IHE-RO: Interoperable Data Standards for Radiation Oncology

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Abstract

Integrating the Healthcare Enterprise in Radiation Oncology (IHE-RO), an ASTRO initiative, seeks to improve the way in which computer systems in radiation oncology share information through coordinated use of established standards. Use cases identified by the IHE-RO Planning Committee are analyzed by the IHE-RO Technical Committee to develop Interoperability Profiles, which define a set of verifiable Transactions among a set of Actors. Interoperability Profiles specify how existing standards, such as DICOM or HL7, are to be used in the clinical context of the Use Case. Adherence to IHE-RO profiles is tested using a structured, cross-vendor, live, supervised test process, referred to as a Connectathon. Since 2007, the IHE-RO has held three annual Connectathons to test Profiles involving basic radiotherapy treatment planning, multi-modality image registration, and advanced radiotherapy planning techniques. Work continues within the IHE-RO Technical Committee to define and test profiles involving treatment delivery workflow and dose compositing.

Keywords

Data Handling, DICOM and Networking, Data Standards, Interoperability

Introduction

Image-based, volumetric treatment planning in radiation oncology has brought with it the need to represent and communicate radiotherapy treatment planning and delivery information. The desire of clinical users to improve workflow and integrate systems from multiple vendors, as well as efforts to collect and analyze treatment planning information for clincal trials, has motivated the development of radiotherapy data exchange formats. [1]

In the mid 1990s, radiotherapy information objects were added to the DICOM standard to represent volumetric and projection images, image segmentations, treatment plans, volumetric doses, and treatment delivery records. A decade later, as commercial treatment planning systems with various DICOM RT capabilities became available, it became clear that additional efforts would be needed to achieve semantic interoperability among these systems in a multi-vendor clinical environment. Integrating the Healthcare Enterprise in Radiation Oncology (IHE-RO) was begun as an ASTRO initiative in 2004. [2]

As the Radiation Oncology Domain of Integrating the Healthcare Enterprise, International, IHE-RO seeks to improve the way in which computer systems in radiation oncology share information through coordinated use of established standards, such as DICOM and HL7. [3], This process involves development of Interoperability Profiles, which specify how the standards are to be used for particular Use Cases. The interoperability of products claiming adherance to these profiles is tested at annual IHE-RO Connectathon events.

Material and methods

Interoperability issues with DICOM RT objects

The current DICOM radiotherapy information object definitions (IODs) have proven successful in representing treatment planning and delivery information for a broad range of clinical practice. However, the structure of the RT objects, the use of optional (Type 2 and Type 3) attributes, and redundant representation of data have led to various, mutually-incompatible, implementations of the standard.

The architecture of the DICOM RT objects, particularly the RT Plan and RT Dose IODs involves the use of a single information object (SOP class) for several use cases. The RT Plan object, for example, is used to specify the geometric and dosimetric parameters of radiation beams or brachytherapy sources at several stages in the planning and delivery process. Thus, the RT Plan IOD may contain information (a) for virtual simulation with only basic beam geometry information,

(b) for fully-specified, dosimetric plans with multiple fraction groups, or (c) for the delivery of a single daily treatment session. Information that is not needed at all stages of the planning and delivery process is encoded as optional attributes. The variety of alternative treatment techniques and beam modification devices also results in many optional attributes.

Multiple uses of the RT Dose IOD also present challenges to interoperability. Doses from individual beams or sources, fraction groups, or entire treatment plans can be presented as (DICOM multi-frame) 3-D matrices, point values, iso-dose curves, or dose-volume histograms.

Another source of optional attributes are DICOM Change Proposals that are used to correct errors or ambiguities in the standard or to enhance the functionality of the RT objects. In most cases, these attributes are required to be optional (Type 3) to preserve the conformance of existing applications.

In several cases, DICOM RT objects contain multiple attributes that represent the same or closely related information. As an example, the RT Structure Set IOD contains ROI Name (3006,0026) and ROI Observation Label (3006,0085) attributes, each of which has been used as the primary identifier for contoured structures. Inconsistent use of identifier, name, label, and description attributes has also been a source of interoperability problems.

