

thickness provided the movement be consistent and periodic. For non-sinusoidal movements phases far from 0% and 50% may introduce significant discrepancies. Both systems are compatible but respiratory training would be necessary to guarantee consistency for a gating strategy while it would not for a MIP-based ITV strategy.

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#### EP-1500

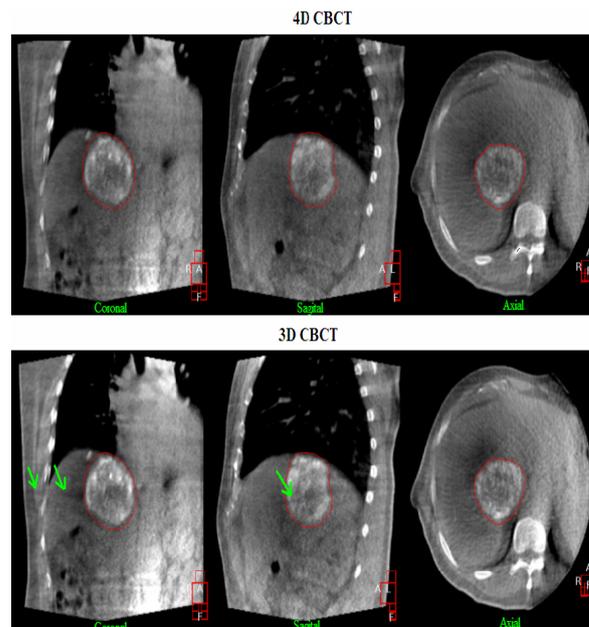
3D versus 4D cone beam computed tomography for lipiodol-guided radiotherapy of hepatocellular carcinomas  
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**Purpose/Objective:** Evaluate the positional uncertainty of hepatocellular carcinomas (HCC) guided by lipiodol on respiratory-correlated (4D) and uncorrelated (3D) cone beam computed tomography (CBCT).

**Materials and Methods:** Elekta XVI v4.5 (Elekta, Crawley, UK) was used to acquire 4D CBCT of 15 HCCs treated by hypofractionated radiotherapy after single trans-arterial chemoembolization (TACE) with lipiodol. 1320 x-ray projections per 4D CBCT scan were sorted into 10 CBCT dataset (132 projections per CBCT dataset). A 4D registration workflow was followed to register the reconstructed time-weighted average CBCT with the planning mid-ventilation CT by an initial bone registration of the vertebrae and then tissue registration of the lipiodol. For comparison, projection data of each 4D CBCT were used to synthesize 3D CBCT images without motion extraction. Uncertainties of the treatment setup estimated from the absolute lipiodol position and the interfractional lipiodol drift relative to vertebrae were analyzed separately from 4D and 3D CBCT images.

**Results:** Qualitatively, 3D CBCT showed better lipiodol contrast than 4D CBCT primarily because of a tenfold increase of projection data applied to the reconstruction. Some motion artifacts were observed on the 3D CBCT but not on 4D CBCT (Fig. 1). Group mean, systematic and random errors estimated from 4D and 3D CBCT are similar, agree to within 0.7 mm in the cranio-caudal (CC), and anterior-posterior (AP) directions, and 0.3 mm in left-right (LR) direction. Systematic and random errors are largest in the CC direction, amounting to 4.7 mm and 3.9 mm from 3D CBCT and 5.5 mm and 4.0 mm from 4D CBCT in terms of the absolute lipiodol position, and 3.7 mm and 3.0 mm from 3D CBCT and 4.3 mm and 2.8 mm from 4D CBCT in terms of the lipiodol baseline drift relative to vertebrae, respectively. Margin calculated from 3D CBCT and 4D CBCT differed by less than 1.9 mm, 0.2 mm and 0.1 mm in the CC, AP, and LR directions in the patient cohort.



**Conclusions:** 3D and 4D CBCT were found equivalent in localizing HCCs guided by lipiodol, resulting in similar safety margin. 4D CBCT offers the advantage of measurements of the changes of tumor motion for assessing the adequacy of the planning margin.

#### EP-1501

Influence of prostate rotation on dose distribution in the target volume

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**Purpose/Objective:** The inter-fraction prostate motion can have a significant impact on dose distribution in the target volume. However, the concept of the PTV was developed to minimize the influence of all uncertainties of target position on dose distribution, the problem of rotations is not entirely analyzed. The aim of this study was to investigate the influence of the prostate rotation on delivered dose for three different techniques.

**Materials and Methods:** For 10 prostate cancer patients previously treated in our hospital 3D-CRT, IMRT and SIB-IMRT treatment plans were prepared. Internal rotations of the prostate in the range from  $-27^\circ$  to  $+27^\circ$  relative to the apex in anterior-posterior direction were introduced. Rotations in rectum direction was defined as a negative angle. Based on originally prepared plans, the DVH for rotated prostate was calculated and compared with the DVH obtained for non-rotated structure. Changes of  $D_{min}$ ,  $D_{99\%}$ ,  $D_{max}$ ,  $D_{1\%}$ ,  $D_{mean}$ , standard deviation and  $V_{95\%}$  as a function of the rotation angle were analyzed. For each treatment planning technique the influence of rotation on the TCP was also determined.

