

Purpose: To experimentally investigate 4D treatment delivery to account for motion, rotation, and deformation of tumors and normal tissues.

Method and Materials: A 4D treatment plan was generated as a function of respiratory phase for an elliptical tumor that translates, rotates, deforms, and exhibits motion hysteresis throughout the respiratory cycle. A programmable motion platform with a marker block simulates the tumor motion. An independent patient position monitoring system monitors motion of marker block and provides 3D position and respiratory phase information in real time for the dynamic MLC motion-tracking software. Using the position and phase information and the 4D treatment plan, the dynamic MLC motion-tracking software repositions and/or reshapes the radiation beams to deliver treatment. An MV imager operating in a cine mode was used to acquire images to quantify tumor motion, rotation, and deformation. 4D treatment delivery was performed when the target motion during treatment delivery was the same as, smaller than, and larger than during imaging. For comparison, static delivery of treatment plans for each of the respiratory phases was performed.

Results: The elliptical tumor segmented from MV images between 4D and static delivery showed the difference of centroid positions less than 5 mm, rotation less than 10 degrees, and major and minor axis lengths less than 2 mm each. 4D treatment delivery was comparable to static delivery of each phase treatment plan, demonstrating the ability of dynamic MLC to account for changes in anatomic motion, rotation, and deformation by varying MLC leaves as a function of phase.

Conclusion: 4D treatment plans generated to account for motion, rotation, and deformation of tumors and normal tissues within a respiratory cycle at the planning stage can be delivered while still accounting for different target motion during delivery at the delivery stage.

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