One-Year Analysis of CT Airway Changes Following Thoracic Central SBRT

Harkiran K Kooner,[1] Cecilia FPM de Sousa,[1] Katherine Illei,[2] Victoria Doss,[1] Chen Hu,[1] Cheng Ting Lin,[3] Todd R McNutt,[1] & K Ranh Voong[1]

[1]Department of Radiation Oncology and Molecular Radiation Sciences, Johns Hopkins School of Medicine, Baltimore, MD; [2]Department of Biological Sciences, University of Notre Dame, Notre Dame, IN; [3]Department of Radiology and Radiological Science, Johns Hopkins School of Medicine, Baltimore, MD

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Background

- SBRT provides excellent control for peripheral lung tumors, but use in central/ultracentral tumors challenging due to proximity to critical structures[1,2]
- Central tumors are within 2cm of airway tree, ultracentral tumors directly abut tree; this region historically considered “No Fly Zone” for SBRT due to toxicity[3]
- Unclear whether airway tree behaves as single OAR or has different segmental radiation tolerances[3-5]
- Existing airway dose constraints based on expert consensus, not clinical validation;[6] volumetric airway dose metrics may predict toxicity,[7] but central airway dose limits remain poorly defined
- **Study Aim:** to conduct the first longitudinal CT-based quantification of airway changes after SBRT for central/ultracentral lung tumors and evaluate their relationship with airway dose

Methods

- **Retrospective single-institution cohort:** adults with central/ultracentral thoracic tumors treated with SBRT 46–50 Gy in 4–5 fractions
- **Airway quantification and dosimetry:** complete airway tree segmented; quantified lumen area, wall thickness, and wall area across anatomically matched airway generations; airway segmentations registered to SBRT plan to obtain segment-level volumetric dose
- **Outcomes and statistics**: longitudinal hierarchical mixed-effects models tested if airway dimensions changed over time with maximum airway dose

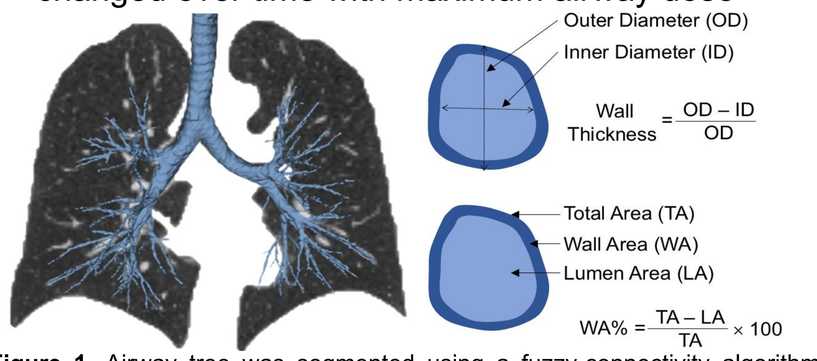

Figure 1. Airway tree was segmented using a fuzzy-connectivity algorithm with adaptive cylindrical ROIs, followed by centerline-guided cross-sectional delineation of the inner and outer airway wall to quantify lumen area, wall thickness, and wall area.

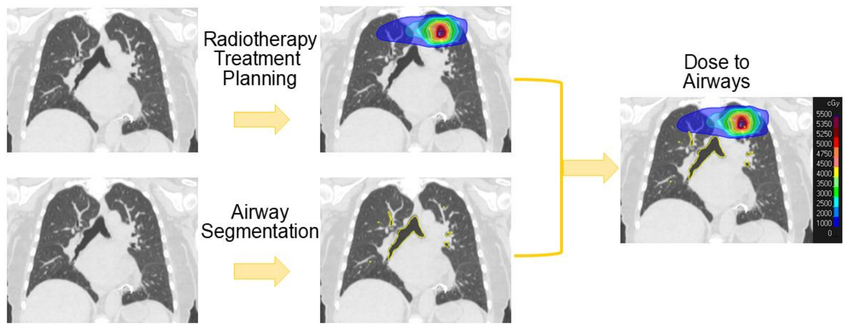

Figure 2. Pipeline outlining the methodology to quantifying dose to airways. Volumetric dose to airway segmentations was quantified via registration of the airway segmentation and dose distribution from the patient’s delivered treatment plan on the simulation CT. Treatment planning simulation CT used as baseline, routine post-treatment chest CTs used for follow-up.

