This article addresses various aspects of the integration of imaging systems and information systems in the radiology department and the hospital as a whole. It includes the technical and organizational obstacles, the role of standards, and some promising recent developments for overcoming the obstacles. Particular attention is paid to the IHE (Integrating the Healthcare Enterprise) initiative.

The IHE initiative was started in November 1998 by the Radiological Society of North America (RSNA) in conjunction with the Hospital Information and Management Systems Society (HIMSS). The aim of the initiative was to devise a technically viable specification for improving communication between the various healthcare systems and medical devices. Representatives of the healthcare providers, the industry, and standardization bodies were invited to participate.

The tasks of the IHE are defined by a Planning Committee, and a Technical Committee is responsible for drawing up detailed technical specifications. The specifications are based on existing standards.

Because hospital-wide integration is a very complex task, the IHE initiative has been divided up into multi-year projects. Year 1 concentrates on integrating the radiology department within the hospital environment. This involves ensuring compatible communication of image information and medical data between the various imaging modalities, Picture Archiving and Communication Systems (PACS), Radiology Information Systems (RIS) and Hospital Information Systems (HIS).

In the course of a 5-year program, the integration will be expanded to include other clinical departments, with the ultimate goal of achieving multidisciplinary clinical documentation with a complete and integrated Computerized Patient Record (CPR).

Comprehensive demonstrations of Simulated Healthcare Enterprises (SHE’s) will be given at major congresses. These allow potential users to familiarize themselves with the functionality, and provide valuable feedback.

The IHE is technically feasible because it is a generic solution, with virtually universal application, and is in strict conformance with the accepted standards for health information systems such as Health Level 7 (HL7) Version 2.3 and DICOM.

The integrated multivendor radiology department

Figure 1 shows the various information and imaging systems to be found in a typical radiology department. In most cases, the hospital will want to mix and match systems from different vendors: imaging modalities, HIS, RIS, ‘stand-alone’ workstations, and PACS. Although the systems may be from different vendors, the hospital will still expect them to form part of an integrated radiology department, with trouble-free transfer of information and images between them.

IHE Planning Committee, Philips Medical Systems, Best, the Netherlands.
With respect to the transfer of information, there will usually be a hospital information system (HIS) and a radiology information system (RIS). There is no agreed definition of the functionality of a HIS and a RIS, and their functionality may, to some extent, overlap.

In general, the HIS provides a range of functions including patient registration and admission, patient transfer, order placing and billing at the hospital level. There is, in fact, much more functionality in a HIS, but this is not relevant for the purposes of this article.

The RIS provides functions specifically for the radiology department, e.g. order-filling, patient/examination scheduling, reporting and materials management. However, there are many variations. For example, the HIS may also provide RIS functionality, or the RIS may also provide patient registration, order filling and billing.

With respect to the images, there are the imaging modalities themselves, PACS and ‘stand-alone’ workstations. The PACS stores the generated images and provides the workstations for diagnostic viewing. It may also be connected to teleradiology facilities, and it may be responsible for the distribution of images and reports to the clinical departments.

Integration of information across the various systems is not trivial: system topologies as well as system functionalities have to be very flexible. Thus, although interoperability is essential, it is sometimes difficult to agree on standards.

**Workflow Integration**

The primary reasons for information integration in a radiology department are increased efficiency and improved patient care, achieved through consistency and continuity of information flow through the different systems.

Table 1 shows a model of the generic workflow through the various systems in the radiology department, with the functions of the various information and imaging systems. It only shows the standard situation. There can be many deviations from the standard workflow, e.g. in case of emergencies. The expected information transfer between RIS, imaging modality and PACS is shown in more detail in Figure 2:

- From RIS to Modality: the worklist with patient demographics and other administrative data, information about the imaging procedure and a unique reference to which the generated images can be related.

- From Modality to RIS: information about the start and the end of the procedure, and the results of the procedure: the number, type and whereabouts of the generated images, dose, contrast agent, etc.

- From Modality to PACS: the images (grouped in a series and/or study), the unique identifiers belonging to study and procedure, and administrative and clinical data related to the patient (as received from the RIS) and the examination result. This information is similar to the information transferred to the RIS, but this time it is added to the image information directly, so that the images are readily understood, even if they are received in isolation.

System topologies and functionalities have to be very flexible.

Equipment from different vendors must be mutually compatible.
- From RIS to PACS and vice versa: information to allow pre-fetching of images, case status reporting, exchange of reports and requests.