Interoperability Efforts

To facilitate consistent implementation of DICOM RT among treatment planning system vendors objects for clinical trial data exchange, the NCI-sponsored Advanced Technology QA Consortium (ATC) held a series of annual DICOM Implementors Workshops from 2001 to 2004. The ATC also worked with treatment planning vendors to test consistency of data exported from their systems. These efforts, as well as point-to-point data exchange testing among vendors, served as a starting point for the later interoperability efforts of IHE-RO.

Integrating the Healthcare Enterprise – Radiation Oncology, an ASTRO initiative, began with an organizational meeting at the 2004 annual meeting of RSNA. Using the IHE organizational model consisting of a Planning Committee and a Technical Committee, participants began work in January, 2005.

The IHE-RO Process

The IHE-RO Planning Committee consists of radiation oncologists and medical physicists, as well as product management and marketing representatives from equipment manufacturers. The task of the Planning Committee is to identify important, clinically relevant interoperablity problems within the Radiation Oncology domain and to abstract these as proposed Use Cases.

The IHE-RO Technical Committee consists of medical physicists, DICOM engineers and analysts representing equipment manufacturers and academia. It is the task of the Technical Committee to evaluate the Use Cases proposed by the Planning Committee and to develop integration profiles specifying how existing standards, such as DICOM or HL7, are to be used to solve these problems.

Development of Interoperability Profiles

The first step in developing an Interoperability Profile is to abstract the Use Case as a set of verifiable Transactions among a set of Actors. An Actor is an abstract entity that performs a function within the Use Case. A product may implement one or more Actors. While much of the behavior of the product is outside the scope of the Profile, the Transactions identify the behavior that is required to assure interoperability. For each Transaction, the Profile identifies the Actors that are involved and specifies precisely how a data or communication standard is to be used to implement it. Generally, this process involves selecting the options of the standard to be used and specifying any additional constraints to be observed by products claiming adherence to the profile.

Once an Interoperability Profile is drafted, it undergoes a revision process within the IHE-RO Technical Committee before being released for a period of public comment. When it is sufficiently mature, a Profile is released for trial implementation. At this point, manufacturers can begin developing products that can be tested for adherence as Actors in the Profile.

Test Tools

As an aid to the development and testing of products as Actors with an IHE-RO Profile, ASTRO has sponsored the development of Test Tools software. These Tools simulate the behavior of other Actors in a given Use Case Scenario and attempt to check consistency of the behavior of the Actor under test with Profile requirements. For several of the Integration Profiles in the Radiation Oncology Domain, the Test Tools provide an input dataset to the Actor under test and evaluate the content of the objects produced by the Actor. The purpose of the Test Tools is to assist manufacturers with in-house testing of software, to assess readiness of products to participate in formal testing events, and as an aid to testers in the formal testing process.

Test Process

Adherence to IHE-RO profiles is tested using a structured, cross-vendor, live, supervised test process, referred to as a Connectathon. [4] All vendors' products are assembled at a single location for approximately one week of testing. IHE-RO testers select clinically relevant test data and provide instructions for partcipants to interact with multiple test partners. Demonstrating adherence to a profile involving input and output datasets requires successful "input" transactions from at least three upstream Actors and successful "output" transactions to at least three downstream Actors.

Since 2007, the IHE-RO has held three annual Connectathons. The emphasis each year has been on testing new profiles. However, in the past two years, there has been sufficient interest in re-testing previous profiles, both by vendors whose product or products had not previously passed the test process and by those who had not previously participated.

In addition to the formal Connectathon, in 2006 and again in 2008 and 2009, the IHE-RO Technical Committee has also held a Radiation Oncology Domain Pre-Testing event. This week-long, supervised, informal test event has provided early feedback to manufacturers regarding problems in their code, as well as their interpretation of the Integration Profiles. It has also given IHE-RO Testers an opportunity for advanced planning of the Connectathon test process.

