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An Individualized Respiration-Pattern-Based Target Definition Approach for Stereotactic Body Radiotherapy of Lung Lesions

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Published 03/04/2026

Steven W. Chen [1], Jiajin Fan [2]

1. Student, Montgomery High School, Skillman, USA 2. Advanced Radiation Oncology and Proton Therapy, Inova Schar Cancer Institute, Fairfax, USA

Corresponding author: Steven W. Chen, chenwz2020@gmail.com

Categories: Radiation Oncology
Keywords: lung lesions, stereotactic body radiotherapy

How to cite this abstract
Chen S W, Fan J (March 04, 2026) An Individualized Respiration-Pattern-Based Target Definition Approach for Stereotactic Body Radiotherapy of Lung Lesions. Cureus 18(3): a1619

Abstract

Objectives: Respiratory motion poses a major challenge in stereotactic body radiotherapy (SBRT) for lung tumors, particularly in patients with large motion amplitudes. Breathing patterns vary widely, from smooth sinusoidal (sine-type) to abrupt pulse-type waveforms. This study evaluates an individualized respiration-pattern-based approach to target definition, aiming to reduce motion margins compared to the conventional internal target volume (ITV) derived from maximum intensity projection (MIP).

Methods: Tumor motion trajectories and breathing waveforms were extracted from 4D-CT scans of five patients. Tumor centroids were delineated across 10 respiratory phases; non-linear interpolation generated 20 phases to enhance temporal resolution. A 3 cm circular tumor was simulated. A time-intensity map was created by overlaying tumor positions across all phases, indicating the percentage of cycle time each voxel was occupied by tumor. Voxels exceeding predefined occupancy thresholds (e.g., 10% or 15%) were selected, and a convex hull encompassing these voxels was generated to define the effective ITV (ITVeff). Superior-inferior (sup-inf) lengths of ITVeff were compared to the conventional MIP-based ITV (equivalent to 0% threshold). A uniform 2 cm sup-inf motion was simulated across all patients for standardization, followed by patient-specific motion ranges. All analyses were implemented in Python.

Results: In the uniform motion scenario, ITV reduction was greater for pulse-type than sine-type breathing: 5–8% vs. 2–5% at 10% threshold, and 13–14% vs. 5–8% at 15%. With patient-specific motion, sup-inf ITV reductions were 2–3 mm (10% threshold) and 4–7 mm (15% threshold). The largest reductions occurred in patients with pulse-type breathing and large motion amplitudes.

Conclusion(s): This respiration-pattern-based approach significantly reduces motion margins in patients with pulse-type breathing and large tumor excursions, particularly near the diaphragm. The resulting smaller ITVs may improve healthy lung sparing in SBRT, especially in patients with limited lung volume. This method may also be applicable to liver SBRT where respiratory motion is similarly prominent. Future studies will expand the patient cohort and include experimental validation.