Purpose: To apply scanned ion radiotherapy to patients with moving tumors, motion mitigation approaches are needed. The purpose of the current study was to determine whether 4D optimized ion beam tracking therapy could reduce dose to critical structures near a moving target while maintaining target dose coverage.

Methods: A conjugate gradient minimization algorithm was developed to incorporate 4D organ motion data in the optimization of scanned ion pencil beam fluences. Treatment plans for 3D and 4D optimized carbon beam tracking were prepared using an in-house code for a sphere target volume moving in water with a proximal avoidance volume. For 1 lung cancer patient, 3D and 4D optimized carbon beam tracking treatment plans were designed to provide uniform dose coverage to a clinical target volume and minimal dose to the heart. For both the water phantom and patient case, 4D dose distributions were calculated. Differences between 3D and 4D optimized beam tracking were analyzed using dose colorplanes, dose-volume histograms, and dose-volume statistics.

Results: For the sphere target, 3D optimized beam tracking achieved target dose coverage of (100.0 ± 0.3)% and a mean and maximum avoidance volume dose of 26.1% and 89.4%, respectively. 4D optimized beam tracking achieved target dose coverage of (99.9 ± 0.4)% and a mean and maximum avoidance volume dose of 7.7% and 42.2%, respectively. For the lung patient, 3D optimized beam tracking achieved target dose coverage of (101.0 ± 5.9)% and a mean and maximum heart dose of 7.7% and 103.4%, respectively. 4D optimized beam tracking achieved target dose coverage of (100.0 ± 0.1)% and a mean and maximum heart dose of 8.7% and 100.3%, respectively.

Conclusions: 4D optimized ion beam tracking therapy may be used to reduce the maximum dose to critical structures near a moving target, compared to 3D optimized ion beam tracking therapy.

Funding Support, Disclosures, and Conflict of Interest:

Work supported by the Rosalie B. Hite Fellowship, The University of Texas M. D. Anderson Cancer Center, Houston, Texas.