Advanced multimodality contouring in Radiation Therapy with syngo.via RT Image Suite

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Introduction

In addition to further developments in hardware technology, software solutions for radiation therapy planning are required that optimize structure delineation based on multimodality imaging. A recent paper by Cyran et al. emphasized the role of tailored imaging in radiation therapy planning. Any improvements in the field of imaging will impact radiation oncology per se [1].

Computed tomography (CT) forms the basis of modern radiation therapy planning thanks to its ability to encode objects in spatial electron density distributions. Only CT can determine the attenuation coefficients per voxel in a patient’s body with the high degree of reliability required by dose calculation algorithms in treatment planning systems (TPS). Clinicians primarily use CT images to delineate planning target volumes (PTV) and organs at risk (OAR), which can be supplemented by co-registered magnetic resonance imaging (MRI) data in accordance with the indications. For example, in the absence of soft-tissue contrast. The use of MRI images to provide attenuation information, commonly known as MRI-only radiation therapy, is currently the subject of numerous research projects [2, 3].

In addition to MRI, positron emission tomography (PET)/CT images have become an established, routine component of staging and therapy planning in radiation oncology [4]. Traditionally, all of the required imaging information is transferred to the TPS and co-registered with the initial planning CT either rigidly or, in selected cases, deformably. Usually only one image series fused to another series can be displayed, such as a CT to MRI fusion, for example. However, the anatomically correctly correlated, simultaneous display of all of the datasets needed to delineate the PTV would be more useful. In the context of respiratory management, it may be beneficial to concurrently view multiple studies, particularly when using time-resolved planning datasets.

It would be optimal to contour or edit structures in all of the assigned image studies in any anatomic orientation. Modern treatment planning systems are normally limited to one monitor – which results in inferior image quality. This limitation has disadvantages not only for radiation planning, but also for post-therapy follow-up or restaging. As a result of these limitations, follow-up or restaging assessments frequently do not take place in the TPS but rather in a PACS viewer.

This study investigates the clinical usability of the new syngo.via RT Image Suite in the context of the abovementioned expanded modern radiation therapy planning requirements.
syngo.via RT Image Suite is based on syngo.via, Siemens’ platform for all medical imaging applications. syngo.via RT Image Suite was designed to enable the efficient use of multimodality imaging in radiation therapy. It allows easy access to the PACS system using a query and retrieve interface.

In addition, a pre-fetching option allows studies to be automatically transferred to selected clients and to be assigned pre-defined workflows. After the datasets have been successfully contoured for therapy planning, connectivity to the TPS or another other node via DICOM export is available (see Figure 1).

Images from any modality are transmitted to the central PACS server using auto-transfer. Between different facilities, data can be retrieved by the syngo server from local clients. If necessary, ConeBeam CTs (CBCTs) can be transferred automatically to the server using pre-fetching. Data that is ready for planning is transferred to the TPS by DICOM export.
Scans from diverse image modalities such as CT, MRI, and PET/CT can be displayed in syngo.via RT Image Suite. Up to four single (or four fused) image studies can be displayed for one patient in parallel, across four panes (see Figure 2).

All displayed image studies are automatically rigidly co-registered when the image is loaded.

When inconsistent tabletops have been used, for example curved tabletops for diagnostic images, deformable registration may be used. PET data, normally interlocked with the associated CT scan, can be projected onto any other image dataset by registering the associated CT with another image series, for example with the planning CT.

Contouring is not limited to the main image study (this is normally the planning CT); it can be performed on every co-registered image, regardless of modality.

If needed, structures created in one study can be mirrored in other studies for further refinement, for example with an MRI sequence.

Contours are saved as a structure set belonging to the user-selected study, typically the primary study. In addition, CBCTs can be automatically imported into the syngo.via RT Image Suite from the TPS database using pre-fetching or by importing images from external media. If required, image studies can be anonymized for study purposes.

