Integrating Digital Imaging and Communications in Medicine (DICOM)-Structured Reporting Into the Hospital Environment

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The Digital Imaging and Communications in Medicine (DICOM) Standards Committee has balloted and accepted a new class of objects dealing with the generation, distribution, and management of reports. The structured reporting (SR) objects bridge the traditional separation between imaging and information systems. The DICOM SR objects offer a higher level of integration of the medical enterprise, providing practitioners with an effective tool to cover all aspects of the medical process from admission to discharge. This report presents the technical challenges posed by integrating the concepts introduced by SR with a complete hospital information system (HIS).

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STRUCTURED REPORTS (SR) are not a new concept. They have been around for a number of years in paper form, where a standard format is dictated by an institution for a specific type of medical report. Structure in reporting increases the efficiency of the distribution of information between the various specialties, and reduces the inherent ambiguity of natural language reports.

In computerized systems, SR allows searching, sorting, and comparison of like data elements. Digital Imaging and Communications in Medicine (DICOM) has standardized an encoding method based on various concepts used in the medical field, creating a structured document architecture that allows the electronic exchange of reports and the consistent rendering of these reports for the clinical users.

The advantages of SR are:

- Linkage of different components
- Ability to search across reports
- Ability to sort results
- Ability to compute elements to provide alerts, etc

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- Continuity of information between systems
- Ability to display results in different ways (text, graphs, different reports, health summary, selected elements as contents of progress notes, discharge summaries, or letters, etc)
- Flexibility in display
- Ability to combine and link multimedia data and textual data at a detailed level

It is essential that this SR information be integrated with the electronic patient record. In order to do this, the information must be communicated from one system to another. Furthermore, there must be a mechanism to match related information to the correct patient and procedure record. This presentation will discuss the requirements to accomplish this.

The Veterans Affairs' hospital information system (HIS), known as VistA, integrates information from a large number of medical specialties into a comprehensive online multimedia patient record (electronic medical record [EMR]) system. A number of specialty software packages combine to make up the HIS, including laboratory, pharmacy, radiology, surgery, and medicine. Each package stores information in its portion of the central database and provides various reports based on selected data elements. Summary reports that cross specialties are also generated; these include data collected during a particular period. The graphical user interface, which runs on the workstations, can present any of these reports to the user.

HIS ARCHITECTURES

Most HIS systems today can be divided into two categories: (1) monolithic integrated systems where database structures are shared among multiple clinical subsystems, and (2) interfaced independent systems where communication is done using Health Level 7 (HL7) messages. The first, by definition, contains the complete EMR. The latter may support an online electronic record using a clinical data repository, or by bringing information together from the disparate systems at the workstation. These different approaches may present different challenges in receiving and utilizing SR.

The HIS stores an enormous amount of data

about patients, their encounters, and the procedural aspects of the care delivered. Just as the clinicians have an internal understanding of how elements of the paper chart relate to the patient's problems and to each other, the designers of the system must use internal structures to indicate that a database table contains records about a patient or procedure and they know, based on the schema design, how a particular piece of information relates to others. Generally, these internal structures are not visible to the user.

WORKFLOW ISSUES

Within an integrated clinical information system, related pieces of information must be linked together to provide a complete record. For example, the order for a procedure must be linked with the procedure results and its report. This is particularly important when data are generated by more than one independent system. To allow these linkages, the DICOM standard requires that each information object generated during the performance of a procedure be assigned a unique identification number (UID). In order to provide linkage throughout the lifecycle of the procedure, these unique keys cannot be changed. It is important that the HIS provide permanent key identifiers, like visit identifiers, at the right point of the procedure, so that they can be incorporated into the information objects and used to create the DICOM UIDs. These UIDs will be used throughout the communication and storage process (Fig 1).

