THE RELEVANCE OF DICOM-RT IN RADIOTHERAPY INFORMATION SYSTEMS

Preliminary Results from a National Survey

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Abstract: Currently, in radiotherapy (RT) departments, there are different manufacturers and stand-alone information systems (IS) for single-purpose applications. These systems have most of the data distributed through different IS. The DICOM-RT extension has six objects that provide a standardized way of transferring the information circulating in the external beam RT. The aim of this study is to assess expert's opinion about DICOM-RT and IS interoperability in the RT context, through the characterization of Portuguese RT facilities, in terms of equipment and IS with the identification of existing interoperability problems. This study is cross-sectional, and the preliminary results presented in this paper are relative to the period May-July 2011. All Portuguese RT departments (i.e. 20) were invited to cooperate in the survey; the response rate was 40% (n=8), while 10% (n=2) of the institutions did not authorize the RT departments to participate. The preliminary results show that the RT departments have some equipment and IS from different vendors contributing for heterogeneity of RT workflows. The experts somehow attribute importance to interoperability, but have low knowledge about their own IS integrations, and DICOM-RT. Compliance with DICOM-RT is recommended when acquiring new RT IS to optimise the interoperability.

1 INTRODUCTION

In modern medicine, one of the most technologically advanced fields is radiotherapy (RT), which is, after surgery, the most successfully treatment modality used for cancer (Schlegel et al., 2006). About 60% of patients with cancer, will require RT during the course of their illness and those who are cured, 80-90% of the patients underwent RT (Perez and Brady, 1998).

RT is probably the earliest example of computer programming application to the solution of clinical treatment decision problems (Kalet, 2008). It is an interdisciplinary field, based on physics, radiation biology, mathematics, computer science, electrical and mechanical engineering. Increasing sophistication in computer-assisted treatment planning and delivery has improved the accuracy and distribution of radiation dose in patient leading to a significant increase of tumor control and the consequent probability of cure (Schlegel et al., 2006); (Levitt et al., 2008).

1.1 Problem Setting

Currently, in RT departments, where the treatments are based in the most technological advancements in diagnostic imaging, image processing and high computerization technology, such as the treatment planning systems (TPS), there is an increase of the complexity of storage and availability of RT data. Often there are different manufacturers and stand-alone information systems (IS) for single-purpose applications (Liu et al., 2007); (Law et al., 2009). These multiple IS, focused on the system instead of being patient-centered, acquire the necessary information during the RT treatment course, being

most of the data distributed through each IS. This data isn't immediately available due to incompatibles formats between the equipment workstations and the IS. This lack of interoperability between the IS causes discontinuity in health care, leading to redundant clinical evaluations and clinical decisions based on incomplete information limiting clinical trials and scientific investigations (Law, 2005).

Some attempts by collaborative groups to improve workflow and integrate IS through the standardization of data exchange formats, resulted in two relevant formats in RT. The standard used by North American Radiation Therapy Oncology Group (RTOG) - format RTOG based on report nr. 10 of the American Association of Physicists in Medicine (AAPM), which was designed for the purpose of transferring RT data to the Radiotherapy and Oncology Group data centre so that quality assurance of clinical trials could be performed. And the standard digital imaging and communications in medicine version 3.0 (DICOM v3.0) with the RT extensions designated DICOM-RT resulted from the working group 7 of the committee formed from members of American College of Radiology (ACR) and the National Electrical Manufactures Association (NEMA) (Schlegel et al., 2006); (Huang, 2010).

1.2 DICOM-RT Description

The DICOM-RT extension consists of six objects for the external beam RT, which provide a standardized way of transferring much of the information circulating in the RT workflow. The six DICOM-RT objects are (Dicom Standards Committee, 1997); (Dicom Standards Committee, 1999):

- **RT Structure Set-** defines a set of structures of significance in RT related to patient anatomy, markers and isocenters;
- **RT Plan-** contains geometric and dosimetric data specifying a course of treatment, including treatment beam parameters (e.g field sizes, beam orientations and modifiers), patient setup, fractionation scheme,etc;
- **RT Dose-** includes the dose data generated by TPS in various formats (e.g. 3-D distribution of radiation dose, isodose curves, dose points);
- **RT Image-** specifies the attributes of RT images that are "acquired or calculated on a conical imaging geometry" giving additional information.
- **RT Beams Treatment Record-** treatment session records during a RT treatment course.
- **RT Treatment Summary Record -** treatment summaries indicating the cumulative state of a treatment course.

