

Abstract

Four-dimensional computed tomography-based ventilation is a developing method for estimating the lung function of patients. The response of 4DCT-based ventilation to radiation therapy (RT) has remained largely uncharacterized. The purpose of this work was to better quantify the response of 4DCT-based ventilation to RT, to create a model that predicts changes of 4DCT-based ventilation after RT, and to investigate the robustness of functional avoidance to respiratory motion during treatment.

Pre-RT and post-RT ventilation estimations were acquired, and the voxel-wise response of the post-RT ventilation to dose and pre-RT ventilation was determined. High-dose regions sustained more ventilation decline than low-dose regions. Increased pre-RT ventilation resulted in increased damage at similar doses suggesting increased dose sensitivity. These results validate the ongoing clinical trials using 4DCT-based ventilation for functional avoidance.

A polynomial regression model was created using pre-RT ventilation and dose to predict post-RT ventilation. This model showed significant predictive power on the cross-validation dataset as measured by gamma pass rates. The model was applied to a validation study from a different institution and showed significant predictive power, suggesting the comparability of inter-institution 4DCT ventilation results. The positive predictive value for the model was 72.5% in regions receiving over 20 Gy for patients with more than 10 cc of predicted functional decline.

Predictive models were created to include the average heart dose and average lobe dose using linear regression and regression neural networks. The linear regression model including heart and lobe dose had the highest predictive power as measured by gamma pass rate and mean squared error. However, the regression coefficients' magnitude suggest that the heart dose and lobe dose have minimal impact on regional ventilation changes.

The impact of respiratory motion on functional avoidance was investigated using three representative dose distributions. The worst-case scenario dose distribution represented the patient at end-inspiration for the entirety of treatment. However, this worst-case scenario resulted in better dose metrics and predictive metrics for a majority of patients, even when only considering regions of high function. These results suggest that deep-inspiration breath hold is the most advantageous method of treatment delivery when using functional avoidance treatment planning.