NoSpc, Het-Spc) metrics for target dose coverage ($D_{98\%}$, $D_{50\%}$, $V_{33.2}^{PTV}$, V_{35}^{PTV}), and rectal dose sparing (V_{18}^{r}, V_{28}^{r}, V_{32}^{r}), were then compared by hypothesis testing (*t*-test, Wilcoxon) at .05 level for statistical significance. Linear correlation and ANOVA analyses between the variations resulting from spacer insertion in the fractional overlap with PTV of the rectum (ΔV_{ovl}^{r}), and the corresponding variations in $V_{33.2}^{PTV}$, and in rectal V_{x}^{r} (x = 18, 28, 32) were also performed.

Results: According to hypothesis testing, by comparing *Spc* vs. *NoSpc* plans reductions in rectal V_{18}^{r}, V_{28}^{r}, and V_{32}^{r}, and improvements in target $D_{98\%}$, and $V_{33.2}^{PTV}$, significantly resulted. By comparing *Het* vs. *Hom* plans, significant improvements in target $D_{50\%}$, $V_{33.2}^{PTV}$, and V_{35}^{PTV}, whereas no significant reductions in any rectal V_{x}^{r}, were computed. By directly comparing *Het-Spc* vs. *Hom-NoSpc* plans, all the conceived metrics were significantly improved, with $V_{33.2}^{PTV}$ increasing from 96.1% (±1.1%) to 98.7% (±1.2%). For spacer insertion, ΔV_{ovl}^{r} significantly correlated with, and was the effective source of variation for the observed decrease in rectal V_{32}^{r}, and V_{28}^{r}. By contrast, ΔV_{ovl}^{r} neither linearly correlated with, nor was the effective source of variation for the observed increase in $V_{33.2}^{PTV}$.

Conclusion: In our patients, planned for 35Gy-in-five-fractions VMAT prostate SBRT, spacer insertion was causative for improvements in rectal dose sparing, but not in target dose coverage ($V_{33.2}^{PTV}$). Whereas a slightly increased $D_{2\%}$ was associated with improved $V_{33.2}^{PTV}$. Therefore, the combined use of both spacer insertion and increased $D_{2\%}$ improved both rectal dose sparing and target dose coverage.

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Evaluation of Respiratory Motion Impact on 3D and 4D PET Imaging

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Purpose/Objective(s): To evaluate the impact of tumor motion on maximum standard uptake value (SUVmax) and volume measurements on both 3D and respiratory-correlated (4D) PET imaging.

Materials/Methods: An anthropomorphic thorax phantom with a spherical plastic ball inside the lung portion of the phantom was used for simulation. The plastic ball of diameter 2.5cm was filled with F18-FDG solution to mimic the tumor. Different types of motions in superior-inferior direction were imposed to the ball by external motor to mimic the breathing motion. A PET/CT scanner was used for PET imaging. First, a 3D PET image of the phantom without any tumor motion was acquired and the parameters extracted from this image were used as the reference values. Then, six different breathing motion patterns were imposed to the tumor, with 2 of them sinusoidal pattern and 4 of them from real patients' breathing patterns. The amplitude of tumor motion ranged from 1.2cm to 3cm. Finally, the phantom with each motion pattern was imaged in both 3D and 4D PET modes. The tumor SUVmax and volume measured from moving phantom were compared with the reference values from the steady phantom. The tumor volume was calculated with two different thresholds, one with absolute value of 2.5 (Vol-2.5) and another with relative value of 40% of SUVmax (Vol-40%).

Results: The tumor SUVmax measured in 3D PET imaging of moving phantom was 20.4%±16.7% (mean ± SD) (range 5.0%-46.0%) different from the reference value, compared to 2.6%±1.9% (range 0.0%-5.7%) difference between SUVmax from the end of exhalation phase of 4D PET image and the reference value. The deviation of tumor volume from the reference value also showed significant decrease in 4D PET imaging compared to 3D imaging (mean value 3.2% vs. 10.4% for Vol-2.5 and 2.3% vs. 24.4% for Vol-40%). The deviation in 3D PET imaging increased generally with the amplitude of tumor motion.

Conclusion: 4D PET imaging reduces the motion impact on measured SUVmax and volume significantly when compared to 3D PET imaging. A 4D scanning protocol should be considered to improve the accuracy of determining SUVmax and volume of the moving tumor when these parameters are critical for treatment and outcome assessment.

