Conclusions
Over a long period, our proton therapy facility has been reliable and accurate in its delivery. As the correctness of each steering file is anyway independently checked by a dose calculation based directly on the content of the steering file, we are therefore proposing to move to a new QA strategy. This will consist of weekly dosimetric verifications of only a standard and quasi-randomly selected field, to ensure consistency in the performance of the proton facility. This policy will improve workflow issues caused by the obligatory field-by-field verification adopted up to now.

PROFFERED PAPERS: RTT 2: GEOMETRIC UNCERTAINTIES: MOTION MANAGEMENT

OC-0161
Simulations of the effects of organ motion on target coverage in proton therapy of prostate cancer
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Purpose/Objective: During radiotherapy of the prostate, inter- and intra-fractional organ motion can cause deviations in prostate location of more than 10 mm away from the position assumed during the planning stage. This can potentially degrade the dose target coverage. In this treatment planning study we have investigated the impact on target coverage caused by organ motion when treating prostate cancer with protons, with an emphasis on the situation when particularly tight margins are applied. The dosimetric effects were compared for two the techniques Intensity Modulated Proton Therapy (IMPT) and passive proton Double Scattering (DS). Materials and Methods: CT scans of 8 prostate cancer patients were consecutively selected from our database; 100 IMRT and 50 SABR patients were positioned on a mattress with arm and knee support. The image guidance protocol for both techniques was identical: 1) a mid-ventilation planning CT; 2) a couch correction was performed to align the tumour; 3) a 2nd CBCT (CBCT2) was acquired to verify the position of the prostate target volume; 4) following a non-coplanar IMRT correction prior to dose delivery; 5) following a non-coplanar IMRT correction prior to dose delivery; 6) following a non-coplanar IMRT correction prior to dose delivery; 7) following a non-coplanar IMRT correction prior to dose delivery; 8) following a non-coplanar IMRT correction prior to dose delivery; 9) following a non-coplanar IMRT correction prior to dose delivery; 10) following a non-coplanar IMRT correction prior to dose delivery; 11) following a non-coplanar IMRT correction prior to dose delivery; 12) following a non-coplanar IMRT correction prior to dose delivery. Results: CTV shifts in all directions caused degradation in target coverage, however, the degradations differed considerably between the two treatment techniques. For the 6 mm shifts in the anterior direction the mean dose coverage across all patients was reduced to 88 ± 2 % with DS and was additionally decreased to 81 ± 4 % with IMPT. Similar trends were seen also for the posterior as well as the superior/inferior directions (Table 1). For the lateral shifts an opposite effect was found, with slightly larger dose reduction for DS compared to IMPT. The effects for 12 mm shifts were enlarged, with larger degradations for the anterior/posterior and superior/inferior directions with IMPT (Figure 1), but smaller for lateral shifts.

Conclusions: In this study we have shown that prostate motion can cause severe reduction in target coverage. The degradations appear to have a higher impact when treating with IMPT than with passive DS.

OC-0162
An evaluation of VMAT and IMRT intrafraction motion in NSCLC patients treated with SABR
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Purpose/Objective: Although Stereotactic Ablative Body Radiotherapy (SABR) has become the standard treatment for T1-T2 inoperable non-small cell lung cancer (NSCLC), the manner in which this is delivered may differ between institutes. Often coplanar and non-coplanar IMRT with 10 or more beams is performed, resulting in long treatment times. Image guidance, imperative for SABR increases this time even further, while intrafraction motion has been found to correlate with the overall treatment time. Since the introduction of volumetric modulated arc therapy (VMAT), treatment times have been considerably reduced. This study aims to evaluate intrafraction motion in NSCLC patients treated with IMRT and VMAT based SABR. Materials and Methods: NSCLC patients treated with SABR were consecutively selected from our database; 100 IMRT and 50 VMAT. All patients were treated using a frameless technique whereby patients were positioned on a mattress with arm and knee support. The image guidance protocol for both techniques was identical: 1) a 1st CBCT was acquired prior to each fraction that was registered using a dual registration algorithm on the bony anatomy and the tumour to the mid-ventilation planning CT; 2) a couch correction was performed to align the tumour; 3) a 2nd CBCT was acquired to verify the correction prior to dose delivery; 4) following a non-coplanar IMRT technique or a dual arc VMAT technique, a 3rd CBCT scan was acquired. Intrafraction motion was evaluated between CBCT and CT. Treatment time was calculated for both techniques and was defined as the difference in time between CBCT and CT. The difference in intrafraction motion between the 2 techniques was analysed in terms of the group mean, systematic and random errors.