1.3 DICOM-RT Benefits

The benefits of using DICOM-RT can be (Law and Huang, 2003); (Law and Liu, 2009):

- Transmission of the textual information and images between IS of different vendors with minimal effort from users providing communication between isolated IS.
- Full integration of IS with technologies from different vendors helping save time and effort spent in searching and minimize the loss of records and images.
- Monitoring and analysis of the RT workflow.
- Integration of the treatment process into an electronic patient record (ePR).
- Platform for information sharing with hospital information systems (HIS) and other IS allowing cross-center clinical research and expert consultation.
- Development of decision support tools and a knowledge base in the medical imaging informatics research through the patient outcomes.

1.4 Aim

The purpose of this study is to know the RT expert's opinion about the DICOM compliance, the DICOM-RT objects utilization and the interoperability existing in the IS of Portuguese RT departments, with the collection of data about treatment equipment, imaging modalities and IS.

2 METHODS

A cross-sectional approach was used to achieve the proposed target.

2.1 Study Participants

The target population of this study are all RT departments in Portugal (i.e. 20). About 60% of institutions are private hospitals and 30% of departments belong to university hospitals or cancer centers. In the scope of this study it was just considered the facilities of external beam RT. All RT departments which have agreed to participate have been included in the present study.

2.2 Design Study

This is a cross-sectional survey representing the reality found in these RT departments, and the preliminary results presented in this paper are relative to the period May-July 2011.

2.3 Questionnaire

A structured questionnaire with five groups, identified in Table 1, was created using expert opinion.

Table 1: Structure of the questionnaire "DICOM-RT in the radiotherapy information systems".

Group	Title
I	Profile of the respondents
II	Characterization of the RT department - Survey of technological resources - Survey of imaging modalities - Survey of IS
III	Characterization of picture archiving and communication system (PACS)
IV	Characterization of IS and the DICOM utilization
V	Opinion about interoperability

The construction of questions of group II relative to the survey of technological resources was based on results from the Portuguese governmental document "Development strategy for the development of radiotherapy in Portugal for the next decade" (Pereira et al., 2008), where it is described a national survey of equipments and staff in all RT facilities, and in some articles of national surveys from other countries (Owen et al., 1997); (Wigg and Morgan, 2001); (Teshima et al., 2008); (Jefferies et al., 2009). The other groups were based on the books: "PACS and imaging informatics: basic principles and applications" (Huang, 2010) and "Handbook of radiotherapy physics: theory and practice" (Mayles et al., 2007). The questions of group V, concerning the opinion about interoperability, were constructed with positive sentences using Likert scales (Mcdowell, 2006).

The questionnaire was constructed aiming to be adapted to the Portuguese reality and was reviewed by three experts (one medical physicist, one radiation therapist, and one professor of radiotherapy) that suggested some changes that were made. The questionnaire was created with the web technologie *MedQuest* (Gomes, 2009).

2.4 Data Collection

All the chiefs of RT departments were informed about the survey and cooperation was asked to send the questionnaire to the chief information officer or the head of medical physics or the manager of radiation therapist. For some institutions, a requirement for authorization to conduct the survey was requested and sent to the administrative councils or ethics committee or research office. After their support and multiple telephone calls with the participants, an e-mail was sent to each department with the URL of the questionnaire addressed to the experts.

2.5 Variables Description

The main variables of the questionnaire can be grouped into the reality existing inside the RT departments and expert's opinions.

2.5.1 Variables about RT National Survey

- Which existing techniques of external beam RT;
- Quantification of the staff;
- Which existing equipment of RT (commercial designation, manufacturer, installation year):
  - Treatment machines;
  - Simulation equipments;
  - Imaging equipments.
- Which IS exist RT (commercial designation, manufacturer, version):
  - TPS;
  - Imaging systems;
  - Record and Verify (R&V) systems;
  - PACS:
    - Which interfaces;
    - Which functions;
    - Compliance with DICOM v3.0.

