PACS in radiotherapy

By John Shakeshaft MA PhD
Chief Physicist, Northern Territory Radiation Oncology
Rocklands Drive, Tiwi, NT 0810, Australia,
email: john.shakeshaft@nt.gov.au

Introduction
Over recent years, the use of PACS and radiology information systems (RIS) in the radiology department has become the norm. These two systems provide a complete electronic solution for image archival, image display, reporting and workflow management. In many configurations these different functions are tightly integrated. Although there are some technical issues remaining (particularly with the lower patient volume modalities, eg nuclear medicine, or newer modalities, eg PET), PACS is a tool that is widespread and is used by most clinical staff in the radiology department and beyond. This change in work practice has been enabled by standards that allow equipment from different vendors to integrate.

However, the use of PACS in the radiotherapy department, other than for viewing diagnostic images usually on a web-based viewer, is not commonplace. This is despite the fact that the issue of image data (typically CT) has been standard in radiotherapy for many years and with the introduction of IGRT the reliance on imaging is becoming increasingly heavy. This article considers the obstacles that prevent the use of PACS for radiotherapy in many departments today and looks to the future and considers how that will change in the future.

Radiotherapy systems
In a radiotherapy department, patient management and workflow is handled by the treatment management system (TMS) in an analogous way to the radiology RIS. At the present time the oncology management system is usually connected to linear accelerators (linacs) on which the majority of patients are treated using a proprietary interface. Other equipment, even that used for diagnostic imaging, is not connected to the TMS. The IHE Radiation Oncology Domain has recently proposed a treatment workflow profile (TBWF) for the radiotherapy department using the frozen DICOM Supplement 96 (Unified Worklist and Procedure Step). If this proposal is adopted by the community then the integration of workflow in a multi-vendor environment should be vastly improved, in the same way that DICOM Modality Worklist and RIS improved workflow in the radiology department.

In addition to the treatment machines and the TMS, much of the work in the radiotherapy department is performed on specialist post-processing workstations, such as treatment planning systems. These systems import standard diagnostic images such as CT, MR or PET using DICOM, or planar images with well-defined geometry from the radiotherapy simulator (DICOM RTIMAGE).

Although CT images are usually used for dose calculation (using the robust electron-density information), sometimes other modalities are co-registered with the CT images. At the present time rigid-body registration techniques are used, which rely on the patient being in the same position for all the image acquisitions. Deformable registration techniques are being investigated by a number vendors but present considerable quality assurance challenges. The IHE have proposed that the results of these co-registrations should be stored on PACS using the DICOM spatial registration object. This proposal has been adopted by some vendors, while others have adopted the less desirable approach of re-sampling the registered series into the frame of reference of the radiotherapy planning CT.

Further ‘radiotherapy’ DICOM objects (see table 1) are then generated which contain information relating to the patient’s treatment. At the present time, although information generated during the radiotherapy planning process are standard DICOM objects, most vendors store the information in either proprietary format or in DICOM format in a proprietary database.

<table>
<thead>
<tr>
<th>Object</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial registration</td>
<td>This is not a radiotherapy-specific DICOM object. It stores the relation between the frames of reference of two image sets. It is used in the radiotherapy community to store the results of image registration.</td>
</tr>
<tr>
<td>RTSTRUCT</td>
<td>Details of structures contoured on images. These structures will either enclose the volume to be treated or critical organs to which the radiation needs to be limited or minimised. Each contour is linked to one or more images. The DICOM RTSTRUCT object contains no pixel (image) data.</td>
</tr>
<tr>
<td>RTPLAN</td>
<td>Treatment delivery details and geometry. Can be linked to a specific structure set (RTSTRUCT) and hence (indirectly) to a particular image set. The DICOM RTPLAN object contains no pixel (image) data.</td>
</tr>
<tr>
<td>RTDOSE</td>
<td>Dose delivered by a specified plan. The dose is encoded as a multi-frame image and a single floating-point scaling factor.</td>
</tr>
<tr>
<td>RTIMAGE</td>
<td>Planar simulator images, digitally reconstructed radiographs (DRR) or planar portal images, acquired during treatment. The DICOM RTIMAGE contains a lot more geometric information about the setup in which it was acquired than a standard diagnostic image.</td>
</tr>
<tr>
<td>RTRECORD</td>
<td>Record of a radiotherapy treatment. This may be a record of a single session or a summary of treatments. This would typically be generated by the treatment management system and at present is not well-supported.</td>
</tr>
</tbody>
</table>