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Comparison of Conformal and Volumetric Modulated Arc Techniques According to RTOG 0915 Protocol Treatment Planning Guidelines in Stereotactic Lung Radiation Therapy

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Purpose/Objective(s): Stereotactic lung radiation therapy is an established technique that has been shown to be effective in early stage lung cancer. In this study, we aimed to compare conformal arc (3DCA) and volumetric modulated arc (VMAT) techniques according to RTOG 0915 protocol guideline using either flattened (FF) or unflattened (FFF) photon beams

Materials/Methods: Twenty stage I non-small cell lung cancer patients were included to this dosimetric study. 3DCA and VMAT non-coplanar plans were generated both with FF and FFF modes using 6 MV photons and two arcs. 95% of PTV is conformally covered by the prescription line. Plans were compared in terms of various dosimetric parameters; ratio of prescription isodose volume to the PTV volume (Conformity index-CI), ratio of 50% prescription isodose volume to the PTV (Intermediate spillage volume-ISV), maximum dose in % of dose prescribed at 2 cm from PTV (intermediate dose spillage location-ISL), and percent of lung receiving 20 Gy (V20) total or more. Deviations were classified as minor and major according to the volume of PTV.

Results: All plans were acceptable and no deviation was observed according to RTOG criteria. CI ranged between 0.97 − 1.26 (Median: 1.06), 1.00 − 1.19 (Median: 1.04), 1.04 − 1.43 (Median: 1.22) and 1.00 − 1.37 (Median: 1.18) for VMAT-FF, VMAT-FFF, 3DCA-FF and 3DCA-FFF, respectively. VMAT-FFF have significantly better conformality index compared to others. (p = 0.001) ISV values ranged between 3.64 and 5.82 (Median: 4.30), 3.37 − 5.04 (Median: 3.96), 3.87 − 6.30 (Median: 4.80) and 3.69 − 5.33 (Median: 4.44) for VMAT-FF, VMAT-FFF, 3DCA-FF and 3DCA-FFF, respectively. VMAT-FFF has significantly lower ISV values which indicates superior falloff gradient. (p = 0.001) ISL values in percentage ranged between 47.8%-71.8% (Median: 60.45%), 47.4%-66% (Median: 58.25%), 47.8%-84.7% (Median: 61.35%) and 47.4%-82.7% (Median: 60.5%) for VMAT-FF, VMAT-FFF, 3DCA-FF and 3DCA-FFF, respectively. VMAT-FFF has significantly lower ISL values which show a better falloff gradient 2 cm away from PTV. (p = 0.001) V20 values for lung ranged between 0.77% − 9.07% (Median: 3.06%), 0.72% − 8.76% (Median: 2.91%), 0.96% - 8.92% (Median: 3.06%), 0.8% − 8.76% (Median: 2.95%) for VMAT-FF, VMAT-FFF, 3DCA-FF and 3DC-FFF, respectively. No difference was found between 4 techniques. (p = 0.069)

Conclusion: Results of the this study have shown that VMAT-FFF technique demonstrated better conformality for high dose spillage region and higher dose falloff gradient for intermediate dose spillage regions with shortest treatment time compared to VMAT-FF and 3DCA FF/FFF using RTOG 0915 guidelines. We believe that VMAT-FFF is the optimal technique for lung SBRT treatments due to high quality SBRT plans obtained and shorter treatment time

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Target Residual Motion During Beam Delivery in Gated Irradiation Using Real Time Tumor Tracking Radiation Therapy System: Analysis of Simultaneous Motion of Multiple Internal Fiducial Markers

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Purpose/Objective(s): In gated irradiation using real-time tumor-tracking radiation therapy (RTRT) system, location of the target tumor during beam delivery should be evaluated with enough temporal and spatial accuracy in order to confirm the precision of the treatment. In this study, residual motion of the target tumor during beam delivery was evaluated by analyzing simultaneous motions of multiple fiducial markers inserted near the tumor in lung.

