Adaptive Stereotactic-body Radiation Therapy (SBRT) Planning for Lung Cancer

Significance and Innovation:
Tumor shrinkage during SBRT of lung cancer has been reported [1, 2]. Applying adaptive strategy to SBRT of lung cancer can potentially further escalate dose to the target and mitigate radiation dose to surrounding healthy tissues. In this study, we investigated dosimetric effects of adaptive SBRT planning for lung cancer using cone-beam CT (CBCT) images.

Introduction:
SBRT is an emerging radiotherapy technique for treating early-stage non-small cell lung cancers (NSCLC) or oligometastatic lesions to the lung [3, 4]. Significant tumor shrinkage has been observed in some patients during the course of SBRT [1, 2]. Adaptive planning has the potential to reduce radiation dose to organs of risk (OARs), and further escalate radiation dose to the tumor. This is especially important for tumors adjacent to OARs, such as centrally located tumors. It is the objective of this study to evaluate potential dosimetric advantages of adaptive SBRT over non-adaptive SBRT for selected lung cancer patients.

Materials and Methods:
48 patients (24 male, 24 female, mean age 73) who had SBRT treatments for lung cancer in our institution were included in this study. All patients underwent a 3D helical CT scan and 4DCT scan for treatment planning. Treatments were delivered on Linac machines equipped with kV-OBI, CBCT, and MV EPID. CBCT was acquired at each fraction prior to treatment for patient positioning. CBCT images of all fractions were retrospectively analyzed to determine the tumor size (diameter) change during the course of treatment for all patients. Among them 10 patients (7 female, 3 male, mean age 75) with the largest percentage of tumor shrinkage were selected for adaptive SBRT planning. Table I summarized patient characteristics and planning parameters. Plans were created on CBCT images for each fraction using the same planning parameters as the original CT-based plans. Tumor internal target volume (ITV) was contoured in the lung window as the visible tumor [5]. Planning target volume (PTV) was generated by adding a 5 mm margin to the ITV. The planning goal was to achieve similar dose conformality to the PTV. MLCs were adjusted in 3D conformal plans and IMRT plans were re-optimized. All plans were normalized so that 95% of the PTV was covered by 100% of the prescription dose. Two accumulative plans, non-adaptive (PNON) and adaptive (PADP), were generated for each patient for comparison. To generate PNON, the treatment dose plan of the first fraction (P1) was multiplied by the number of fractions. To generate PADP, treatment dose plans of all fractions were registered to P1 and summed up via deformable image registration in Velocity AI (Velocity Medical Solutions). Dosimetric comparisons between PNON and PADP were performed for all OARs (lungs, esophagus, cord, chest wall, and heart) using RTOG0915 metrics. Since only part of some OARs was imaged due to limited FOV of CBCT, all metrics were recorded in absolute values. Paired t-test was performed on the comparisons with a 0.05 significance level.

Results:
Fig. 1 compiles the relative tumor diameter changes during the course of SBRT for all 48 patients. Colored lines represent the 10 patients selected for adaptive SBRT planning. Mean (±SD) change of tumor diameter after the treatment was 7.85 (±11.45)%. Fig. 2 shows the comparison of DVHs between PNON and PADP for Patient 6. It can be seen that doses to chest wall, esophagus, and carina were significantly reduced in PADP. DVHs of other OARs were similar between PNON and PADP because these OARs were further away from the PTV. GTV received comparable dose coverage in both plans, indicating that adaptive SBRT planning maintained similar target volume coverage. (It appears PTV received less coverage in PADP, but this PTV is the PTV of the first fraction. The real PTV changes in each fraction and 95% of the PTV received 100% of the dose in each fraction.) Table II summarizes the results of dosimetric comparisons for all 10 patients. Conformality ranged from 1.03 to 1.41 and has small intra-
subject variations (SD ranges 0.01 to 0.06). Compared to $P_{\text{NON}}$, $P_{\text{ADP}}$ reduced all dosimetric metrics and significantly in the following (p-value range: 0.02-0.04): V20Gy of lungs; D0.35cc, D1.2cc and maximum dose of cord; D5cc and maximum dose of esophagus; D30cc of chest wall; and D15cc of heart. Dose coverage to original GTV is comparable in both plans (p-value: 0.07). Significant dosimetric difference in OARs and comparable coverage to original GTV indicates adaptive SBRT planning reduces dose to OARs while maintaining target coverage.

Conclusions:
Significant tumor shrinkage was observed in some patient during SBRT of lung cancer. Adaptive SBRT planning for selected patients resulted in significant dose reduction to adjacent OARs. It has the potential to further escalate dose to tumor and mitigate dose to OARs.

Fig. 1. Tumor volume changes for 48 patients. Colored lines represent the 10 patients chosen in our study.

Fig. 2. DVHs of adaptive treatment planning ($P_{\text{ADP}}$, solid lines) and non-adaptive treatment planning ($P_{\text{NON}}$, dotted lines) for different structures in patient 6.

Table I. Patient characteristics and planning parameters

Table II. Summary of the mean and standard deviation of different parameter doses/volumes for both the traditional treatment planning ($P_{\text{NON}}$) and adaptive treatment planning ($P_{\text{ADP}}$). P values from paired t test are listed for each parameter. Bolded p values being statistically significant.

References: