Conclusions: Highly detailed time-resolved internal 3D motion was determined throughout lung IMRT using standard imaging equipment and presented for one out of four recruited patients. While the tumor motion was governed by respiration, the LNs had substantial cardiac induced motion. More patients will soon be included in the study.

PD-0460
Performance of digital tomosynthesis for tumor motion monitoring: a phantom study
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Purpose/Objective: Short arc digital tomosynthesis (DTS) is a technique for reconstructing volumetric images in planes parallel to the detector plane using limited numbers of kV projections. It provides better contrast compared to traditional X-ray images as DTS reduces over-projections from other planes. DTS may provide fast positional monitoring for mobile stereotactic lung targets. We evaluated the potential of DTS for motion monitoring in a moving lung phantom by comparing DTS images generated from CBCT fluoroscopic images, with reference CT images.

Materials and Methods: A heterogeneous lung phantom (Quasar) with mobile lung insert containing a polystyrene sphere was used. Aluminum strips were paced around the phantom to simulate ribs. CBCT scans of the phantom with sinusoidal motions (5 to 20 mm in longitudinal direction, period of 3 to 5 s) and 3 clinical irregular motion patterns were acquired on a TrueBeam linac. To simulate lateral and vertical motion, the phantom was rotated 7° and tilted 3° and CBCTs with sinusoidal motions (10 and 20 mm, period of 3 and 5 s) and 2 clinical irregular motion patterns were acquired. DTS images were generated using research software (Varian Medical Systems) and 2D-registered to DTS images from reference CT-datasets acquired in the same position. DTS images were created using 3° arc segments for every 3° of arc rotation. Since shorter DTS angles reduce the plane-plane resolution, the third dimension (combination of vertical and lateral directions) was obtained by triangulating the registration data with data obtained >3° earlier. All registered data were compared to motion profiles of the lung insert.

Results: For sinusoidal motion, the combination of motion amplitudes and frequencies resulted in average target speed 2 to 13.3 mm/s. For longitudinal sinusoidal motion, the average absolute registration error was 0.4 ± 0.2 mm and correlated to the target speed (P=0.008, Pearson’s correlation). For target speed <10 mm/s, errors were <0.5 mm with SD ± 0.4 mm. The analyses of random motion patterns showed the same trend. The 3 random motion patterns (average speed of 8.1, 5.7 and 3.3 mm/s) showed absolute matching errors of 1.0 ± 1.3mm, 0.6 ± 0.5mm and 0.3 ± 0.4mm, respectively. For 3D sinusoidal motions with the tilted phantom (10/20 mm and 3/5 seconds), average absolute errors were 0.2 ± 0.2mm, 0.5 ± 0.5mm, 0.2 ± 0.1mm, for vertical, longitudinal, lateral directions respectively. Figure 1 shows 3D motion detected by DTS combined with triangulation and the reference random motion profile. Absolute errors for x-, y- and z-axes were 0.4 ± 0.3mm, 0.7 ± 0.5mm and 0.6 ± 0.5mm respectively.

Conclusions: Using short arc DTS plus triangulation, tumor location in a phantom can be verified every second, even for irregular motion. DTS in combination with triangulation merits further evaluation as a fast online solution for tracking mobile lung tumors.

PD-0461
Population-based vs patient-specific margins for intra-fractional motion in adaptive bladder radiotherapy
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Purpose/Objective: The bladder is an appealing target for adaptive radiotherapy (ART) strategies due to large inter-fractional motion and deformations, but it may also display considerable intra-fractional changes. The aim of this study was initially to calculate population-based margins for intra-fractional bladder changes using a comprehensive data set of repeat volumetric magnetic resonance imaging (MRI), and secondly to explore the possibilities of deriving patient-specific intra-fractional margins, relevant in particular within the setting of online ART for bladder cancer.

