Comparison of margins derived with a statistical deformation motion model versus a conventional margin recipe

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Purpose/Objective: Margins in radiotherapy are traditionally calculated for a population of patients, with the magnitude of the margins determined by the patients displaying the largest geometrical uncertainties. For simultaneous irradiation of more than one target (when including elective targets), the relative target motion and deformations are additional challenges for margin calculations. In this study we have therefore evaluated margins derived by a statistical deformable motion model and compared this to an established margin recipe. The investigations were performed in a series of patients with locally advanced prostate cancer, focusing on the two elective targets, the seminal vesicles and the pelvic lymph nodes, with different patterns of deformation and motion relative to the target used for set-up i.e. the prostate.

Materials and Methods: The study was based on 12 prostate cancer patients, each with a set of 2 rest and 2 repeat CT scans with target delineations. Following a rigid registration (translations only) based on intra-prostatic fiducial markers of the repeat images, a statistical deformable motion model for each patient was constructed. The motion model was based on principal component analysis (PCA) of the displacement vectors calculated between the target shapes in the planning CT and those in the repeat CTs. The model was employed to generate coverage probability (CP) distributions for 100 simulations of 100 shapes of the targets. These coverage probability (CP) based margins were compared to the margins calculated with the widely accepted conventional margin recipe. The investigations were performed in a series of patients with locally advanced prostate cancer, focusing on the two elective targets, the seminal vesicles and the pelvic lymph nodes, with different patterns of deformation and motion relative to the target used for set-up i.e. the prostate.

Results: Table 1 summarizes the results. For 2-arc plans delivered using 2400 MU/min, maximum dose deviation of up to 9.4% was found in a single arc delivery (patient 6). This was reduced to < 7% in the sum plans, and further reduced to < 5% and 3% when combining measurements performed at 2 and 3 different initial breathing phases, respectively. For a single arc of the 2400 MU/min 2-arc plans, the average surface with gamma >1 ranged from 3.6 to 16.9%. However, for all 27 cases, >99% of the area within the ROI passed the gamma criteria when combining all 3 measurements at different initial phases of the breathing cycle. 2400 MU/min plans with fewer control points (e.g. one single arc) showed higher dose deviations in single measurements, however, this effect diminished when summing the dose distributions over 2 fractions. All plans delivered using 2400 MU/min showed good agreement in just one single fraction measurement.

Conclusions: Interplay is observed during RapidArc SBRT using high dose rate FF beams to treat mobile targets within a free-breathing ITV. This might lead to dose deviations within the target region, especially when treating with a single arc and one fraction. Using 2 arcs and delivering the dose in 2 or more fractions reduces the effect. In such situations the dosimetric impact of interplay is most likely clinically insignificant.

Dosimetric impact of interplay during lung SBRT with FFF RapidArc

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Purpose/Objective: RapidArc stereotactic body radiotherapy (SBRT) using flattening filter free (FFF) beams can deliver a fraction of 18 Gy within 3 minutes. We investigated the possible dosimetric impact of interplay effect between multileaf collimator (MLC) motion and tumor motion during RapidArc delivery for lung SBRT using FFF beams with dose rates up to 2400 MU/min.

Materials and Methods: 7 patients treated using RapidArc 10MV FFF beams with tumor motion ranging from 8 - 20 mm were selected. 13 different plans (described below) were investigated and a total of 100 arc deliveries were measured in a static and sinusoidal moving phantom using GaChromatic EB3 film. All plans delivered the prescribed dose to 95% of the PTV, which was created using a 5 mm isotropic expansion of the free-breathing ITV. Plans contained 2 arcs, and were delivered using maximum dose rates of 2400 and 400 MU/min. For all plans of 2400 MU/min, measurements were repeated at 3 different initial breathing phases to investigate the interplay effect over 2-3 fractions. For 3 cases, 2 extra plans were created to evaluate interplay effects of plans using either 1 full rotational arc or 1 partial arc of approximately 220°. Dose deviations within a region of interest (ROI) receiving >50% of the PTV dose were evaluated using gamma analyses of 3% dose difference and 1 mm distance to agreement between the measurements of the moving phantom and the convolution of the motion with the static measurements. The percentage of points that failed the gamma criteria and maximum dose deviations were noted.

Results: Table 1 summarizes the results. For 2-arc plans delivered using 2400 MU/min, maximum dose deviation of up to 9.4% was found in a single arc delivery (patient 6). This was reduced to < 7% in the sum plans, and further reduced to < 5% and 3% when combining measurements performed at 2 and 3 different initial breathing phases, respectively. For a single arc of the 2400 MU/min 2-arc plans, the average surface with gamma >1 ranged from 3.6 to 16.9%. However, for all 27 cases, >99% of the area within the ROI passed the gamma criteria when combining all 3 measurements at different initial phases of the breathing cycle. 2400 MU/min plans with fewer control points (e.g. one single arc) showed higher dose deviations in single measurements, however, this effect diminished when summing the dose distributions over 2 fractions. All plans delivered using 2400 MU/min showed good agreement in just one single fraction measurement.

Conclusions: Interplay is observed during lung RapidArc SBRT using high dose rate FFF beams to treat mobile targets within a free-breathing ITV. This might lead to dose deviations within the target region, especially when treating with a single arc and one fraction. Using 2 arcs and delivering the dose in 2 or more fractions reduces the effect. In such situations the dosimetric impact of interplay is most likely clinically insignificant.

Comparison of dosimetric and geometric tolerance limits in image guided correction strategies during SBRT

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Purpose/Objective: Image guided correction for tumor baseline shifts is essential for accurate delivery in SBRT. Due to differential motion between tumor and organs at risk (OAR), such corrections can lead to exceeding the tolerance dose of these OARs. A clinically available solution is to set geometrical corrections for the differential motion. When these restrictions are exceeded, a compromise is made between tumor alignment and OAR sparing. Although the restrictions are