Purpose or Objective: The dose variation of stereotactic body radiation therapy (SBRT) for lung cancer varies due to the interplay effect between multileaf collimator (MLC) motion and tumor motion. The aim of this study was to assess the relationship between dose variation and factors related to the interplay effect and clarify optimal conditions for SBRT.

Material and Methods: Respiratory motion data and MLC motion data were obtained from 30 patients who underwent treatment with SBRT for lung cancer. We calculated number of breaths (NB) during irradiation, maximum craniocaudal tumor motion (Amp), and MLC motion complexity (MCSv, modulation complexity score applied to VMAT). Parameters assessed for each treatment plan were MCSv, a divisor combination of Amp and MCSv (AmpMCSv), and a multiplier combination of AmpMCSv and NB (IVS, interplay effect variable score). Static and dynamic measurements were performed with a PinPoint chamber (0.015cm3, PTW, Germany) in a Quasar phantom (Modus Medical Devices, Canada). Pearson’s correlation analysis was used to assess the effect of dose variation on individual parameters.

Results: A wide range of NB (28.9 to 100.7 times) was observed. The standard deviation of dynamic measurement ranged from 1.3 to 12.5 Gy. Dose variation was negatively correlated with AmpMCSv (\(r = -0.52, p < 0.05\)) and IVS (\(r = -0.62, p < 0.05\)). IVS was obtained stronger correlation than AmpMCSv by considering NB. Significant dose variation was found in cases with the lowest NB (28.9 times).

Conclusion: Patients that had fewer than 40 NB, <150 s irradiation time, and a respiratory cycle of >4 s had the highest dose variation, and therefore required careful attention during SBRT treatment.

EP-1753
Intrafraction setup variability for breast Helical Tomotherapy

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Purpose or Objective: To investigate intra-fraction breast motion during long-lasting (10-20 min) breast Helical Tomotherapy (Accuray, Madison, WI, USA) by means of optical tracking.

Material and Methods: Twenty locoregional breast cancer patients underwent Helical Tomotherapy irradiation after receiving conservative surgery or mastectomy. Non-invasive monitoring of respiratory motion during the entire treatment course, from setup verification to dose delivery, was achieved through infrared tracking of a passive marker placed near the surgical scar. In order to obtain the displacement deriving from the patient movement only, we subtracted the trace of an additional marker placed on the treatment couch. Respiratory signals were analyzed in terms of peak-to-peak amplitudes and baseline drifts, obtained by low-pass moving average filtering with a time window of 60 sec. Anisotropic Clinical Target Volume (CTV) safety margins expansion due to intrafraction organ motion was calculated relying on a synthetic representation of the specific patient respiratory pattern, obtained by adding half of the most probable respiratory amplitude to the non-respiratory movement of the scar trace in each anatomical direction (Fig 1).

Results: The most probable measured breathing amplitudes among all patients was (median inter-quartile range): 0.25±0.12 mm (right-left), 1.31±0.63 mm (inferior-superior) and 1.22±0.70 mm (posterior-anterior). Each patient featured a small inter-fraction variability of expected motion ranges, thus confirming a good reproducibility of respiratory motion during the entire course of treatment. Scar baseline drifts were mostly in posterior and in the inferior direction for all patients in most fractions, with the exception of patient P2, who exhibited a relevant baseline shift in superior and anterior direction with a large variability (Tab.1). The distribution of right-left shifts resulted in almost zero median, with a narrow interquartile range. Patient P20 showed stationary breathing, with a median baseline shift around zero in all anatomical directions. Conversely, patient P15 had a wide inferior-superior and posterior-anterior motion with large interquartile ranges. Resulting anisotropic safety margin expansions across all patients with the exception of P2, considered an outlier, were 1.38-2.44 mm in right-left, 4.41-3.65 mm in inferior-superior and 3.78-2.15 mm in the posterior-anterior directions, respectively.
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.

EP-1754

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 the accuracy of the frameless ExacTrac X-Ray verification system at non-zero couch angles was assessed.

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 imaging and iii) MV images taken from the AP direction. In the latter only deviations in the couch rotation plane were measured, assuming negligible deviations in the vertical direction. The Winston-Lutz test was performed to validate this assumption. The AP-MV imaging was used as the golden standard and was compared with the ExacTrac IR and X-ray results for each couch angle to determine the accuracy of the ExacTrac system. All data were relative to couch angle 0° and calculated in the Linac coordinate system. A one sample T-test was performed to determine statistically significant (p<0.05) differences between the systems.

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 0.1mm. X-Ray verification at different couch angles showed significant differences with the AP-MV imaging of 0.23±0.12mm and 0.30±0.21mm 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 0.63mm in lateral and 0.50mm 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 -1.55mm (at couch angle 270°) and 1.14mm (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.

EP-1755

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 static 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 sinusoidal 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 heart surface averaged a rate of 86.4 ± 2.0 bpm during the 3 fractions that were investigated (Figures 1c-d).

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