organ motion during tangential breast treatments on TomoTherapy. Further studies into these breast treatment exit detector fluences are necessary for this method’s verification and future development of method robustness. The future applications for this method include better dosimetric understanding of tangential breast treatments as well as possible dynamic delivery compensation for organ motions to reduce the patient’s lung and heart dose.

Purpose or Objective: Stereotactic Body Radiotherapy is increasingly used for early stage Non Small Lung Cancer (NSCLC) or oligometastatic disease. For patients with two adjacent homolateral tumours, high quality treatment plans can be designed to simultaneously treat both tumors with a single isocentre. The accuracy of treatment delivery is then potentially compromised. A compromise needs to be made for differential motion of the two tumors. The aim of this study was to quantify inter- and intra-fractional differential motion of adjacent tumors eligible for SBRT with a single isocentre.

Material and Methods: Patients treated with SBRT for lung tumours since 2014 were retrospectively selected from our database. Patients were included if they presented with 2 adjacent homolateral tumours with a distance between the 2 lesions of ≤5cm (Figure 1). Prior to each treatment session patients received a CBCT (CBCTprecor) for tumour alignment. Both GTVs in the CBCTprecor were local-rigidly registered to the planning CT scan (pCT) using two separate shaped regions of interest. These registration results were then subtracted to give the differential motion. The post treatment CBCT (CBCTpostRT) and post correction CBCT (CBCTpostcor) were similarly used to quantify the difference in intra-fraction motion (IFM) between the two lesions. Subsequently the group mean (GM), systematic (Σ) and random (σ) position variabilities were calculated for Left/Right (LR), Cranial/Caudal (CC) and Anterior/Posterior (AP) directions.

Results: Nine patients were included in this analysis, 7 male 2 female, median age was 63 years. The median distance between the tumours was 2.7 cm (range 1.2-4.7cm) All tumours were peripherally located, with a median Gross Tumour Volume (GTV) of 1.95cc (range 0.2-38.2cc) and median tumour amplitude, derived from the 4D pCT of 0.2,0.4 and 0.4 cm in LR, CC and AP directions respectively. The inter-fraction differential tumour motion in terms of GM, Σ and σ is shown in Table 1. Systematic displacements in CC and AP were somewhat larger than the random displacements. In 5 patients the tumours moved on average towards each other, in the remaining 4 patients the tumours moved further apart. Differential IFM (table 1) was typically somewhat smaller than inter-fraction motion. Inter-fraction motion did not significantly correlate with the inter tumor distance for the systematic component but was highly correlated (r=0.75; p<0.02) to the random component.

Conclusion: Differential motion of 1-3 mm (systematic and random variation) was observed in this small retrospective study between adjacent lung tumours eligible for single isocentre SBRT. However, as a compromise can be made for tumour alignment, the values reported in this study should be divided by two when calculating margins.

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Intra-fraction patient movements during SBRT: CBCT vs Surface Optical Markers
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Purpose or Objective: To evaluate and to compare the intra-fraction movements, during Stereotactic Body Radiation Therapy (SBRT), obtained with two different methods: Cone Beam CT (CBCT) and an infrared Optical Tracking System (OTS).

Material and Methods: 10 patients (pts) with lung lesions (primary tumour or metastasis) were irradiated with a total dose ranging from 36 to 42 Gy in 3 fractions using one or two 6 MV photons volumetric-modulated arcs by a Varian Clinac linear accelerator. Pts were positioned with the arms raised on a breast setup system (PositionBoardTM, Civco) with a vacuum customized cushion. The OTS SMART-DX (BTS Bioengineering, Milano, Italy) was used to record the 3D coordinates of multiple passive markers (6-8) placed on the patient’s thoraco-abdominal surface. Ungated CT images was acquired for treatment planning (TP). 4DCT images were used for clinical target volume (CTV) delineation and a 5mm isotropic planning target volume (PTV) was generated. Before the daily treatment a CBCT was acquired and registered to the planning CT to obtain and apply the setup corrections (only translations allowed). After the irradiation a second CBCT was performed and rigidly registered to the first CBCT with a mutual information algorithm focusing on the CTV region. A rigid transformation was also estimated from surface markers coordinates acquired by the OTS just before the two CBCT scans. Setup corrections were subtracted from the rototranslation parameters obtained from both CBCT and OTS, in order to evaluate intra-fraction patient reproducibility. The results for both CBCT and OTS methods were evaluated and compared regardless of rotations coordinates always found to be less than 1 degree.