Results: For prostate the average value of the D99% were  $99.19\% \pm 0.25\%$ ,  $79.62\% \pm 13.23\%$ ,  $91.42\% \pm 7.19\%$  of prescribed dose, for  $0^\circ$ ,  $-27^\circ$ ,  $+27^\circ$  rotation angles respectively. For IMRT and SIB-IMRT techniques decrease of D99% was reduced for maximum angles by 12% and 26.5% respectively and results were rotation direction independent. The rotation had no impact on D1%. A negligible influence of rotation for 3D-CRT and IMRT on the  $D_{\text{mean}}$  was observed. For 3D-CRT and IMRT techniques decrease of  $D_{\text{mean}}$  was greater than 2% only for maximum analyzed angles in 1 and 3 cases respectively. For SIB-IMRT, the 2% decrease of  $D_{\text{mean}}$  was observed for 5 patients for rotations larger than  $21^\circ$ , regardless of the direction of rotation. For group of 8 patients with low grade tumors the average value of the TCP for non-rotated prostate were calculated and equal to  $83.4\% \pm 0.2\%$  and  $83.3\% \pm 0.3\%$  for 3D-CRT and IMRT respectively. For rotations smaller than  $18^\circ$  the TCP was close to 80% for all patients. For SIB-IMRT plans the TCP decreased from 88.3% to 80.0% for  $18^\circ$  rotations.

Conclusions: Our results showed that the change of dose distribution in the target volume depend on the angle of rotation and the treatment delivery technique. Only rotations larger than about  $21^\circ$  influence significantly on the DVH and the TCP. The 3D-CRT showed the smallest sensitivity to prostate rotations. SIB-IMRT technique was the most sensitive to rotations, however the increased prescribed dose to prostate compensated reduction in the TCP. It remained comparable to the TCP obtained for 3D-CRT and IMRT techniques.

#### EP-1502

Lipiodol versus diaphragm as tumor surrogate in 4D CBCT-guided radiotherapy of hepatocellular carcinomas

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Purpose/Objective: To compare lipiodol and diaphragm as tumor surrogate in hypofractionated radiotherapy of hepatocellular carcinomas (HCC) using 4D cone beam computed tomography (CBCT).

Materials and Methods: Treatment verification 4DCBCT scan were acquired using Elekta XVI v.4.5 (Elekta, Crawley, UK) for 15 HCC patients who had prior single transarterial chemoembolization (TACE) with lipiodol. Automatic 4DCBCT image registration with the planning mid-ventilation images was performed initially by bone registration of the vertebrae followed by a 4D registration based on either lipiodol or diaphragm on the reconstructed time-weighted average images. Uncertainties of treatment setup and interfractional tumor baseline drift estimated by lipiodol and diaphragm were analyzed.

Results: All lipiodolized HCCs were clearly visualized on the time-weighted average 4D CBCT images. Lipiodol visibility decreased with increasing tumor size due to limited amount of lipiodol per TACE. Group means and random errors of the treatment setup and interfractional baseline shift based on lipiodol and diaphragm are similar, agree to within 0.5 mm in left-right (LR) and anterior-posterior (AP), and 0.1 mm in cranio-caudal (CC) directions, and systematic errors differ by 1.5 mm, 0.7 mm and 0.2 mm in the LR, AP and CC directions, respectively. Using lipiodol instead of diaphragm as tumor

surrogate in our margin calculation led to 0.6 mm decrease in the CC direction, 1.3 mm and 3.1 mm increase in AP and LR directions in the patient cohort, respectively.

Conclusions: Lipiodol offers the potential of target localization with motion blurring minimized on the 4D CBCT images. Using diaphragm as tumor surrogate can lead to misalignment of the tumor. The amount of TACE lipiodol may need to be adjusted according to the tumor size to improve its visibility on 4D CBCT.

#### EP-1503

Rigid and non-rigid registration dose propagation for brachytherapy treatment combined with radiotherapy

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Purpose/Objective: Cervical cancer is the fourth most common cancer in women with an estimate of 266'000 death per year worldwide. It has been reported that by combining HDR brachytherapy (HDR) with external beam radiotherapy (EBRT) the local tumor control can be further improved. The dose distributions for these two treatment modalities are based on CTs which differ in the patient positioning. The dose planned with EBRT and HDR has to be added together in order to assess the dose to the target and to the organ at risk. Furthermore, the medial field border for EBRT will be based on the dose distribution from the HDR plan. In order to propagate the dose from one CT to the other, image registration is required. In this work we evaluated the benefit of using a non-rigid algorithm compared to a rigid registration for dose propagation.

Materials and Methods: Ten patients treated with HDR (5x5Gy, Manchester method) combined with Boost-EBRT to the parametrium (3x2Gy) were included in this study. The EBRT treatment consisted of 2 opposing fields, in which the medial border was based on the 50-80% isodose line from the first HDR treatment. The total dose was calculated by registering the CT in a rigid or a non-rigid way using Velocity (Varian Medical System, Palo Alto, CA). The total dose obtained with the rigid and non-rigid registration was then compared together based on dose distribution as well as dose-volume histogram parameters.

Results: The position of the 50% HDR isodose line propagated on the EBRT CT between the rigid and non-rigid registration was different by up to 1cm in all directions, thus substantially affecting the choice of field size for the subsequent EBRT. The change of dose distribution between both registration modalities did not affect the dose to the femoral heads. Larger dose difference to the rectum and bladder was observed. Dose to 0.1cm<sup>3</sup>, 1cm<sup>3</sup>, 2cm<sup>3</sup> and 5cm<sup>3</sup> of the rectum volume could increase by up to 37%, 22%, 18% and 10%, respectively. For the bladder, dose to 0.1cm<sup>3</sup>, 1cm<sup>3</sup>, 2cm<sup>3</sup> and 5cm<sup>3</sup> could change by more than 41%, 21%, 22% and 28%, respectively.

Conclusions: The registration modality used for dose propagation has to be carefully evaluated when matching CTs were taken with the patient lying in different positions, as is the case in HDR and EBRT. Wrong registration could result in cold spots in the tumor region or hot spots in the organs at risk.