Workflow integration and interoperability is at present hampered by a number of serious obstacles. Many of these are related to the mismatch between the DICOM standard for digital image communication in medicine, and the HL7 standard for health information systems.

**DICOM**

Imaging modalities must be able to communicate images in a digital format to workstations and image management systems such as PACS. The ACR (American College of Radiology) and the NEMA (National Electrical Manufacturers Association) cooperated in the 1980's to define a standard for digital image communication. The standard is referred to as DICOM (Digital Image Communication in Medicine). The introduction of the third generation of the DICOM standard, in 1993, was a major step forward both in functionality and in specification methodology. It allowed the continued evolution of the standard.

Initially DICOM was introduced for the communication and printing of images, through networks as well as through media. In 1997 facilities were introduced to communicate information related to patients (demographics) and examinations. In recent years, the emphasis has shifted from the communication of images to the integration of modalities, workstations and PACS in the total hospital [1, 2]. This requires interoperability with hospital information systems (HIS) and radiology information systems (RIS).

DICOM is based on a model that assumes that a request or order for an examination consists of one or more requested procedures, which in turn consists of one or more procedure steps. The DICOM worklist contains the requested procedure steps per patient. The DICOM services include:

- Basic worklist management. This allows the modality to request the worklist from a RIS or HIS. Selection of the patient and the scheduled procedure step is done at the modality. Because the modality takes the initiative in querying the worklist, it will be able to take into account any changes in the worklist at the RIS before the procedure-step is started.

- Performed procedure step. This allows information to be sent from the modality to the information system (RIS, HIS, PACS) on the start of a procedure step, and the results of a procedure step (images generated, radiation dose, type and quantity of contrast agent, etc.).

Inclusion of these features in DICOM was a big step forward in enabling integration of the modality workflow into that of the radiology department as a whole. However, DICOM is a separate standard, and can only work if the RIS or HIS system also supports the DICOM standard for worklist management. Moreover, DICOM only addresses the RIS-modality interface, not the RIS-PACS interface.

**Table 1. Generic workflow in a radiology department.**

<table>
<thead>
<tr>
<th>Action</th>
<th>HIS</th>
<th>RIS</th>
<th>PACS</th>
<th>Modality</th>
<th>Viewing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient Registration</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Place Order/Request</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schedule Patient</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patient arrives</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retrieve Old Exams</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Examination</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quality Control</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diagnosis, Dictation</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transcription</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Authorization</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Communication</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Archiving</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Billing</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

DICOM is the standard for digital image communication in medicine.

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**Fig. 2. RIS - modality - PACS information transfer.**
Obstacles to integration

The introduction of modality worklists in DICOM did not solve the problem of integration between imaging systems and information systems. Many of the obstacles are related to the mismatch between different standards.

Different standards
The RIS and HIS vendors, especially in the USA but increasingly in Europe as well, use Health Level 7 (HL7) as a standard interface for alphanumeric information, such as patient demographics, orders, reports and laboratory values (Fig. 3). This means that any interface between a modality and a RIS will require a protocol translation between HL7 and DICOM.

Different data models and terminology
DICOM and HL7 have their own views of the world (Fig. 4). For example, there is no agreed mapping between the HL7 vocabulary of an order, the 'real world' vocabulary of request, visit and accession, and the DICOM terms of procedure and procedure step. When a report is generated in the DICOM environment, based on a procedure and, of course, a series of images, it is not clear what the corresponding level of order or request would be in the HL7 environment.

No application level interoperability within the standard
Standards are always the result of negotiation between the stakeholders. Sometimes, the standard offers different ways of doing the same thing. In this respect, HL7 is less mature than DICOM. In fact, it may even be necessary to translate between two different implementations of HL7. However, there are also situations in DICOM where application interoperability cannot be achieved, due to different choices of optional features.

No agreed product boundaries
As mentioned above, there are no agreed boundaries to the functionality of certain products. For example, the functionality of a HIS, a RIS and a PACS may overlap to a greater or lesser degree. This is a major obstacle to the development of standards, because if there is no agreement about the functional boundaries of a product, it will be impossible to achieve an interface standard at a sufficient high application level.