Figure 2: Screen grab of a dual monitor workstation with the syngo.via RT Image Suite application
A 73-year-old patient with initial non-small cell lung cancer (NSCLC) in the left superior lobe (staging: pT1b pN0 L0 V0 R0 G2) was to receive fractionated stereotactic body radiotherapy (SBRT) to the right inferior lobe. The planned therapy was comprised of four to five fractions per week with a 7 Gy single dose (SD) and up to 70 Gy total dose (TD). Planning was carried out using VMAT technology and respiratory gating (gated CT with respiration monitoring, no phase triggering). Phase-based CT datasets of 0% – 100% (in 10% increments) and the resulting average CT were generated for the planning process. A vacuum mattress for immobilization as well as the Varian RPM™ gating system were used. A diagnostic PET/CT was performed on a curved tabletop.

In syngo.via RT Image Suite, the procedure was as follows:

- The average CT was used as the primary study for dose calculation
- Due to the small size of the lesion, PET/CT was loaded
- Afterwards, the internal target volume (ITV) was contoured directly on the average CT

Despite differences in patient positioning, the result achieved by the rigid fusion was sufficient for identifying the PET enhancing tissue in this case.

The result of the rigid registration of the CT dataset with the average CT is illustrated here (Figure 3). In addition to displaying the PET data on the associated CT, the PET data can also be fused onto the average CT. The fact that the PET data could be fused directly onto the planning dataset proved to be advantageous in this case. It would normally not have been possible to display the average CT fused onto the PET study – including the associated CT – in the TPS. Without syngo.via RT Image Suite, our workflow required either a TPS and PACS viewer next to each other or the creation of an additional structure on the PET/CT to be used as a “supporting structure”.

With syngo.via RT Image Suite, we can significantly streamline the contouring workflow for such patients.
Figure 3: Registration of treatment planning CT and diagnostic PET/CT: Crosshairs show the position of the gross tumor volume

Left: Average CT sequence with vacuum mattress fused with the PET data

Right: Rigidly co-registered diagnostic PET/CT
Case 2

Liver SBRT of a NSCLC patient

A 67-year-old oligometastasic left-sided NSCLC patient was to have an SBRT of the liver. The planned therapy was comprised of fractionated stereotactic radiotherapy using VMAT technology and imaging (IGRT) of the liver lesion in segment 4b on the left side. The prescribed dose of 7 Gy SD was delivered four times per week, up to 70 Gy TD.

CT studies with different respiratory phases, native free breathing and contrast agent phases during inspiration, expiration, and midline were generated for planning purposes. A vacuum mattress was used as a positioning aid. Furthermore, an MRI was performed in the planning position (flat tabletop without positioning aids) to identify the hepatic focal finding with suspected metastases. It was possible to use a diagnostic F18-FDG PET/CT (patient positioning with a curved tabletop) as an additional modality.

The procedure in syngo.via RT Image Suite was as follows:
- The native free breathing CT was used as the primary study
- The ITV was contoured directly on all of the contrast agent planning CT phases
- As the lesion was enriched with only a little contrast agent, a PET/CT for tumor position verification was used
- The latter was achieved by deforming the CT of the PET study and subsequently fusing the PET data with the primary study
- After localization, a deformable registration of a T1-weighted MRI with a contrast agent-enhanced planning CT study was carried out in order to obtain a better impression of the size of the metastases in the noisy planning CT image (see Figure 4).

After this, the ITV was contoured using the contrast agent CT studies with simultaneous mirroring of the contour onto the native free breathing study. After contouring, it was possible to directly check the ITVs with reference to the three contrast agent phases, as well as the MRI and PET/CT data, in all three orientations. The registration results of the planning CT with a contrast agent phase, an MRI sequence, and the PET/CT are shown. Elastic registrations had to be used due to the partial use of an abdominal press.