Results and discussion

Basic RT Treatment Planning Profile (2007)

The first IHE-RO Interoperabilty Profile, tested initially at the 2007 Connectathon, emphasized interperable use of DICOM RT information objects for treatment planning. It addressed the "normal flow" of clinical data from CT scanner through treatment plan review for 3-D conformal, external-beam radiotherapy. Five Actors are defined for this Profile: Contourer (segmentation workstation), Geometric Planner (virtual-sim), Dosimetric Planner (TPS), Dose Displayer (plan review workstation), and Archive (RT-PACS).

Adherence to the 2007 Basic RT Treatment Planning Profile was tested at the 2007 IHE-RO Connectathon with seven vendor participants. A total of 20 Actors passed this test. The Profile was re-tested in 2008 with six vendors participating and ten Actors passing, and again in 2009 with five vendors participating and five Actors passing. (Some vendors participated in more than one connectathon with updated versions of their products.)

Multimodality Registration Profile (2008)

The second IHE-RO Profile addressed multi-modality (rigid) registration of CT, MR, and PET images for RT treatment planning and review using the DICOM Spatial Registration object. Five Actors were defined for this Profile: Registrator (creates spatial registrations), Registered Display (displays registered image series), Registered Contourer (permits segmentation of registered image series), Registered Dose Display (uses spatial registrations to display images, contours, doses), and Archive (RT-PACS).

Adherence to the 2008 Multimodality Registration Profile was tested at the 2008 IHE-RO Connectathon with eight vendor participants (nine products). A total of 26 Actors passed this test. The Profile was re-tested in 2009 with five vendors participating and 10 Actors passing.

Advanced RT Objects Profile (2009)

The 2009 IHE-RO Profile addressed the need to extend the Dosimetric Planner Actor of the 2007 Basic RT Objects profile to a large variety of external beam treatment techniques. It identified a set of 14 beam techniques and defined a Producer (treatment planning system) and Consumer (treatment planning system, treatment management system) Actor for each beam technique. Transactions for this profile support storage and retreival of RT Plan information objects and specify the beam-technique-dependent requirements for their interoperable exchange.

Adherence to the 2009 Advanced RT Objects Profile was tested at the 2009 IHE-RO Connectathon with six vendor participants. A total of 58 Actors passed this test.

Integration Profiles in Development

The Dose Compositing Profile supports the process of combining information from two or more spatially related dose matrices and in using one or more spatially-registered prior doses for creating a new treatment plan and dose. It defines five new actors: a Registered Dose Compositor, a General Dose Viewer, a Registered Dose Viewer, a Compositing Planner, and a Single Plan Dose Producer.

The Integrated Positioning and Delivery Workflow Profile represents the first effort within IHE-RO to address treatment delivery workflow. It makes use of DICOM Supplement 74 (Utilization of Worklist in Radiotherapy Treatment Delivery) and Supplement 96 (Unified Worklist Procedure Step) to define Transactions between Treatment Management System and Treatment Delivery System Actors to coordinate treatment plan delivery on systems with integrated patient position verification capabilities. A early version of this profile was prepared for the 2009 IHE-RO test cycle. However, deficiencies in the Profile were

identified in the test process and the Profile is being revised.

The Enterprise Schedule Integration profile extends treatment delivery workflow management to include information systems outside the Radiation Oncology Department. It makes use of HL7 to define transactions between the Treatment Management System and the Order Placer (nominally a Hospital Information System). This effort has been led by Japanese members of IHE-RO.

Conclusion

Integrating the Healthcare Enterprise in Radiation Oncology (IHE-RO), an initiative of ASTRO, has made substantial progress toward realizing interoperable, cross-vendor exchange of clinical treatment planning and verification data in radiation oncology. This progress has been noted in AAPM working group discussions.

For vendors, the IHE-RO process continues to promise cost-effective and efficient testing of interfaces, reduced cost of solving connectivity and workflow problems, and simplified RFP response.

For healthcare professionals, IHE-RO promises simplified integration of hardware and software products, allowing selection based on features, productivity, and cost efficiency, and ultimately improving patient care.

Future work within IHE-RO includes the application of DICOM Supplement 96 (Unified Procedure Step) to other workflows within the Radiation Oncology Department (e.g. Treatment Planning, QA, manufacture of devices such as compensators and blocks), and the inclusion of Ion and Brachy Therapy.

This effort has been substantially funded by ASTRO.

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