Effect of PTV Margins and Lung Density Variations on Target Coverage for Small-Volume Lung Lesions in SBRT

2026 JULY 19–22 VANCOUVER, BC
JOINT AAPM | COMP MEETING

Indra J Das, PhD; Chee-Wai Cheng, PhD
Department of Radiation Oncology, Northwestern Memorial Hospital, Northwestern University Feinberg School of Medicine, Chicago, IL, USA

ABSTRACT

Purpose: Target coverage in lung SBRT is influenced by tumor size, PTV margin, and local lung density. This study investigates target dose coverage in low-density lung as a function of PTV margins and lung density.
Methods: A small-volume central lung patient was selected for an *in silico* lung SBRT study. Lung densities ranging from 0.1–0.4 g/cm³ (−900 to −600 HU) were used. Spherical GTVs with diameters of 1, 2, and 3 cm were generated, each expanded by 2, 3, or 5 mm to form the PTV. Using the Eclipse treatment planning system (TPS), 48 plans were created with identical optimization criteria using 6 MV beams. For each plan, D100, D98, D50, D2, maximum dose, monitor units (MU), and conformity, homogeneity, and gradient indices (CI, HI, GI) were evaluated.
Results: Across all 48 plans, target coverage was adequately maintained, though at the expense of increased MU. For the 1-cm lesion, HI remained below 0.04 regardless of PTV margin or lung density. For the 2-cm lesion, HI was <0.12 and decreased with decreasing density; larger PTV expansions resulted in lower HI as expected. For the 3-cm lesion, HI decreased with density, but margin size had minimal influence. MU/Gy ranged from 400–500, 500–600, and 450–600 for the 1-, 2-, and 3-cm lesions, respectively, across densities of 0.1–0.4 g/cm³. Smaller margins produced higher MU in low-density lung by up to 12%.
Conclusions: Despite the buildup effect in lung, adequate target coverage (CI ≈ 1.0) can be achieved, though at the cost of increased MU/Gy, which strongly depends on lung density. HI is also density-dependent. PTV margins have relatively limited dosimetric impact and should be selected primarily based on clinical considerations and OAR

constraint

Indra J Das
IndraJdas@gmail.com
[215-385-4523]

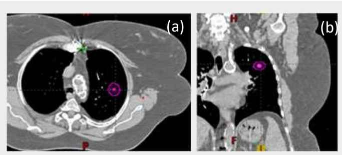
INTRODUCTION

Lung cancer screening has transformed the paradigm of lung cancer detection and management, resulting in reduced mortality. Routine screening shows that nearly 70% of detected tumors are stage I, which is associated with significantly better outcomes. Stereotactic body radiation therapy (SBRT/SABR) has become the hallmark treatment for small lung lesions, offering both clinical effectiveness and cost efficiency (1). Megavoltage photon beams exhibit a dose-buildup effect when transitioning from air or low-density lung tissue to higher-density tissue, an issue recently highlighted in the literature (doi.org /10.3390/jcm15020603). However, the dosimetric impact of tumor margin size and lung density is not well understood. This study investigates these effects using an in-silico approach. We modeled a centrally located lung lesion with spherical gross tumor volumes (GTV) of 1–3 cm in diameter, planning target volume (PTV) expansions of 0.2–0.5 cm, and lung densities of 0.1–0.4 g/cm³—values commonly corresponding to −900 to −600 HU in patients. These SBRT plans were generated using the Eclipse Treatment Planning System (TPS), version 16.2.1. For each case, dosimetric parameters (D_{100}, D_{98}, D_{50}, D_2, maximum dose, MU/Gy) and indices (CI, HI, GI) were analyzed.

METHODS AND MATERIALS

A left central lung lesion was chosen. Since systematic study is not possible on patient, an *in-Silico* study was performed by creating studies with variable size of tumor, PTV target expansion and varying lung densities. The GTV sizes chosen were 1, 2 and 3 cm diameter; PTV margin expansion of 0.2, 0.3, and 0.5 cm from GTV along with density variation from 0.1-0.4 g/cm³. The patient chosen is shown in figure 1 indicating axial and coronal plane. The beam arrangement was two ipsilateral arc for VMAT optimization and dose calculation.

In all cases 6 MV photon beam was used using eclipse 16.1 version software. DVH constraints were identical in all plans. Dosimetric parameters were recorded and compared.



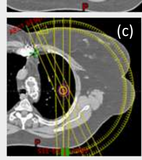


Figure 1(a) axial slice showing the position of lesion. (b) Coronal view and (c) 2 ipsilateral semi-arc beam arrangement

RESULTS

Conformity across all 48 plans was excellent (CI ≈ 1.0). However, MU/Gy varied significantly with changes in GTV size, margin expansion, and lung density, as shown in Figure 1(a,b). Lower lung density was associated with higher MU/Gy. Homogeneity index (HI) results for the different GTV sizes and PTV expansions are shown in Figure 2(a,b), demonstrating substantial variability. These findings should be discussed with the clinical team when determining PTV expansions, particularly in patients with very low lung density or those treated using deep-inspiration breath hold (DIBH). The unexpectedly high MU values in low-density lung should also be considered during treatment planning and quality assurance.