In this case, the elastic registration proved to be advantageous. Thanks to the deformation of the MRI and PET data, we were able to obtain additional information on the localization and size of the lesion. In the TPS, however, the contouring of the GTVs would have been performed on the 3 contrast agent CT phases, since rigid registrations with the modalities without an abdominal press would not have delivered a sufficiently precise result in this case.
**Figure 4:** View of the elastic registration results of multimodal liver SBRT planning

From **left to right**: Average planning CT, contrast-enhanced CT and T1-weighted MRI data as well as PET/CT data.
Case 3

Follow-up of a NSCLC patient

A fractionated SBRT with a scheme of 10 x 6 Gy was applied to the left lung of a 60-year-old patient with NSCLC. In the course of follow-up, CT scans were to be performed at three-month intervals and transferred to the syngo database. The response during the entire follow-up can be assessed at a glance. The projection of the initial GTVs onto the follow-up CTs is advantageous (see Figure 5). Additional follow-up results obtained in the future can be input into the database successively.

Having four datasets side-by-side enable an easy assessment of the efficacy of the treatment without the need to perform sequential assessments in the PACS viewer or TPS. syngo via RT Image Suite saved time and reduced the risk of errors when comparing structures.
Figure 5:
View of the registration results of the planning and follow-up CT scans

From left to right: The initial planning CT, along with the follow-up CTs from three, six, and nine months after the RT. The initial gross tumor volume (GTV) is projected onto all the datasets.
Conclusion

With syngo.via RT Image Suite and its capacity to display up to eight datasets simultaneously, the full potential of multimodality imaging from diverse imaging methods can be realized. Editing structures superimposed over any image series and instantly observing changes was perceived as being tremendously helpful.

In all of the cases, the time required to contour using syngo.via RT Image Suite was at least equivalent to or faster than our TPS since it could display all the image series concurrently and contour them at the same time using parallel contouring – rather than requiring sequential contouring in the TPS. As TPSs are oriented towards planning datasets, additional modalities have to be superimposed/projected onto the primary dataset in succession. Since the TPS is optimized for therapy planning, follow-up checks are not adequately supported. Image retrieval from the image archive can be time consuming; image viewing is often restricted to viewing a maximum of two image series as a fused image, and then requires blending to switch between images. As a result, response to therapy is normally assessed using a PACS viewer in radiology, but this has the disadvantage that the RT structure sets often cannot be loaded.

In syngo.via RT Image Suite, all datasets needed for follow-up checks are available via pre-fetching from the image archive. Furthermore, eight image series can be visualized concurrently (four single series or four fused series) including RT structure sets, which simplify follow-up checks. Fusion accuracy was rated as clinically suitable by the participating radiation therapists. The deformable image registration was also used for cases where the positioning and the immobilization of the patient deviated significantly, such as in the SBRT of the liver.

Vorwerk et al. have defined requirements that should be fulfilled by software regarding data import, registration and contouring for highly conformal radiation treatment. The requirements are divided into categories for safety, accuracy and efficiency. These functionalities are then further divided into three groups ranging from minimal to enhanced and optimal requirements (best possible feature). Most of the enhanced and optimal requirements were met by syngo.via RT Image Suite, for example it fulfilled the optimal requirement for flexible registration between different datasets [5].

The inclusion of dose as well as the deformable registration of dose distributions would allow syngo.via RT Image Suite develop its full potential in the future. The vector field between two volume image studies could be used to deform the assigned dose, which would clarify the additional therapy options available to the patient, such as the re-irradiation of previously treated areas, for example.

The direct connection between the PACS system and syngo.via RT Image Suite enables better streamlining of certain workflows for the radiation oncologist. User-define pre-fetching means that the latest study is directly available and already registered to the planning dataset. This workflow accelerates the evaluation of the current study with respect to former GTV/CTV contours. In a treatment planning system, these steps must be done manually, which makes the workflow impractical in clinical routine. Most clinics do not have access to synchronic image acquisitions like PET/MRI on a broad basis. syngo.via RT Image Suite provides an alternative, allowing clinicians to obtain synergies by enabling the concurrent registration and viewing of multiple modalities and creating a kind of "virtual PET/MRI". Working with syngo.via RT Image Suite proved to be efficient and meant we could streamline the contouring and follow up workflows in our department.
References


5. Vorwerk et al. Making the right software choice for clinically used equipment in radiation oncology. Radiation Oncology 2014 9:145

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