Results: CTV shifts in all directions caused degradation in target coverage, however, the degradations differed considerably between the two treatment techniques. For the 6 mm shifts in the anterior direction the mean dose coverage across all patients was reduced to 88 ± 2 % with DS and was additionally decreased to 81 ± 4 % with IMPT. Similar trends were seen also for the posterior as well as the superior/inferior directions (Table 1). For the lateral shifts an opposite effect was found, with slightly larger dose reduction for DS compared to IMPT. The effects for 12 mm shifts were enlarged, with larger degradations for the anterior/posterior and superior/inferior directions with IMPT (Figure 1), but smaller for lateral shifts.
Purpose/Objective: A remaining uncertainty in breast cancer irradiation is the effect of respiratory induced motion on target area and organs at risk. In case of whole breast irradiation (WBI) respiratory induced motion will have hardly any impact on coverage of the target area. Even coverage of the boost area is ensured since almost 100% of the total dose is delivered via tangential fields to the WBI. However, in partial breast irradiation (PBI), uncertainties in correct definition of the target area and its localization during treatment can lead to a geographically miss.

In literature, several surrogates have been used to evaluate respiratory induced motion, e.g., clips/markers, chest wall, using 3D or 4DCT data. Also motion differences within targets have been described. To summarize all respiratory induced motion for target area and organs at risk within one patient, we used 4DCT data and selected different regions of interest (ROIs).

Materials and Methods: For ten patients two CT scans were acquired; a 3DCT scan for planning purposes and a 4D respiratory correlated CT scan to investigate intrafraction motion due to respiration. The 4DCT scan was reconstructed into ten equal phases, each phase corresponding with one breathing cycle.

To rule out patient motion between the 3D and 4DCT scan, the 4DCT scan was first registered to the planning CT scan on bony anatomy (spinal cord). Second, each phase of the 4DCT scan was registered to the planning CT, based on 8 different ROIs: (1) Ribs and a part of the sternum, (2) heart, (3) breast surface, (4) tumour bed, (5-8) four quadrants of the breast.

For ROI (1) a bony anatomy registration based on a chamfer matching algorithm was performed. For ROIs (2-8) masks were created on the planning CT. Anatomical landmarks or surgical clips were used for the mask registrations of the four breast quadrants and demonstrated a surrogate for tumour position. The mask registrations were based on grey values. For each patient and each ROI (1-8), the mean (M) and standard deviation (SD) of the motion errors were calculated, as well as the amplitude of the motion.

Results: For all ROIs, except the heart, the M magnitude of the breathing motion was <0.05 cm. Systematic errors of all ROIs were between 0.03-0.05 cm in LR, 0.09-0.22 cm in CC and 0.08-0.15 cm in AP direction. The amplitude of the motion was 0.09-0.11 cm in LR, 0.18-0.26 cm in CC and 0.14-0.20 cm in AP direction (table 1). No difference was found between the quadrants of the breast.

Conclusions: Large respiratory induced motion was found for the heart: in cases where the treatment beams are close to the heart an organ at risk margin is required. For all other ROIs the motion was very small. In cases of PBI, the additional margin required to account for respiratory induced motion of the target area will therefore be negligible.