Normal Tissue Doses During Isotoxically Dose Escalated Lung Radiation Therapy Using MR-Linacs

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Purpose/Objective(s)

Real-time imaging using MR-Linac during lung radiotherapy may allow PTV margin reduction, permitting increased isotoxically prescribed doses. However, this may affect the doses received by nearby critical organs at risk (OARs) when respiratory motion is considered. It is hypothesized that surrounding OARs may require monitoring to ensure dose tolerances are not exceeded during treatment over the respiratory cycle.

Materials/Methods

Isotoxic plans with a range of PTV margins based on MR-Linac tracking accuracies were generated on the mid-ventilation phase of a 4DCT image for 10 patients with locally advanced NSCLC. The dose-distributions were time-integrated over the respiratory cycle of the planning scan (CT1), using a deformable registration algorithm to map distributions back to the mid-ventilation phase. For 5 patients with repeat 4DCT scans, the time-integration was performed on 2 further image sets acquired at a range of 7-22 days (CT2) and 27-50 days (CT3) after CT1 to investigate the effects of changes in respiration/anatomy.

Results

Planning CT results show that for ~50% of plans, small volumes of a single OAR (heart, trachea, pulmonary artery, esophagus) may exceed the dose tolerance. 17/18 of these OARs were the dose limiting structure at planning; the remaining OAR lay at 99.7% of tolerance but over the respiratory cycle received a small increase of 0.4 Gy. For later image sets, the number of plans with OARs exceeding tolerance ranged from 75-90% of plans, and the maximum number of OARs per plan

increased from 1 (CT1), to up to 4 (CT2) or 5 (CT3). The dose violations also increased in magnitude, up to 4.8 and 9.2% of tolerance for CT2 and CT3. The regions of overdose within OARs were small (median volume of 1.72 cm^3 for CT1), and generally located at or near areas of PTV and OAR overlap.

Abstract 1101; Table 1. Results across whole respiratory cycle for OARs that exceeded tolerance.

Structure	Structure composition	Number of OARs exceeding tolerance across all plans (max % above tolerance)		
		CT1	CT2	CT3
PTVstandard	ITV + 5 mm (CTV) + 5 mm (PTV)	4/120 (+2.5%)	6/60 (+4.0%)	10/60 (+8.9%)
$PTV_{MRtrack\_lo\_acc}$	GTV_{midV} + 5 mm (CTV) + 5 mm (PTV)	4/120 (+2.4%)	7/60 (+4.8%)	10/60 (+9.2%)
$PTV_{MRtrack\_hi\_acc}$	GTV_{midV} + 5 mm (CTV) + 2 mm (PTV)	5/120 (+3.2%)	8/60 (+3.1%)	10/60 (+6.3%)
$PTV_{MRtrack\_ideal}$	GTV_{midV} + 5 mm (CTV) + 0 mm (PTV)	5/120 (+2.4%)	11/60 (+3.1%)	16/60 (+8.2%)

ITV – internal target volume, GTV_{midV} – gross tumor volume on mid-ventilation phase of 4DCT.

Conclusion

These results show that for MRI-Linac LA-NSCLC plans created on the mid-ventilation phase of that day's 4DMR image, and delivering high prescribed doses using tight PTV margins, OAR tolerance violations in doses considered over the whole breathing cycle are small and occur at predictable locations. However, these violations grow when dose-distributions are time-integrated over 4D-CT images acquired 1-7 weeks after the planning scan, indicating that frequent re-imaging and plan re-optimization is required to minimize tolerance violations.

Author Disclosure:**L. Bendall**: None. **J.D. Fenwick**: None. **B.W. Papiez**: None. **M.A. Hawkins**: None.