Conclusions. Lung-tumor movements were most pronounced in inferior-superior direction and the motion amplitude in this direction was larger for tumors located in the lower compared to the upper part of the lung. Tumor size did not correlate with motion amplitude. The motion pattern was in all cases best described with a squared sinusoidal function.

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[OA009] Motion inclusive variations in bladder dose surface maps during the course of high-precision radiotherapy for prostate cancer

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Purpose. Modern radiotherapy (RT) protocols for prostate cancer often involve the use of narrow margins and image-based monitoring of rectum/bladder fill status. These protocols have allowed safe prostate dose escalation, maintaining acceptable levels for organs at risk (bladder and rectum). However, daily cone-beam CT (CBCT) image-guided RT has demonstrated considerable bladder volume variation throughout treatment, which suggests dose delivered may vary. By using CBCT-based parametrized 2D dose surface maps (DSM) of the inferior bladder, this study aims to evaluate bladder volume impact on bladder DSMs during high-precision RT for prostate cancer.

Methods. Seven prostate cancer patients treated using daily CBCT-based image-guided VMAT/IMRT were included in this study (81.0 Gy prescription dose). Planning CT and RT delivery adhered to a full bladder/empty rectum protocol, where daily CBCTs were used for patient realignment and to assess bladder/rectum filling status. Fourteen CBCTs per patient were rigidly registered to the planning CT using recorded treatment shifts, and the bladder was manually contoured on each CBCT. Contours were validated by the responsible radiation oncologist. For the planning CT and each CBCT, bladder wall dose was digitally projected onto 1024x1024 DSMs using orthographic ray-traced surface dose sampling. Bladder wall volumetric meshes were generated from contours using restricted Delaunay triangulation. Surface dose was sampled at ray-wall intersections, sub-pixel sampling was used to improve image quality, and rays were oriented parallel to the prostate-bladder center-of-mass connecting line. DSM dose distributions were compared between planned and delivered. Correlation with bladder volume variations was evaluated.

Results. Bladder volumes varied considerably during RT (15–42%), with slightly larger volumes at planning compared to treatment (p = 0.16). Differences at the central part of the DSM ranged between 1% and 7%. Overall, delivered doses were lower at the central part of the DSM compared to planned (range: −5.4 to 0.9 Gy). Plan-vs-delivery mean dose differences were slightly correlated with bladder volume differences (Rs = 0.55, p = 0.3).

Conclusions. No significant variations were observed in delivered doses at the interior part of the bladder although considerable bladder volume changes occurred during the RT course. The generally smaller treatment bladder volume possibly explains lower dose delivered to the inferior bladder sector.

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[OA010] A 4D Monte Carlo (MC) dose calculation framework with statistical breathing phase sampling to quantify interplay effects

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Purpose. The interplay between dose application by complex techniques and respiratory motion of a tumor can potentially lead to undesirable and non-intuitive deviations from the planned dose distribution. We developed a 4D dose calculation framework to precisely simulate dose distributions for moving target volumes. In this study we randomly sample the simulated application of delivered dose fragments on 4D-CT phases.

Methods. The workflow combines MC dose calculation with linac-log files and dose accumulation based on 4D-CT images. Treatment plan fragments of 0.2s duration are retrieved from linac-log data and calculated on ten 4D-CT phases using MCVerify/Hyperion V2.4 (research version of Monaco 3.2). The resulting dose fragments allow the simulation of arbitrary respiratory curves (e.g. changes in breathing frequency and pattern) with a resolution of 0.2 s by assigning every fragment to a distinct 4D-CT phase. Using deformable image registration (plastimatch) the dose fragments are accumulated by AVID, a software system for automated processing and analysis of radiotherapy data. In addition to the patient’s recorded normalized breathing curve, three statistical approaches are implemented: (1) random phase shift of the breathing curve, (2) random phase assignment of every 0.2s fragment and (3) random phase assignment of 1MU dose fragments.

Results. An exemplary 3 Gy, VMAT, SBRT treatment of a 9 cm³ lung tumor with 1.6 cm cranio-caudal movement was analyzed. 128 random treatments were simulated for the three statistical approaches. In all three cases the mean 4D-CT calculated dose (original plan calculated on ten 4D-CT phases) and the mean of the randomly simulated doses agree. The dose deviations for the 128 runs are very similar for the three methods (average dose deviations: σD50 % ≈ 0.41%, σD50% ≈ 0.25% and σD98% ≈ 0.68% for the three approaches).

Conclusions. The described random assignments (2) and (3) have similar statistics as the random start phase approach (1) and are hence promising methods to comprehensively cover treatment plan and technique specific interplay effects without the need for daily breathing curves. The MU-based random sampling approach (3) is in addition independent of the linac-log data. The introduced framework has the potential to comprehensively include breathing motion induced interplay effects in the treatment planning and evaluation process.

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