Materials/Methods: Motions of the multiple fiducial markers inserted in lung were analyzed retrospectively from the fluoroscopic images recorded during respiratory-gated radiation therapy using RTRT system. Each patient had two or three 1.5 mm gold spheres near the tumor. Image sequences were gathered from 7 patients; 2 patients had markers in the upper region, 3 had in middle and 2 had in lower. Time interval of analyzed marker motion was 0.033 second, time duration of image sequence was about 1 minute and calculation accuracy of marker coordinates was 1 mm. Motion of one marker was used in order to simulate beam gating. Therapeutic beam was gated at the end of expiration only when the marker for gating is within the gating window. Motion of another marker, which was also inserted near the tumor in the same patient, was assumed to be tumor motion and its motion during beam delivery was defined as the residual motion of the target tumor. Evaluation was conducted in 28 sets of two markers. The distance between two markers was 24.9+/-9.8 mm. In the past treatment plans for RTRT, distance between the marker nearest from the isocenter for gating and the planned isocenter located in the tumor was 23.4+/-11.9 mm. Hence, the results can be regarded as the possible residual motion of the target tumor in usual clinical case of RTRT.

Results: The mean and SD of the 90th percentile range of the amplitude of all the markers were 1.8+/-0.5 mm, 7.9+/-6.6 mm and 4.1+/-2.2 mm for LR, SI, and AP direction, respectively. With the gating window of +/-2 mm, residual motion of the marker for gating were 1.1+/-0.3 mm, 2.4+/-0.7 mm and 2.1+/-0.8 mm in 28 cases, respectively. Corresponding residual motion of the target tumor were 1.0+/-0.3 mm, 2.6+/-1.0 mm and 2.2+/-0.9 mm for LR, SI and AP direction respectively. In gated irradiation using internal fiducial markers, the residual motion of the target tumor during beam delivery was thought to be equivalent to that of the marker for beam gating. It was expected that respiratory motion of the target tumor could be compensated precisely with RTRT system.

Conclusion: Target localization during beam delivery in RTRT was evaluated quantitatively with utilizing multiple marker motions having enough temporal and spatial accuracy. Effectiveness of RTRT using internal fiducial markers was highly suggested.

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Image Guided Planning for Prostate Carcinomas With Incorporation of Anti-3-[18F]FACBC Positron Emission Tomography: Workflow and Initial Findings

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Purpose/Objective(s): Anti-1-amino-3-[18F]fluorocyclobutane-1-carboxylic acid (FACBC) is a novel radiotracer with little renal excretion that has demonstrated high sensitivity and specificity for detection of prostate cancer. Our goal is to report the initial results (from a randomized controlled trial [RCT]) of the integration of FACBC into treatment planning for defining prostate bed and lymph node target volumes.

Materials/Methods: We report our initial findings on a cohort of 21 patients (of the first 44 enrolled on the RCT) who were randomized to the FACBC arm. All 21 patients underwent FACBC PET/CT for detection of metabolic abnormalities as well as high-resolution CT for treatment planning. The two datasets were registered first using a rigid registration. If soft tissue displacement was observable, the rigid registration was improved with a deformable registration using the BSpline model and a multi-modality metric. Each of the 38 FACBC abnormalities (i.e., region of uptake) was transferred to the simulation CT and segmented as percent of the maximum SUV within a small region of interest around the abnormality. The percentage best describing the SUV fall-off was selected (iso-SUV) (a process that involved clinical judgment in choosing an isolevel visually that encompassed disease with minimal normal tissue overlap) and transferred to the treatment planning station. The FACBC segmentations were integrated in planning by union of the CT-based target volumes with the selected iso-SUV.

Results: In 50% (19/38) of the abnormalities, a deformable registration was needed to map the FACBC activity into the simulation CT. The most commonly selected percentage was 50% of max SUV, although values ranged from 15% to 70% were used on specific cases, illustrating the need for a per-patient selection of a threshold SUV value. Inclusion of the FACBC changed the planning volumes for 34/38 (86%) of the target volumes (17/38 [44%] in the pelvic lymph nodes, 14/38 [37%] in the prostate bed, and 3/38 [8%] in the seminal vesicles/remnants). Only 5/38 (13%) of PET abnormalities were fully contained in the standard target volumes based on the CT-based segmentations and did not necessitate their expansion to include all disease in the target volume.

Conclusion: Integration of FACBC PET-CT in the planning is feasible in routine clinical practice leading to augmentation of the target volumes in 76% (16/21) of the patients and 86% (34/38) of the target volumes studied. Longer follow-up is needed to determine the impact of FACBC on cancer control (the primary endpoint of the RCT).

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Radiation Therapy of Synchronous Bilateral Breast Carcinoma (SBBC) Using Volumetric Modulated Arc Therapy (VMAT)

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Purpose/Objective(s): Synchronous malignancy in bilateral breasts is an uncommon clinical entity. The treatment planning of patients with