Materials and Methods: Nine patients treated in a phase II clinical plan selection ART trial for bladder cancer were included. The patients underwent pre-treatment and weekly repeat MRI series (mDixon sequence; voxel size: 0.9x0.9x1.5 mm; scan time: 40 s), where in each series a volumetric scan
was acquired at \( t = 0, 2, 4, 6, 8, \) and 10 minutes. Treatment and MR scanning was performed on voided bladders. The bladder CTV was delineated in all scans and each CTV was described using spherical coordinates with origin at the centre of volume of the first scan of the first session of each patient. Population-based 2D margin maps were derived by adapting a published margin recipe for bladder (Meijer et al, IJROBP 2003), characterising in the spherical coordinate system the intra-fractional changes (between the scans at \( t = 0 \) min to \( t = 10 \) min) in terms of systematic and random errors. Secondly, the possibility of deriving patient-specific intra-fractional margins was explored by using only the bladder expansions occurring in the first two series (the pre-treatment and the first week series). A linear model was used to fit the radial changes occurring as a function of time. Focusing on the patients and directions where an expansion larger than 5 mm was observed, the patient-specific margin was defined as the upper 96% confidence limit of the linear coefficient multiplied by the relevant intra-fractional time (here assumed ten minutes).

Results: The population-based 2D margin map is shown in Fig 1; when excluding the one female patient, the margins at superior and anterior directions were 14 mm, posterior 9 mm and the other directions (inferior, left and right) 5 mm. Intra-fractional margins specific for each patient could be derived from the linear model fit (ranging up to 12 mm; R² in the range: 0.33-0.68).

Conclusions: This is the first study to present both population-based and patient-specific margins for intra-fractional motion for the bladder. The population-based margins were large in superior and anterior directions, and are a concern in particular if pursuing on-line re-planning/optimization. We also found that the large intra-fractional margins required for some patients can be identified and estimated from limited data on bladder expansions from scans acquired before or early in the treatment course.

Purpose/Objective: Target tracking during RT is taking its first steps in clinical practice. The next challenge is correcting for organ motion induced dosimetric deviations (due to tissue heterogeneity, distance to source variations, etc.). A VMAT adaptation strategy has been developed and was evaluated using 3D dose measurements in a dynamic prostate phantom.

Materials and Methods: An initial VMAT plan (Plan₀) was optimized in Eclipse to deliver 77Gy with an integrated focal boost (prostate: 2.2Gy; boost: 2.7Gy/fraction) to the prostate of the Dynamic Pelvis Phantom (CIRS, Virginia, USA, Figure 1, upper panel). Different realistic prostate motions were executed by the phantom; and for each, three different VMAT treatment adaptation strategies were measured: 1) The current clinical practice: delivery of Plan₀ without plan correction. 2) MLC-only: a correction of the MLC positions of Plan₀ according to the tracked target position. 3) A MLC+MU adaptation, which uses point dose calculations to correct MU per gantry angle in addition to the MLC correction. All corrections were driven by the positions of four fiducial points.

3-D dose of each strategy was measured using a stack of EBT films inserted in the phantom (10 planes [63.50x63.50mm²] separated by 4.16mm). Next, DVHs are calculated for the measured dose planes and corresponding calculated planes. VMAT delivery and phantom motions were synchronized to enable comparison of different treatment strategies for a given motion pattern.

Results: Measurements without motion agreed with the intended Plan₀. For a prostate drift motion (Figure 1, lower panel), all treatment strategies showed a blurring of the prostate dose (less steep DVHs), and a consequently increased dose to the part of the rectum included in the measurement volume. Without adaptation, the prostate and boost dose were reduced compared to Plan₀ (Clinical practice: \( D_{95\% \text{ Prostate}} = 93\% \), \( D_{95\% \text{ Boost}} = 96\% \)), both adaptation strategies improved the target coverage (MLC: \( D_{95\% \text{ Prostate}} = 100\% \), \( D_{95\% \text{ Boost}} = 104\% \); MLC+MU: \( D_{95\% \text{ Prostate}} = 97\% \), \( D_{95\% \text{ Boost}} = 100\% \)). For the boost volume, which is surrounded by less steep dose gradients, no blurring was observed and the MLC+MU adaptation coincided completely with the intended dose, while the lack of MU correction of the MLC-only adaptation showed an increased boost dose.