Current state of practice for workflow integration

At present, every integration between imaging systems and information systems in the radiology department requires a special solution. Almost every situation requires an analysis of the data model, vocabulary and workflow, with a separate 'interface engine' between RIS and PACS, and between RIS and the modalities. It is not uncommon for several interface engines from different vendors to be used. Figure 5 shows the functions of such an interface engine: the EasyLink (Philips Medical Systems, Best, the Netherlands).

In this example, EasyLink is shown as an interface between RIS and a modality. However, it also has the required functionality for a RIS-PACS interface. In addition to providing an interface between HL7, DICOM and other proprietary message protocols, such as those based on file transfer or SQL-queries, it can also buffer HL7 messages. This is necessary because HL7 implementations are often event-based, so that all systems have to be continuously in the 'listen' mode in order to ensure that no event is lost. Modalities are not designed to operate in this mode, but they are generally able to cope with queries. Consequently, an intermediary is required which will capture the events and buffer them for later querying.

The IHE initiative started by the Radiological Society of North America (RSNA) in conjunction with the Hospital Information and Management Systems Society (HIMSS) represents a major breakthrough in achieving a standard for workflow integration through the so called IHE Initiative (Integrating the Healthcare Enterprise).

IHE: demonstrating standards

In the past, the RSNA successfully promoted the DICOM standard by using a series of public demonstrations. The society suggested that a similar approach might be used to overcome the various obstacles to the integration of imaging systems and information systems.

In order to get the healthcare information system vendors on board, as well as the vendors of radi-
ology systems, the RSNA secured the support of HIMSS, the Healthcare Information Management Systems Society.

Representatives of the healthcare providers, information system vendors, imaging system vendors and standardization bodies were invited to participate. The initiative was called IHE: Integrating the Healthcare Enterprise.

Its goal is to achieve non-proprietary workflow integration and interoperability across the healthcare enterprise, based on available standards, through a process of public demonstrations.

The approach is as follows:
- RSNA and HIMSS will support a 5-year series of open demonstrations of healthcare interoperability at their respective exhibitions
- Both organizations will provide an infrastructure for the vendors to meet, in order to identify priorities and solutions for interoperability, and will support the demonstrations with project management, test tools and marketing.
- IHE will concentrate on demonstrating interoperability within the current standards. It is not a standards organization itself, but will cooperate closely with the existing standards organizations.

Benefits for vendors and users
IHE offers several major benefits for both vendors and users.

Benefits for the vendors
- Various user groups are pressing their interoperability requirements on the vendors. IHE will enable the vendors to come up with one generally accepted solution, rather than several different ones.
- The RSNA and HIMSS are in a position to provide excellent support for marketing the results. The successful demonstration at the RSNA 1999 in Chicago was an outstanding example. It is hoped that users will follow the IHE recommendations.
- The demonstrations will provide an excellent opportunity for the vendors to test interoperability with each other’s equipment.
- As a spin-off, the demonstrations will generate software tools that can be used in the development and testing of the various implementations.

Benefits for the users
- There will be better integration of systems from various vendors, because workflow integration will be based on non-proprietary solutions.
- Specifications for tenders will become simpler, because reference can be made to the IHE Technical Framework.
In some cases the performed procedure step is different because the scheduled step is considered inappropriate (e.g. scheduled contrast agent may not be used because of a previously unknown allergy). The modality then reports the difference back to the information system through the Performed Procedure Step message. Because of the common information model, the RIS or HIS can relate this to the original order.

The IHE Technical Framework is not a complete hospital information architecture. It only describes the parts relevant to the IHE demonstration. Hospitals may choose to implement the complete framework, or only part of the framework. (Fig. 6).

The choices for IHE Year 1

Figure 7 shows the actors for the Year 1 demonstrations in November 1999 at the RSNA and in April 2000 at the HIMSS. Some actors have been grouped together. This means that no transactions have been defined between them.

The corresponding transactions and the standards used are shown in Table 2.

Vendors participate in the demonstration on the basis of the actor(s) that they choose to implement. They have to provide the transactions specified for that actor. For Year 1, the conditions of participation for the acquisition modalities have been somewhat relaxed: vendors have a choice of implementing Storage Commit or Performed Procedure Step (or both).

The simulated healthcare enterprises

The demonstrations at the RSNA in November 1999 were set up as four Simulated Healthcare Enterprises (SHE’s). More than 20 vendors participated in the demonstrations, with some 40 different systems. The demonstrations showed different clinical scenarios, depending on the acquisition modalities in the various SHE’s.

