assuming the 3D CT scans can be convolved as though they were end-exhalation scans (the breathing state of maximum duration). Work is ongoing to test the effect of this assumption. All 219 patients were analyzed by using both the planned and the breathing-weighted dose distributions. RP risk models were re-derived using the new breathing-weighted dose distributions from a set of clinical, dosimetric, and position related factors.

Results: The breathing-weighted distributions have a decrease in high dose volumes (smearing) and a corresponding increase in low dose volumes which is consistent with geometric effects of breathing. Breathing-weighted V_x and D_x values had higher correlations with RP than the original treatment planning system (TPS) values. Statistical modeling indicated a three or four variable model was optimal. The most frequently selected variables remained superior-inferior position, D_{35}, and maximum dose, as previously reported for non-breathing-weighted analyses. The use of breathing motion-weighted dose information did not change the parameters selected for the model, but did increase the correlations for the resulting model (Rs = 0.294), modestly, when compared to the original TPS DVH information (Rs = 0.279).

Conclusions: Retrospective modification of treatment planning data with a 4D-CT derived breathing motion data is feasible. The apparent effects on dose distributions and resulting improvements to models that predict RP are modest. Future investigations will include prospective breathing-weighted dose calculations using full 4D patient-specific data.

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2547 Reduction of Tumor Volume During Radiation for Non-Small Cell Lung Cancer (NSCLC)

J. L. Fox[1], E. Ford[1], K. Janson[1], J. Zhou[2], L. Myers[1], D. Y. Song[1]

[1]Johns Hopkins Department of Radiation Oncology and Molecular Sciences, Baltimore, MD, [2]Johns Hopkins School of Medicine, Baltimore, MD

Purpose/Objective(s): Dose escalation for lung cancer is limited by volume of lung irradiated. We evaluated patients using sequential CT scans to determine whether there is radiographically measurable tumor shrinkage during a course of radiotherapy. Such an effect would have important implications for possible lung sparing boost radiotherapy.

Materials/Methods: Seventeen patients were treated for Stages I-III NSCLC using 2 Gy daily fractions; 11 received concurrent chemotherapy. All patients had 2 repeat CT scans during the course of radiation. The first rescan was performed nominally at a treatment dose of 30 Gy (range, 8–40 Gy); the second rescan was performed at a nominal dose of 50 Gy (range, 42–66 Gy). Respiration-induced motion compensation techniques varied depending on degree of tumor motion identified at simulation. All scans were compared with other scans using similar technique (e.g. 4-D, free-breathing, or breath hold using Active Breathing Coordinator). Gross tumor volume (GTV) was delineated on all free-breathing scans, as well as on the individual phases of all subsequent 4D-CT scans. Only parenchymal tumor volume was evaluated unless nodal volume was larger or was the primary lesion. All original tumor contours were delineated by an attending physician. Subsequent image sets were spatially co-registered with the original simulation data sets, and contoured by a single investigator to limit inter-user variability. Identical windowing settings were used within a given patient's scans. To measure possible variation in GTV across different phases of respiration, volume data from 5 patients were analyzed across 10 phases of each 4D-CT scan. Variation in volume within a scan was 10% or less for the 5 patients analyzed across all phases of 4-D scans. For all other 4-D patients, averages of respiratory phase 0% and 50% were used for comparisons.

Results: Mean GTV volume at first rescan was 0.69 of the volume at time of simulation (range: 0.38–1.03). This represents a significant volume decrease ($p < 0.0001$, one-sample t-test). Mean volume at second rescan was 0.55 of the simulation volume (range: 0.29–0.98), also a significant decrease ($p < 0.0001$). There was a significant difference in the amount of volume decrease by the second rescan among patients who received concurrent chemotherapy as opposed to those who did not (0.46 vs 0.72 of initial volume, $p = 0.007$).

Conclusions: In patients receiving definitive treatment for NSCLC, we observed significant reductions in primary tumor volumes over the course of radiotherapy. On average the volume is reduced by approximately 50% at 50 Gy. Furthermore, significant reduction in tumor size is observed by 50 Gy in patients receiving concurrent chemotherapy. It is possible that some reduction may represent resolution of atelectasis which was indistinguishable from tumor at time of simulation. Our findings indicate that reduced boost volumes may be feasible, allowing for higher treatment doses.

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2548 Retrospective Evaluation of Setup Reproducibility for Thoracic and Upper Gastrointestinal Radiotherapy Through Volumetric Imaging: Stability and Dependence on Immobilization

W. Li, D. Moseley, J. Bissonnette, L. Le, T. Purdie, A. Bezjak, J. Kim, D. Jaffray

Princess Margaret Hospital, Toronto, ON, Canada

Purpose/Objective(s): Radiotherapy (RT) is a common treatment modality for thoracic and upper gastrointestinal (UGI) cancer. Increased precision of RT delivery for daily setup variation is now achievable with cone-beam CT (CBCT). This study evaluates the setup reproducibility and stability of thoracic and UGI RT patients for 2 immobilization devices (chest board [CB] and evacuated cushion [EC]), and presents margin calculations from our observations.