The lifecycle of a procedure contains steps such as:

- Procedure order
- Procedure scheduling
- Transmission of patient and procedure identification information to modality
- Performance of procedure
- Collection of measurements, images, etc
- Result interpretation and production of report
- Transmission of report and results to other systems
- Linkage of report and results to online patient record
- Generation of bill and/or workload report

The DICOM workflow model uses the UIDs to track procedure information throughout the lifecycle. SR requires the tracking and integration of work items from the admission to the order to the

Fig 1. Major work products in DICOM.

report. A well-integrated EMR will require that the SR containing the report be directly traceable to the patient's encounter with the provider. (In DICOM, this link is modeled through the Imaging Service Request.)

In reality, often the final existence and identification of an information element is not known during certain stages of the procedure lifecycle. For example, when an appointment is scheduled, its planned visit date and time are known, but it is not known whether the patient will actually show up for the procedure. At a later time, it is known that the patient did show up and the procedure was performed. Later, the images and the report results and interpretation can be identified. Finally, procedure codes can be assigned retrospectively and bills created.

In addition, it is possible that a patient can be scheduled for two appointments at the same date and time, eg, a computed tomography scan of the chest and abdomen, or an ear, nose, and throat examination. There may also be procedures performed that are not ordered.

DICOM TECHNICAL FRAMEWORK

A single order can be placed for a set of procedures, as happens when a protocol is ordered. DICOM creates an internal model of these real-world objects in order to track them. The generation of the objects is driven by the external workflow as described earlier. The DICOM model includes an imaging service request containing all the procedures ordered at the same time. Each procedure contains the scheduled steps that the modality is expected to perform. The modality

informs the HIS about its work products via the modality performed procedure step service.

In the future, performance of the interpretation workflow will follow similar models allowing the linkage of a specific report to a specific requested procedure and ultimately to the originating order. Before these DICOM objects are communicated, they must be labeled with a DICOM UID.

HIS capabilities for identifying information at different stages of the procedure lifecycle may vary by specialty. It may not be possible to force all specialties to conform to DICOM's workflow model based on radiology because this may not be cost-effective. There must be mechanisms to adapt to the variety of processes in the real world.

To overcome the limitations, several layers of mapping may be needed between a unique identifier of the procedure results and the internal HIS identification. In some cases, the internal identification is a record number, and in others, the record is identified by its content. It may be a visit date/time, which does not always guarantee uniqueness. The correction of this condition may require the insertion of a quality-control step.

Once the UIDs are established they are exported via DICOM worklist services, allowing the integration of modalities, or other application entities, into the workflow.

PRESENTATION ISSUES

The DICOM SR is a document architecture designed for the encoding of information into a defined hierarchical structure. For each data element contained in the report, there is a descriptive label identifying the element and a value providing the associated data. An example of a label would be "% occlusion" and the associated data might be 90%. This type of structure facilitates the exchange of complete data, allowing its placement in a database. The hierarchical structure generated by the system that created the SR object can be faithfully reconstructed by the receiving system. Thus, the ability to search for specific information or to perform calculations on the quantitative sections of the report is facilitated. Logical operations can be performed on the data in order to automatically generate alerts to clinicians when abnormal conditions occur.

SR does not provide information about the display of the data for the user. In fact, the order of the data elements is not even controlled. This is true

whether SR is created using the current standard DICOM encoding system or the future extensible markup language (XML)-based encoding system. Neither contains information that dictates the form in which the information is presented. Additional formatting information is required to determine the order of presentation of the elements, the fonts used for different parts of the report, etc. This kind of information can be provided in a separate template to guarantee consistent presentation.

SOURCES OF SR OBJECTS

The modality vendor community is the driving force behind the generation of SR objects that go beyond the handling of basic text.

Visible light modalities and ultrasound are at the forefront of this movement. In general, the devices where the provider is both the performer of the procedure and the diagnostician will want to convey the report generated during or immediately following the examination.

Comprehensive SR classes can be used to provide linkage of image and measurement data, a feature not previously available in clinical information systems. SR is an effective vehicle for such data exchange.

SR STORAGE

SR object instances are handled the same as images. SR data must be integrated with HIS data. The HIS database can point to the entire structured report as a single entity. To be maximally useful, however, each data element from the structured report can be separated out and individually inserted into the HIS database. This latter approach can become a very large task, but in certain instances, it must be performed to avoid jeopardizing the quality of care. These conversions also ensure that the tools developed in support of the management and analysis of the clinical data will work on the SR data as originally designed. The information extracted from the SR object will vary based on the content of the individual structured report, and by the target information system.

USER ROLE IN IMPLEMENTING DICOM SR FOR ANY INFORMATION SYSTEM

Members of the DICOM community have spent years learning how to deal with modalities. The freedom allotted by the DICOM standard

had to be curtailed in order to achieve successful integration of the modalities into any large-scale information system. What we learned is crystallized in the Integrating the Healthcare Enterprise² (IHE) technical framework, the Veterans Affairs' modality interface requirements,⁴ and other similar documents. We must provide control over the format and content of SR objects generated by the external devices, or else have to deal with an exponential increase in integration difficulties.

DICOM allows more leeway than is needed for each individual application of SR, and provides a template mechanism to define the details of the specific usages. The user community is responsible for creating templates that define what is to be included in reports of different types; these will continue to develop over time. It is very important that template requirements be included in procurements in a way similar to DICOM conformance requirements.

Otherwise, DICOM SR will have the same problems as HL7 where each implementation of the standard was different. DICOM SR must follow the path paved by modality procurement where a combination of user-defined requirements designed to work in the real operating environment and large institutions (government, health maintenance organizations, and hospital systems) insisting on compliance through contractual arrangements lead to a smoothly operating, practical standard.

USE OF TEMPLATES

In theory, the standardized templates will ease these difficulties, but without a mechanism to distribute them, they cannot be effective. Every site would have to create their own, and vendors could not comply with all requirements.

Additionally, an information system should have the ability to make its own preferred templates available to the generating systems. For example the information system should be able to inform an ultrasound device that the report shall use the institution's standard format and it shall contain all the information required by that format. The responsibility should be placed on the generating devices to either automatically detect what concepts can be communicated to the information system and what format shall be used in communicating the report, or there

should be a manual configuration process achieving the same goals.

DICOM has several communication negotiation models in place to deal with similar problems:

- Connection negotiation
- GET requests
- Query/retrieve

Negotiation needs to be accomplished at connection time. The DICOM Standards Committee is currently working on resolving these issues.

INITIAL EXPERIENCES AND OBSERVATIONS IN THE HIS ENVIRONMENT

During the initial analysis of implementing SR in the current environment, we have identified a number of problem areas that require resolution. These are:

- Although DICOM established a rigorous workflow model for tracking the objects produced during the performance of clinical procedures, the HIS may not implement the complementary structures. In addition, trigger events in the workflow may not be clearly identifiable.
- Procedures sometimes are not formally ordered; the report provides the UID, but this does not exist until after the procedure is done and the report is transmitted.
- Hospital visits may span a considerable period of time; the UID must consist of more than a visit number.
- Once SR objects are received, they need to be distributed to the clinicians. The main access point to a patient record may not currently have the ability to display a general-purpose structured document. In order to make use of the information stored in the SR objects, the various coded concepts will have to be mapped into the appropriate structures of the patient record.
- There are significant problems when there is no repository for storage of SR data elements received. This is the case where integration is occurring at the workstation. To generate consistent presentation, the templates must be complete enough to control display of report data.

CONCLUSIONS

The challenge of integrating these new multimedia structured reports into an information system requires careful planning. The workflow in many

specialty departments does not parallel the DICOM model. The HIS may not contain the data structures to handle structured reports. The complexities associated with SR objects will not diminish in the future since the flexibility inherent in the encoding of SR will undoubtedly generate increasingly complex reports. Users will need to play an active role in the process of defining the report templates. These requirements will need to be enforced through contract mechanisms and the publishing of standards.

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