2.5.2 Variables about DICOM-RT Expert's Opinion

- Profile of the respondent:
  - Age group, sex;
  - Academic qualification, professional experience and position;
  - If know DICOM standard (level of knowledge);
  - If know DICOM-RT extension (level of knowledge).
- Characterization of IS:
  - Compliance with DICOM v3.0;
  - Compliance with DICOM-RT;
  - Which DICOM-RT objects are in use;

- Utilization of other communication standards.
- How to describe utilization of DICOM-RT in the workflow of RT;
- How to describe the IS behaviour;
- When purchasing a new IS for the department, if the interoperability issue is addressed:
  - Which factors are more important;
  - Who defines the integration of IS.
- For a good policy is it better one single vendor or multiple vendors;
- Which procedures are more important, to achieve IS interoperability with the DICOM-RT;
- Which factors are more important, for the immaturity of the DICOM-RT implementation;
- Which benefits of DICOM-RT are more important;
- If there are any interoperability problems between the IS:
  - If yes, identify the existing interoperability problems, specifying the IS participants.

The data obtained from the questionnaires was exported by *MedQuest* to the IBM® SPSS® software version 19 for statistical analysis.

3 RESULTS

Until July 20 the response rate was 40% (n=8), while 10% (n=2) of the institutions did not authorize the RT departments to cooperate in the survey. The institutions that answered the questionnaire are widely separated geographically and of varying departmental size (facilities with only 1 treatment unit to 8 treatment units). The number of RT professionals per institution varies between 9 and 68, with a median of 14.5. Per RT department, the radiation oncologists with a median of 3.5, the medical physicists with a median of 3, and the radiation therapists with a median of 9. The nursing staff, the assistants and the clerks were not considered.

3.1 RT National Survey

All of the RT departments have 3-D conformal RT, and 37% have intensity modulated RT. In terms of treatment machines, all of the facilities have exclusively linear accelerators with the median installation year 1997, rather than cobalt units and orthovoltage. 50% of the departments are multiple-treatment units, and of these, only one department has machines from different manufacturers. Relatively to simulation, 50% have this equipment and the other 50% have virtual simulation. The simulators come from two vendors and the virtual simulation comes from other three vendors. Concerning imaging, the vast majority of the centers (75%) have computed tomography (CT) department, and only one department has a dedicated magnetic resonance imaging (MRI) for RT planning purposes. All this imaging equipment comes from three vendors. All the departments use digital image, including image registration carried out between planning CT and MRI or positron emission tomography. For the image guidance, all of the institutions have portal images with megavoltage and 37% with kilovoltage.

Regarding IS, all the departments have at least one TPS and one institution has three systems from different vendors. Imaging systems are from three different vendors. About R&V systems, in departments with single-treatment unit, this system is from the same vendor of treatment machine. In departments with multiple-treatment units, the R&V system is from the same vendor of one of treatment machine. Several departments (37%) have PACS, which have interface with TC workstation, TPS, simulator workstation and R&V systems, having as mainly functions: storage, image reception, and database update.

In terms of distribution of suppliers by country of origin, Germany is the country with the highest expression (43%), followed by United States of America (29%), Sweden (14%) and Netherlands (14%).

3.2 DICOM-RT Expert's Opinion

The respondents were mainly medical physicists, with a mean experience of 10,5 years, being 63% Head of Medical Physics. All the participants knew the DICOM standard and the RT extensions, and 63% of those consider their level of knowledge as reasonable.

According to 63% of participants, RT IS are DICOM-RT compliant. Although the RT plan and RT structure set are implemented in all departments, the RT dose is only in seven departments, and the RT image and RT beam treatment record are only in six departments. According the same 63% of respondents, the imaging systems are in conformance with DICOM v3.0 too. The use of other communication standards is referred by 37% of participants, but the only standard identified was health level 7 (HL7).

Respecting expert opinion, 50% of respondents

consider that the utilization of RT objects in the RT workflow is very good, and the remaining thinks that is good or reasonable. The behaviour of the IS, according to most of the participants, is interoperable because they integrate information from different IS vendors.