Materials/Methods: Patients undergoing curative or high dose palliative RT for thoracic and UGI (lung, esophageal, pancreatic, stomach) cancer at our institution have been routinely imaged with daily CBCT since April 2006. A total of 65 patients (33 CB, 32 EC) were included in this REB-approved study. CBCT images were registered to the planning CT using automatic bony anatomy matching. Discrepancies >3 mm between the 2 datasets, in any translational direction, were corrected prior to initiation of RT, and verified with another CBCT to assess residual error. Datasets were collected and analysed to assess the magnitude and frequency of these discrepancies.

Results: Both CB (797 scans) and EC (757 scans) had similar setup error distributions. Using General Estimating Equation (GEE) to adjust for treatment technique differences and within patient correlation, the difference in magnitude of translational setup between the devices was $p = 0.08$ for left/right (L/R), $p = 0.32$ for superior/inferior (S/I), and $p = 0.0002$ for anterior/posterior (A/P) with CB showing less discrepancy. The discrepancy in the A/P direction was attributed to restriction of in room setup limitations as the EC obscured measurements taken from couch top. Implementation of permanent shifts throughout treatment for both immobilization groups decreased systematic uncertainties (Σ), but random uncertainties (σ) remained unchanged. With an online action level of 3 mm, the residual error distributions were similar between CB and EC (932 verification CBCTs). Comparison of kurtosis, Σ, σ, and the associated margin calculation is shown in Table 1. The kurtosis value was highest in A/P for CB while the EC had more outliers in the S/I.

Conclusions: Setup between CB and EC cohorts was comparable, with both benefiting from CBCT guided corrective strategies. With CBCT available for clinical use, the role of rigid immobilization may become secondary to patient comfort and ease of setup. CBCT allows for increased geometric accuracy in RT, and could lead to the reduction of margins. The reduction of geometric uncertainties may lead to improved tumour control in thoracic and UGI cancer RT.

Table 1: Comparison between chest board (CB) and evacuated cushion (EC) for set-up displacement and true residuals after IGRT with CBCT. For kurtosis, values greater then 3 indicate fatter tails than a normal distribution. The systematic uncertainties (Σ), random uncertainties (σ), and van Herk Margin calculations ($2.5 * \Sigma + 0.7 * \sigma$) are also presented

	CB			EC		
	L/R (cm)	S/I (cm)	A/P (cm)	L/R (cm)	S/I (cm)	A/P (cm)
Set Up Displacement						
Kurtosis	3.28	2.84	3.80	3.27	3.51	3.24
Group Systematic Error	0.12	0.15	−0.09	0.06	0.28	−.014
$\sum$	0.27	0.50	0.28	0.24	0.55	0.39
σ	0.25	0.42	0.19	0.21	0.55	0.33
van Herk Margin	0.86	1.54	0.83	0.75	1.77	1.20
Residual Error						
Group Systematic Error	0.01	0.01	−0.02	−0.02	0.03	−0.02
$\sum$	0.08	0.09	0.14	0.10	0.08	0.13
σ	0.19	0.19	0.15	0.17	0.19	0.21
van Herk Margin	0.34	0.37	0.45	0.36	0.34	0.48

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2549 Anatomical Changes During Radiotherapy of Lung Cancer Patients

J. Belderbos, S. van Beek, S. van Kranen, C. Rasch, M. van Herk, J. Sonke

The Netherlands Cancer Institute, Amsterdam, The Netherlands

Purpose/Objective(s): In radiotherapy (RT) it is commonly assumed that the anatomy of the patient is constant over the course of treatment (5–6 weeks). However, during lung RT many anatomical changes occur such as increasing/decreasing atelectasis, pleural effusion, and tumor progression or regression. These might require replanning during the course of treatment. With the introduction of cone-beam CT (CBCT) guided RT, repetitive imaging of the anatomy of the thorax in three (3D) or four dimensions (4D) is feasible. The purpose of this study is to quantify the occurrence of anatomical changes during conventional RT with curative intent.

Materials/Methods: In this study, 132 lung cancer patients were included, treated with conventional RT with a dose ranging from 44 Gy to 87.5 Gy over 5–6 weeks. Tumor stage ranged from T1N0 to T4N3. Patients received repetitive 3D or 4D CBCT scans for an offline setup correction protocol based on bony anatomy or tumor position. The number of scans per patient ranged from 5 to 13 per patient (average 8.5). An expert radiation technologist evaluated all the scans for visible anatomical changes. A panel of radiation oncologist and physicists reviewed the patients with observed anatomical changes. Tumor regression and progression, the occurrence or dissolving of atelectasis, and pleural effusion were scored qualitatively.

Results: Forty-seven patients (36%) manifested considerable anatomical changes in at least one of the scored categories (Figure 1). Tumor regression was observed in 32 patients (24%), while only one patient (1%) showed tumor progression during therapy. Changes in atelectasis were observed for 18 patients, with 11 cases of dissolving (8%) and 7 cases of increase (5%). Finally, pleural effusion was found in 10 patients (8%). Clinically, the CBCT information led to replanning for 6 patients, mainly in case of atelectasis increase.

Conclusions: Anatomical changes occur frequently over the 5–6 week course of conventional RT for lung cancer. CBCT guided RT provides an ideal platform for the monitoring of such changes. Objective quantitative criteria for replanning, however, are currently lacking. In order to ensure that the delivered dose meets the treatment intent in the presence of anatomical changes, decision rules for intervention need to be developed.