Conclusion: Respiratory and non-respiratory motion during prolonged treatment induces significant position errors. Resulting CTV to Planning Target Volume (PTV) margins are within the 5 mm isotropic expansion generally used in clinic. Non-invasive continuous monitoring of intra-fraction motion should be implemented for an accurate definition of PTV.

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The accuracy of ExacTrac X-ray intra-fraction verification at non-zero couch rotation

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**Purpose or Objective:** Submillimeter accuracy of patient positioning is mandatory in stereotactic radiation therapy (SRT), since a high dose per fraction is given to relatively small lesions using tight PTV margins. SRT treatment techniques normally use couch rotations to achieve optimal irradiation. In frameless SRT intrafraction positioning verification at non-zero couch angles is recommended to ensure correct dose delivery. In this study we assessed the accuracy of the frameless ExacTrac X-Ray verification system at non-zero couch angles.

**Material and Methods:** An Alderson head phantom with a hidden marker was immobilized in a BrainLAB frameless mask on the Novalis Tx system. The phantom was positioned using the ExacTrac X-Ray system at couch angle 0°. For 13 different couch angles the phantom position was determined using the i) infrared (IR) optical markers, ii) X-ray verification at non-zero couch angles was assessed.

**Results:** Deflection of the couch in the vertical direction was within 0.23 mm at couch angle 0° and variation at other couch angles is less than 0.1 mm. X-Ray verification at different couch angles showed significant differences with the AP-MV imaging of 0.23±0.12 mm and 0.30±0.21 mm on average for longitudinal and lateral direction respectively. Maximum deviations between AP-MV imaging and ExacTrac X-ray were found at couch angle 30° of 0.63 mm in lateral and 0.50 mm in longitudinal direction. Verification with the IR markers shows larger deviations than the X-ray verification. Largest mean deviations for longitudinal and lateral direction were -1.55 mm (at couch angle 270°) and 1.14 mm (at couch angle 90°).

**Conclusion:** X-Ray verification at non-zero couch angles using the ExacTrac system is sufficiently accurate to be used in SRT. Deviations in X-Ray verification were largest at couch angle 30° but this will be of minimal importance clinically, since in non-coplanar SRT treatment techniques multiple couch angles are used. The IR system shows deviations that exceed accuracy requirements for SRT.

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Visualization of respiratory and cardiac motion via TomoTherapy exit detector fluence

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**Purpose or Objective:** To demonstrate that respiratory and cardiac motion is observable and quantifiable on the CT detector during TomoDirect breast treatments.

**Material and Methods:** A preliminary study for motion management in breast radiotherapy was performed using the exit detector fluence of tangential IMRT fields on TomoTherapy. Two patients in treatment for left breast cancer were selected randomly for study. After their radiotherapy treatments, the raw pulse-by-pulse detector data was downloaded from the CT detector for analysis. The pulse-by-pulse detector data is sampled at a frequency of 300 Hz. The exit detector channels with fluences corresponding to the breast and heart surfaces were identified within the recorded treatment sinograms. These channels’ fluences were then investigated at the temporal projections in which respiratory and cardiac motion were expected (Figures 1a-b).

**Results:** Sinusoidal and waveform variations in fluence were observed where respiratory and cardiac motion was expected. The fluence variations we have observed on the pulse-by-pulse detector data would fit reasonably within 86.4 ± 2.0 bpm during the 3 fractions that were analyzed. The cardiac waveform motion recorded on the detector data at the expected heart surface averaged a period of 2.8 ± 0.1 sec during the 4 fractions that were analyzed. The cardiac waveform motion recorded on the detector data at the expected breast surface averaged a period of 2.8 ± 0.1 sec during the 4 fractions that were analyzed. The cardiac waveform motion recorded on the detector data at the expected breast surface averaged a period of 2.8 ± 0.1 sec during the 4 fractions that were analyzed.

**Conclusion:** The fluence variations we have observed on the pulse-by-pulse detector data would fit reasonably within respiratory and cardiac motion. These preliminary results are indicative of the ability for visualization and quantification of cardiac motion.
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 tumours 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 tumours. The aim of this study was to quantify inter- and intra-fractional differential motion of adjacent tumours 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 ≤5 cm (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 1.2-4.7 cm). All tumours were peripherally located, with a median Gross Tumour Volume (GTV) of 1.95 cc (range 0.2-38.2 cc) 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.

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 (PosiBedTM, 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.