Results

Table 1. Demographic Characteristics

Baseline Characteristics	All (n=27)
Age (years), median (range)	70 (57 – 88)
Sex Assigned at Birth, n (%)	
Female	20 (74)
Tumor Location, n (%)	
Central	21 (78)
Ultracentral	6 (22)
Diagnosis, n (%)	
Malignant Neoplasm of Lung	21 (78)
Solitary Pulmonary Nodule	3 (11)
Secondary Malignant Neoplasm of Lung	3 (11)
AJCC Group Stage, n (%)	
1	19 (70)
2-3	2 (8)
4	6 (22)
Dose Per Fraction (Gy), median (range)	10 (10 – 12.5)
Total Dose (Gy), median (range)	50 (46 – 50)
Time to Follow-up (months), median (range)	3.4 (2.7 – 8.3)

Table 2. Mixed Effect Model for Airway Measurement Change Over Time

Outcome	β (95% CI)	P Value
Lumen Area	0.05 (-0.10, 0.20)	0.52
Wall Thickness	-0.026 (-0.033, -0.020)	<0.001
Wall Area Percent	-0.0068 (-0.0081, -0.0056)	<0.001

Note: β value evaluates whether airway measurements change over time from simulation CT (pre-irradiation) to follow-up clinical CTs (post-irradiation) following SBRT to central/ultracentral tumors.

Table 3. Mixed Effect Model Evaluating Longitudinal Change in Airway Measurements as a Function of the Maximum Point Dose Delivered to Each Airway Segment, Adjusted for PTV, Lung Volume, Comorbid Disease, and Smoking Status

Outcome	β (95% CI)	P Value
Lumen Area	2×10^{-6} (-1×10^{-4}, 1×10^{-4})	0.8
Wall Thickness	3×10^{-7} (-4×10^{-6}, 4×10^{-6})	0.9
Wall Area Percent	7×10^{-8} (-9×10^{-7}, 9×10^{-7})	0.9

Note: β value (time-by-dose interaction) evaluates whether airway segments receiving higher maximum volumetric radiation dose exhibit a different trajectory of morphologic change over time.

