Integrating the Healthcare Enterprise: A Primer

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

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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

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

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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 Grayscale 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 Soft-copy 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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