The demonstrations were intended to give visitors a feeling for what had been achieved in terms of standard transactions between the systems. Philips Medical Systems participated with its Integris V5000 angio system and its PACS. At
more than 3000 visitors went through one or more SHE’s. 

IHE: not a standards organization

IHE has achieved interoperability by reaching agreements between already existing standards, rather than by creating new standards of its own. This will continue in the coming years. However, this require a very good relationship with the standards organizations:
- The standards organizations are consulted as necessary on the interpretation of certain parts of the standard
- The IHE may ask the standards organizations to prioritize the development of certain standards because the IHE considers them as essential for its mission.

An example of a prioritization request and its effects is the standardization of Structured Reporting. DICOM was asked to standardize this because it was high on the list for IHE Year 2.

The leaders of DICOM and HL7 have now decided to intensify their contacts as a result of the IHE, and a new joint working group is being set up to address the issues of image and information integration.

So far the IHE has only considered parts of standards that were thought to be widely supported in the industry. This may become a problem in the coming years because, as the demands for integration increase, the appropriate well-supported standards may not be available.

IHE in the coming years

The abbreviation IHE suggests that the goal is not just integration in the radiology department. The founders of IHE – RSNA and HIMSS – want to address the whole healthcare enterprise. The potential dimensions of growth for the IHE initiative are shown in Figure 8. Details of the various domains are given below:
- In addition to radiology, other clinical ‘vertical’ domains should be addressed, such as cardiology, laboratory and pathology. These vertical domains will use the standards prevailing in their own domain.
- The various vertical domains should be able to share common data across the enterprise, such as patient registration, order placement, and image management.
IHE is a major step forward in achieving integration of information.

as the master patient index, scheduling calendar, and a list of physicians with their roles and access rights.

- Information exchange between the domains should be supported, in terminology appropriate to the target domain. For example, information on allergies and laboratory results for relevant patients should be communicated to radiology in a suitable form for the radiologist. On the other hand, images and reports from the radiology department should be available in an appropriate presentation for the referring physicians.

A number of new items have already been chosen for the IHE Year 2 demonstrations:

- The ‘loop’ in radiology will be closed by including reporting and report management using DICOM Structured Reporting.
- Trauma cases will be included in which patient and image information have to be reconciled between different systems after the examination.
- The RIS will be able to query whether images are available from the PACS.
- The DICOM presentation state will be introduced, which ensures consistent image quality across display stations and printers, and allows transfer of information about the presentation of the image.
- It will be possible to import values from outside radiology, but only through DICOM Structured Reporting.
- All three DICOM services for the modalities (Basic Worklist Management, Performed Procedure Step and Storage Commit) are now required. The Image Manager/Archive has to support both Performed Procedure Step and Storage Commit.

However, there are still major challenges ahead for the IHE. In its ambition to exchange information across domains it is, in principle, addressing the same problem as the Computerized Patient Record (CPR). At present, there are too many approaches to the CPR, while there is no single standards organization that addresses all aspects of the CPR.

Current (proprietary) approaches are being increasingly based on a service-oriented interface (for example based on CORBA and XML) rather than on a message-oriented interface (DICOM and HL7).

The IHE should play a stimulating role in this area, because otherwise it may alienate vendors who will increasingly base their products on modern web-based and service-based technology, while these are areas that the IHE has not yet begun to address.

DICOM Structured Reporting is a very good standard for multi-media reports. There will be a lot of interest in a good standard for multimedia medical reports outside radiology, but little interest in introducing DICOM for this purpose alone. The IHE could play a stimulating role by emphasizing the importance of an XML encoding (and therefore a standard DICOM-to-XML mapping) of Structured Reporting.
Conclusion

IHE made a promising start at the RSNA in Chicago in November 1999. It has not only shown that integration between information and imaging systems is possible within the current standards, without requiring proprietary solutions using interface engines, but has also provided the IHE Technical Framework as a blueprint for implementing these standards. Vendors can use this document for their implementations, and users can reference the document when they are purchasing equipment.

Philips Medical Systems was a prominent member of the first group responsible for defining and shaping the IHE initiative, and is committed to continuing its support for the IHE in its important mission.

The demonstrations in Year 1 concentrated on radiology. In the coming, enterprise-wide integration will have to be addressed. This means that other standards will have to be included, based on modern service-type interfaces such as CORBA and web-based standards such as XML. We hope that the IHE will also have a stimulating role in developing healthcare interoperability standards based on these modern IT technologies.

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