TABLE 1
The radiotherapy DICOM objects detailed in table 1 contain an unusually large number of optional data and alternative implementations. This has led to a greater number of interoperability problems than were experienced in the early days of DICOM in radiology departments and encouraged manufacturers to use proprietary storage methods. Therefore, in a typical radiotherapy department today there can be multiple copies of the same (image) data held in different systems. This is not good practice and leads to an unnecessary management overhead.

The most established IHE profile (Normal Treatment
Planning-Simple (NTPL-S) in radiotherapy proposes a standard set of DICOM elements that should be used by each process in radiotherapy planning and that the result of each process should be stored back to a (common) PACS. Most major vendors are working towards compliance with this standard, although few currently support the use of a third-party PACS for storage of data.

It seems likely that within a few years most data within the radiotherapy department will be stored within a PACS system, probably associated with the TMS, and other specialist systems will access data and store data back to this PACS as required. In this scenario the radiotherapy PACS is providing storage and archival of the high volume data while review facilities of current or historic data is provided by the TMS. The availability of these data is probably local to the radiotherapy department, although this potentially could be extended as the major TMS systems now support access using thin client systems.

**PACS and radiotherapy in the wider healthcare enterprise**

So far discussion has been limited to use of a local PACS within the radiotherapy department in conjunction with the radiotherapy TMS. As most hospitals these days have an enterprise PACS which is accessible across the whole hospital, and in the case of the English NHS potentially many other hospitals too, it is reasonable to consider whether radiotherapy data should be stored to the enterprise PACS as well.

The benefits are that radiotherapy data would be archived and potentially available to other healthcare professionals. It can be useful for staff outside the oncology department to know which anatomy has been treated. Potentially it would also allow better collaboration between clinical oncologists and radiologists. However the radiotherapy data stored in PACS would not represent a full record and there is a danger that it could be over-interpreted. For example, a patient could have a treatment planned for a dose of 60Gy, but this treatment could be terminated early. Under the English PACS data-sharing, this plan could be called up in another hospital and the management of the patient could be incorrectly changed because of the belief that the patient had already received 60Gy to particular anatomy.

The scope of this article does not allow for a full discussion of the risk and benefits of storing radiotherapy data in the enterprise PACS. However a proposal has been made to store a subset of data which is thought to be safe and useful, because it cannot be fully interpreted without reference to the definitive treatment records. However, for the benefits to be fully realised, enterprise PACS manufacturers need to enhance their viewing products to support:

1. The display of co-registered images with reference to the DICOM spatial registration object (figure 1).
2. The display of structures on CT (or registered images) from data stored in the DICOM RTSTRUCT object (figure 2).
3. The overlay as contours or colour-wash of the data stored in DICOM RTDOSE object and the associated CT images (figure 3).

Although this would not seem to involve a significant amount of development time for PACS manufacturers as, for example, some systems already support the DICOM spatial registration object for PETCT, most of the major manufacturers do not provide the required functionality and it is probably now the responsibility of us as users to start demanding it.

**References**

1. IHE Technical Framework: Managed Delivery Workflow Addenda 2008. ASTRO. Available at: http://www.ihe.net/

**FIGURE 1**

Pre-surgery MR of the brain overlaid on the radiotherapy planning CT. The relationship between the two image sets is stored in the DICOM spatial registration object. The position of the surgically-removed tumour can be seen well inside the proposed treatment volume indicated by the yellow contour.

**FIGURE 2**

Structures (both target and risk organs) shown overlaid on the radiotherapy planning CT. This information is stored in the separate DICOM RTSTRUCT object.
FIGURE 3
Planned dose shown overlaid on the radiotherapy planning CT as a colour-wash. As proposed in IPEM report 99,4 the dose is shown in relative mode so that reference needs to be made to the definitive treatment record to determine the actual dose that was delivered.