When purchasing a new IS for the department, 75% respondents think that the interoperability issue is addressed; the others have no knowledge about it. The vast majority believes that the important factors, by order of importance, in this issue are: 1st existing IS integration problems, 2nd IS need, 3rd interoperability problems in the workflow, 4th context of purchasing. The integration of the new IS in the workflow, is commonly defined by the vendor together with the informatics and the medical physicist.

For a good policy, most experts assume that the more sophisticated equipments and flexibility of IS for the integration in multi-vendor context are more important compared with context of one single vendor. To achieve SI interoperability, with the DICOM-RT, the procedures considered more important are: replacement of analogue by digital image, determination of workflows, frequent updating versions of SI. The three most frequently mentioned reasons to justify the immaturity of the DICOM-RT implementation are: 1st inexistence of DICOM-based database, 2nd lack of strategic management of the department, 3rd low compliance to standard by suppliers. Regarding DICOM-RT benefits the experts classified by the following order of importance: 1st transfer of information between different IS vendors, 2nd integration of RT technologies in IS multi-vendor context, 3rd integration into the ePR, 4th communication with other institutions, 5th communication with other specialties, 6th workflow monitoring, 7th support for computer-assisted decision, 8th helpful in clinical research, 9th assistance for the knowledge base creation.

For the open question about the existence of interoperability problems between the IS of the RT department, only two participants assume that have problems. One specified that the problem lies in the interface between the R&V system with three HIS. The other identified that the problem is based on the fact of having many different suppliers in the department.

4 DISCUSSION

Currently in the RT departments, the question of interoperability is considered as crucial for achieving gains, by improving the quality and continuity of care, allowing cost reduction by minimizing repeated procedures or exams, improvements in research, decision support, among many others.

In RT context more important that achieve connectivity “plug and exchange” between two systems is to accomplish application interoperability “plug and play”. The complexity of interoperability in RT is greater compared with the radiology.

A limitation of this study is the inexistence of other similar studies for comparison. It was found national surveys of RT (Alto Comissariado Da Saúde, 2008) but only focusing in the workforce, workloads and equipment. None of none of them focuses on IS, DICOM-RT and interoperability.

These preliminary results show that the RT departments have some equipment and IS from different vendors contributing for heterogeneity of RT workflows. The experts somehow attribute importance to interoperability, but have low knowledge about their own IS and respective integrations. The same happens about the familiarity with DICOM, DICOM-RT and other communication standards; in the questions about the conformance with the DICOM v3.0 and DICOM-RT, there are a significant percentage of respondents that answered “I have no knowledge”.

Essential for the RT departments’ cooperation has been the issue of confidentiality and anonymity of participants. The data collection, in the majority of the cases, was hard. This may be over due to the lack of documentation regarding existing IS and their integrations.

This survey has assessed the current status of RT technologies and IS. This characterization is helpful to understand the real RT workflows of each department. The expert’s opinion about interoperability and DICOM-RT reveals that they trust in the standard but with lack of specific information about this issue.

The questionnaire aimed to explore issues that could help departments to optimise their IS in the RT workflow. But as the participants think that have no interoperability problems and those who think that have, didn’t detailed with enough information. Therefore, only general recommendations can be suggested. Experts of this study believe in the benefits of integration between the IS and equipments but with few knowledge about this pertinent issue. Information that can be drawn from these opinions is that the RT professionals don’t have sufficient training on issues such as: DICOM-

RT, application interoperability, other communication standards, etc.

General recommendations for RT professionals to achieve or optimize the interoperability at the RT departments:

- When purchasing a new IS for RT department request a IS compliant with DICOM-RT with all RT objects available.
- When purchasing new equipment for RT department only buy a machine in conformance with DICOM v3.0.
- When implementing the new device DICOM conformant, specification and testing of the clinical application capabilities and data flow needs to be performed by the RT facility to ensure effective integration.
- For a good policy in RT department, the strategy must focus on reliable computer applications with a high degree of built-in connectivity.
- Use the PACS model in the RT department, whether departmental or institutional, with the DICOM v3.0 and DICOM-RT.
- It is important to adapt the existing RT workflows to those publicised by integrating the healthcare enterprise (IHE) (I.H.E., 2011) integration profiles and technical frameworks providing a common platform to use DICOM and HL7.

The implementation of these recommendations will be essential to optimise the interoperability in the RT context.

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