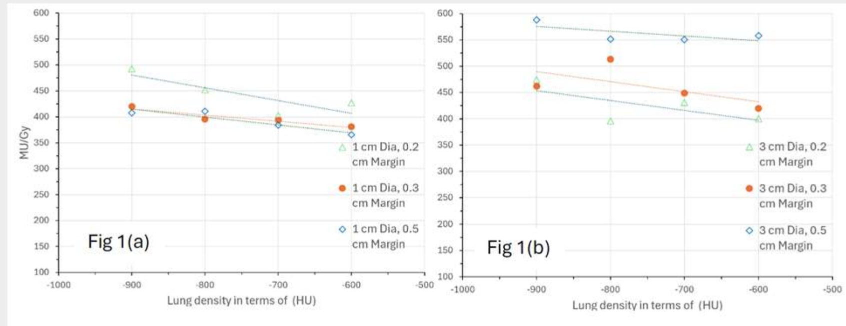


Figure 1. Monitor Unit (MU/Gy) versus lung density for various PTV margins (a) for 1 cm diameter and (b) 3 cm diameter lesion.

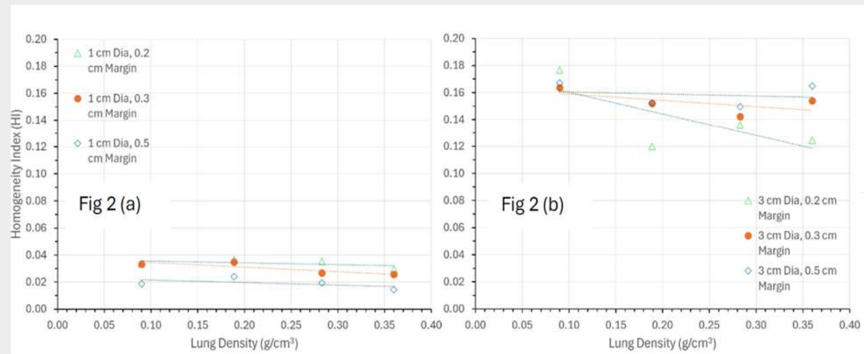


Figure 2. Homogeneity index (HI) versus lung density for various PTV margins (a) for 1 cm diameter and (b) 3 cm diameter lesion.

CONCLUSIONS

- Despite the low density and buildup effect, conformity across all 48 plans was excellent (CI ≈ 1.0).
- However, MU/Gy varied significantly with changes in GTV size, margin expansion, and lung density, as shown in Figure 1(a,b) (2,3).
- Lower lung density was associated with higher MU/Gy. Homogeneity index (HI) results for the different GTV sizes and PTV expansions are shown in Figure 2(a,b),
- These findings should be discussed with the clinical team when determining PTV expansions, particularly in patients with very low lung density or those treated using deep-inspiration breath hold (DIBH) (4,5).
- The unexpectedly high MU values in low-density lung should also be considered during treatment planning and quality assurance

REFERENCES

1. Schonewolf CA, Heskel M, Doucette A, Singhal S, Frick MA, Xanthopoulos EP, et al. Five-year Long-term Outcomes of Stereotactic Body Radiation Therapy for Operable Versus Medically Inoperable Stage I Non-small-cell Lung Cancer: Analysis by Operability, Fractionation Regimen, Tumor Size, and Tumor Location. Clin Lung Cancer. 2019;20(1):e63-e71.
2. Fogliata A, Cozzi L. Dose calculation algorithm accuracy for small fields in non-homogeneous media: The lung SBRT case. Phys Med. 2017;44:157-62.
3. Yadav P, Desrosiers CM, Mitra RK, Srivastava SP, Das IJ. Variability of Low-Z Inhomogeneity Correction in IMRT/SBRT: A Multi-Institutional Collaborative Study. J Clin Med. 2023;12(3):906.
4. Das IJ, Francescon P, Moran J, Ahnesjö A, Aspradakis MM, Cheng CW, et al. Report of AAPM Task Group 155: Megavoltage photon beam dosimetry in small fields and non-equilibrium conditions. Med Phys. 2021;48(10):e886-e921.
5. Das IJ, Yadav P, Andersen AD, Chen ZJ, Huang L, Langer MP, et al. Dose prescription and reporting in stereotactic body radiotherapy: A multi-institutional study. Radiother Oncol. 2023;182:109571.