Purpose: To improve IMRT treatments for lung cancer patients who exhibit breathing motion uncertainty; to demonstrate that combining adaptive radiation therapy with robust optimization can lead to simultaneous improvements in tumor coverage and healthy tissue sparing over non-adaptive robust optimization methods.

Methods: A model of breathing motion uncertainty was derived from previous robust optimization research. We then developed two algorithms - exponential smoothing and running average - to up-date this model from fraction to fraction, using a sequence of retrospective motion probability mass functions (PMFs) from real patients. A robust optimization problem was solved for each fraction with an updated uncertainty model to generate a sequence of treatments. Delivery of the entire treatment was simulated and dose was accumulated according to the sequence of PMFs. The breathing motion model was created and updated in MATLAB, while CPLEX was used to solve the corresponding robust optimization problem as a linear program. The adaptive robust treatment was then compared with a robust treatment in which the uncertainty set was not updated over the treatment course.

Results: Our adaptive robust optimization method exhibited a simultaneous improvement over non-adaptive robust methods in both tumor coverage and healthy tissue sparing. The adaptive robust treatments were insensitive to the choice of the initial uncertainty model, and also closely comparable to idealized treatments that would be obtained with perfect foresight – i.e., treatments created with a priori knowledge of the entire sequence of future patient PMFs.

Conclusions: By combining adaptive radiation therapy and robust optimization, our method combats both the instantaneous breathing motion uncertainty realized in each fraction and changes in the uncertainty that occur from fraction to fraction. Our method demonstrates that it is possible escalate dose to the tumor from the level possible with current robust methods without sacrificing healthy tissue sparing.