Results: In 39 analyzed fractions the mean absolute values of translational displacements obtained with the CBCT method was 0.6±0.9 mm in the latero-lateral (LL) direction, 0.7±1.0 mm in the antero-posterior (AP) direction and 1.0±1.0 mm in the cranio-caudal (CC) direction. The same analysis achieved in 26 fractions with surface markers, revealed absolute displacements of 1.1±1.1 mm in LL, 1.5±0.9 mm in AP and 1.7±1.7 mm in CC direction. Comparing the shifts obtained with the two systems in the same sessions, the resulting mean difference was 1.1±1.2 mm in LL, 1.8±1.3 mm in AP and 1.7±1.6 mm in CC.
Conclusion: The differences between the intra-fraction patient displacements observed through CTV overlapping using CBCTs and through the surface markers registration seem to be clinically acceptable for the PTV considered. The relatively greater spread using markers is probably due to the larger portion of patient’s surface covered by the OTS compared to the CTV region. Considering the adopted PTV margin, the non-invasive OTS could be therefore used to monitor the intra-fraction movements as alternative to a post treatment CBCT, possibly using markers positioned in a restricted area around the target.

Purpose or Objective: SBRT is now an accepted treatment for inoperable pts with stage I lung cancer and oligometastatic disease. Particularly for SBRT, tumor motion must be taken into consideration due to high dose per fraction. It is unclear which system provides the best accuracy for target localization. The aim of this study is to evaluate the role of lung optimization treatment(LOT) simulation for the best tumor tracking using Cyberknife SBRT.

Material and Methods: From September 2014 to July 2015 we evaluated 143 consecutive pts referred to our department for tracking modality. For everyone a CT scan was performed in inspiratory and expiratory phase. During the simulation the position and setup were the same as those during the treatment. The real-time images were compared to the DRRs where the target was evidenced. Cyberknife includes a small 6 MV LINAC mounted on a robotic arm, two diagnostic X-ray sources (installed in the ceiling of the treatment room) attached to digital image collectors, placed orthogonally to the patient to provide real-time treatment guidance, and a table remotely controlled that can move around different axes and adjust the patient position.

Results: According to the accuracy of the LOT system in target identification we observed these solutions: we treated 102 pts (71%) with Xsight lung technique, 80 pts in 2-view modality in which only one camera was used. Xsight lung along with Synchrony Respiratory Tracking can automatically track and adjust the beam to tumor motion, using the lesion as a fiducial. The GTVs were expanded by 3 mm in all directions to create the CTV. Cyberknife includes a small 6 MV LINAC mounted on a robotic arm, two diagnostic X-ray sources (installed in the ceiling of the treatment room) attached to digital image collectors, placed orthogonally to the patient to provide real-time treatment guidance, and a table remotely controlled that can move around different axes and adjust the patient position.

Conclusion: LOT simulation system is a very effective, useful and non-invasive technique. Dramatically reducing PTV margins and consequently the risk of potential toxicities related to the high doses, LOT simulation system and Xsight lung are considered the best choice in the management of lung lesions in our clinical practice.

Purpose or Objective: We report the preliminary clinical results organ motion mitigation strategies in the treatment of moving target with active scanned carbon ion beams.

Material and Methods: Since September 2014 26 patients with tumors located in the upper abdomen and chest were treated with active scanned carbon ion beams. Patients were affected by pancreatic adenocarcinoma, HCC, biliary tract cancers and sarcoma of the spine retroperitoneum and heart. Tight thermoplastic mask was selected as the optimal abdominal compression device. 4D CT scan with retrospective reconstruction, with phase signal obtained with Anzai system (Anzai Medical Co., LTD), was employed for planning. Automatic assignment of raw data to respiratory phases was checked and, if necessary, modified by the medical physicist. Planning was performed using end expiration phase. Planning CT scans were visually checked for motion artifacts. Contouring was performed on end expiration phase and on the adjacent 30% expiration and 30% inspiration phases. Beam entrance was selected in order to avoid the bowel in the entrance channel. The lung diaphragm interface was contoured in the different respiratory phases and beam angles were chosen to avoid passing tangential to the lung diaphragm ITV. IMPT was used for plan optimization. Plans were recalculated in adjacent phases and if DVHs were degraded in an unacceptable way they were modified iteratively. Weekly verification 4D CT scans were performed and, if needed, a new plan was re-optimized adaptively. Set up was verified with gated orthogonal X-rays and non-gated cone beam CT in treatment room. Threshold for gate-on signal was initially set at 10% pressure signal dynamic and qualitatively adjusted in an asymmetric way according to results of plan recalculation in 30% expiration and inspiration. Gating signal was fed to the accelerator to enable beam delivery. Each slice was re-scanned 5 times to smears out possible interplay effects. Acute and early toxicity was scored according to CTCAE 4.0 scale.

Results: GTV and diaphragm excursion between end expiration and adjacent 30% phases was reduced to less than 5 mm. GTV (995%) and critical OARs (D1%) DVH in 30% inspiration and expiration phases showed on average minimal (less than 1%) differences as compared to planning end expiration plan. Toxicity was minimal with no G3 event. G2 toxicity was observed in 10% of patients during treatment, and in 10% of the patients at 3 months. Median follow up was rather short (3 months) nevertheless in 23 patients the dose limiting OAR was either stomach or small bowel or esophagus, therefore early toxicity data are informative.

Conclusion: Active scanning with carbon ion beams for the treatment of moving target using abdominal compression, 4D simulation, robust planning, gating and rescanning is feasible and safe. Longer follow up is needed to evaluate oncological outcome.

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