Stereotactic Body Radiation Therapy (SBRT) of liver metastases using a SOMATOM Definition AS Open 4D-CT scanner and gold marker implants

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Figure 1: Localization of the liver metastasis using a three phase diagnostic CT.

Figure 2: Scout view presenting the localization of the gold markers and the pressure sensor of the Anzai Respiratory Gating System.

Figure 3: Illustration of motion field and magnitude between end-expiration and end-inspiration. The PTV resulted from the ITV plus 4 mm setup margin.
A 61-year-old female patient with a solitary liver metastasis from breast cancer was referred to the radiation oncology department for SBRT, recommended in the interdisciplinary tumor board of the UKE. Neither surgical resection nor radiofrequency ablation of the metastasis was an option due to location and size of the lesion. As presented in Figure 1, the metastasis was centrally located in the caudate lobe with a size of 3.5 cm x 4.3 cm x 3.5 cm.

 MOTION MANAGEMENT AND TREATMENT

For verification of target localization and patient repositioning before dose delivery, three gold fiducial markers (diameter 1.2 mm, length 3 mm, 17G needle) were implanted percutaneously under computed tomography (CT) guidance in the healthy liver tissue surrounding the liver metastasis (cf. Figure 2). Subsequently, a 4D-CT scan was performed in order to accurately determine the magnitude of respiratory motion of the target volume and to reach a decision on respective motion control interventions. CT data were acquired using a SOMATOM Definition AS Open 4D-CT scanner and the Anzai Respiratory Gating System.

The Anzai system provides an external respiratory signal in real time using a pressure sensor (cf. Figure 2). The signal was used to retrospectively reconstruct CT slices for 10 different respiratory phases. A dose saving protocol was applied to minimize the dose exposure of the patient. The patient was asked to breathe freely during data acquisition. Finally, a two phase contrast media CT scan was carried out in the same session to help defining the Gross Tumor Volume (GTV) in the CT slices of the respiratory phases.

As shown in Figure 3, the metastasis was located in an area of small to medium motion amplitudes. Analysis of the 4D-CT data resulted in a mean target motion of 5.3 mm in magnitude (LR 1.8 mm, AP 2.2 mm, CC 4.5 mm). Thus, expected motion-induced uncertainties of the target localization did not require a breathing gated dose delivery. Contouring, target delineation, and dose calculation on the average CT was done using the Eclipse TPS from Varian Medical. The GTV contours of the single calculated respiratory phases were transferred to the average CT of the 4D-CT data to generate the Internal Target Volume (ITV).
The Planning Target Volume (PTV) was constructed by adding a 4 mm setup margin to the ITV as indicated in Figure 3. Highly conformal dose coverage of the PTV was achieved by a volumetric modulated arc therapy (RapidArc) treatment plan using 6 MV photons from a Varian TrueBeam linear accelerator (Figure 4). The final plan consisted of two 360° arcs of 130 and 115 seconds in total 245 seconds gantry rotation time.

Treatment was given within two weeks in five fractions of 7.0 Gy, prescribed to the 100% isodose covering the PTV (dose optimization constraint), which resulted in coverage of the ITV by the 160% isodose (56 Gy). Kilo-voltage cone beam CT (CBCT) scans were created before each fraction to verify and adjust the target localization. Image fusion of the average treatment planning CT and kV-CBCT scans allowed for superposition of patient anatomy and gold marker position and resulted in patient repositioning in the order of 2-3 mm magnitude per fraction (Figure 5).

COMMENTS

In this case study on SBRT of a liver metastasis, 4D-CT data was acquired for target motion management and treatment planning, i.e. (1) to decide on potential benefits of breathing gated radiation therapy application; (2) to define appropriate safety margins to compensate for motion-induced target location uncertainties; and (3) to verify and adjust the target position before dose delivery. Gold markers proved to be a reasonable approach for determination of target localization in the liver at the time of treatment.
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INTRODUCTION
Liver is a common site of metastases, e.g. from colorectal, lung, and breast cancer. Surgical resection remains the standard of care. However, in the case of unresectable lesions, stereotactic body radiation therapy (SBRT) is rapidly emerging as an attractive option. Compared with other approaches of local treatment as radiofrequency ablation, SBRT is in principle non-invasive. The objectives of SBRT are to escalate the dose to the target lesion and thus to increase local control while limiting dose to nearby critical structures and normal tissue. The fundamental requirements of SBRT include precise localization of the target lesion in the treatment planning process; account for tumor motion due to respiration; highly conformal dose distribution to the target volume including a steep dose gradient to maximize liver sparing; and image-guidance at the time of dose delivery for verification and adjustment of the target localization. This study aims to demonstrate the benefit of using gold marker implants and 4D-CT data to meet SBRT requirements in the case of a liver metastasis.

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