More Than Volume: Capturing Airway and Functional Dependencies in Lung Radiation therapy

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Radiation therapy planning is fundamentally a multi-objective optimization problem: the goal is to achieve optimal control of malignant tumors while simultaneously sparing surrounding healthy tissue, especially critical structures. For the lung, which is considered a parallel organ due to its many functionally similar subunits, clinical guidelines for organs at risk are typically formulated as dose-volume constraints, such as "No more than 20% of the lung volume may receive more than 30 Gy." These constraints rely on the idea that a certain fraction of lung tissue can be damaged without causing severe complications because the remaining units can compensate.

However, this statistical approach can be insufficient, as functional dependencies between cells do arise from the organ's branching structure. Sparing small airway branches may not be effective if essential supply pathways are damaged, potentially causing indirect destruction of larger regions. The approach also does not account for the fact that some regions of the lung function better than others due to wear and tear or degeneration.

Previous studies have recognized and begun to address these shortcomings. This poster presents ideas for a mathematical modeling framework that aims to further improve the representation of airway and functional dependencies in dose-volume constraints for the lungs. The approach employs multi-objective mixed-integer optimization methods applied to a network model that represents the lung airways.