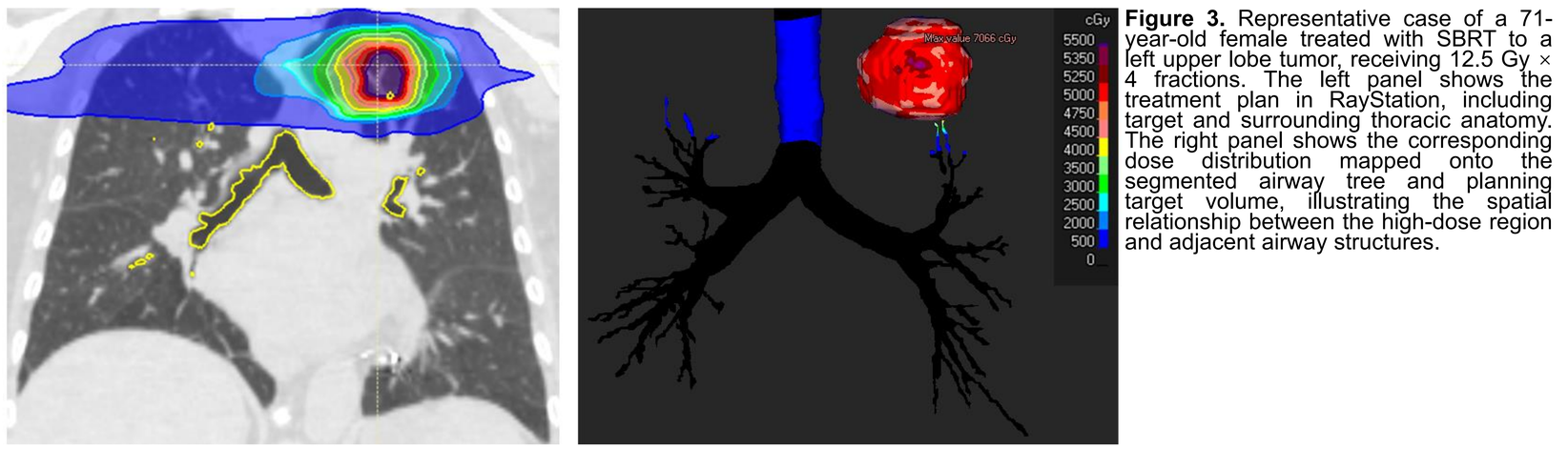

Figure 3. Representative case of a 71-year-old female treated with SBRT to a left upper lobe tumor, receiving 12.5 Gy × 4 fractions. The left panel shows the treatment plan in RayStation, including target and surrounding thoracic anatomy. The right panel shows the corresponding dose distribution mapped onto the segmented airway tree and planning target volume, illustrating the spatial relationship between the high-dose region and adjacent airway structures.

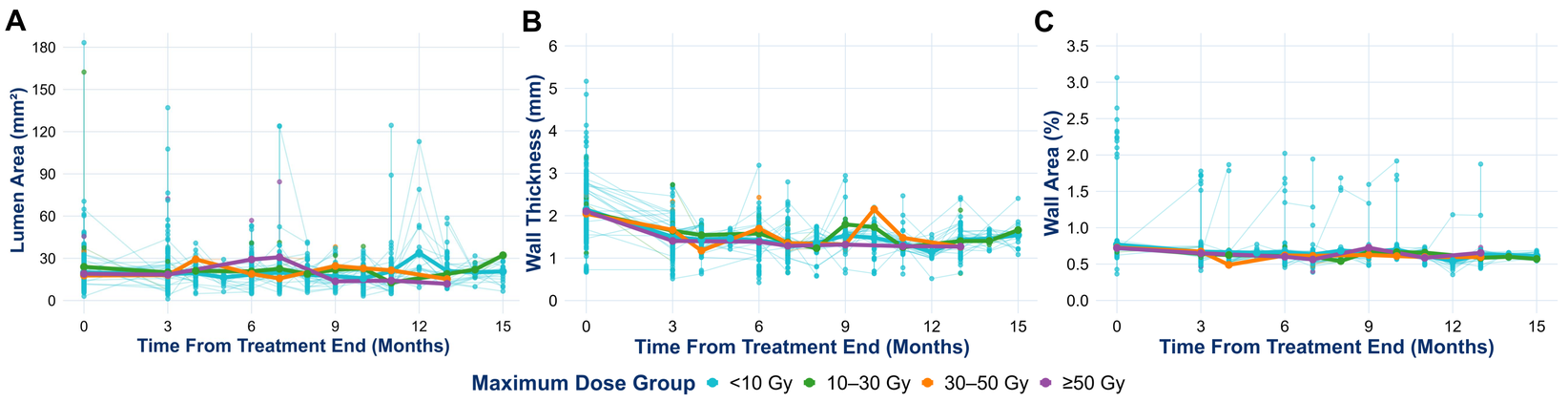

Figure 4. Longitudinal change in airway lumen area (A), wall thickness (B), and wall area percent (C) over time after SBRT, stratified by maximum airway dose group. Thin lines and points represent individual airway segment measurements and thicker lines with points represent group mean values at each follow-up time point.

Conclusions

- We demonstrated airway wall thickness and wall area statistically decreased in one-year following SBRT for central and ultracentral thoracic tumors
- No consistent dose-response relationship was identified between maximum airway dose metrics and longitudinal airway change
- First study to quantify pre-clinical wall thinning on CT following SBRT

References

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Contact: hkooner1@jh.edu