. They should identify clinicians in their departments with technical backgrounds or interests and encourage and support them in participating in IHE committees. They should encourage students and residents in their departments to recognize healthcare informatics as a legitimate area of research so as to foster the next generation of clinicians capable of further advancing medical informatics technology. Together with department administrators and senior institution management including chief information officers, they should require standards conformance and IHE compliance in all relevant purchases.

Similarly, department administrators should constantly look for work-flow problems in their departments that IHE efforts could possibly remedy. These suggestions should be forwarded to the IHE committees. As stated, administrators should demand IHE compliance and standards conformance in all purchases. When purchasing new equipment, they should consider not only the chemistry or physics and functionality of the device but make a special effort to consider its informatics and how it fits into the work flow of and communicates with other systems in the department or institution.

In the trenches, technologists, radiologists, and clinicians should be documenting information and work-flow problems they encounter in daily practice. These problems should be forwarded to the IHE committees. These individuals should not be intimidated by a lack of technical expertise (remember, you don't need to know how to forge iron to use a hammer): The IHE initiative needs to identify clinically relevant problems to solve, and you can help. You should become active in your professional societies, and if they are not participants in the IHE initiative, lobby them to join. You can also participate directly in the IHE committees. It is extremely interesting, educational, rewarding, and even fun to participate in these efforts. It is especially rewarding to see the rapid incorporation of IHE efforts into real-world products and the immediate benefit of IHE technology in the clinical workplace.

Chief information officers and others in senior management should lobby their professional societies to join the IHE initiative. They should insist that all their information system vendors participate in the IHE effort, not just those involved in departmental or specialty systems. There can no longer be islands of information in a healthcare enterprise. All information systems must work synergistically to get the job of delivering optimal healthcare done.

Any vendor of a device that contains a computer of any sort should become involved in standards bodies related to their domain. In addition, they should participate in the IHE initiative and encourage the inclusion of the appropriate standards from their domain in the IHE toolbox.

There is a role for everyone in integrating the healthcare enterprise. Got IHE?

References

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2. Radiological Society of North America/Healthcare Information and Management Systems Society. IHE technical framework, year 3, version 4.6. Oak Brook, Ill: RSNA, March 2001.
3. Channin DS. Integrating the healthcare enterprise: a primer. II. Seven brides for seven brothers: the IHE integration profiles. RadioGraphics 2001; 21: 1343–1350.