

Purpose: To develop 4D optimization for respiratory phase-dependent IMRT treatment planning with dynamic MLC motion tracking, including MLC leaf motion constraints, which takes respiration-induced anatomic motion into account and is robust to the variations of fractional time spent in respiratory phases within a 4D CT planning scan.

Method and Materials: A tool for 4D treatment-planning optimization that integrates a commercially available treatment-planning system and a general-purpose optimization system was developed and applied to the 4D CT planning scans of two lung cancer patients. The optimization variables were MLC leaf positions as a function of monitor units and respiratory phase. The objective function was the deformable dose-summed 4D treatment plan score. MLC leaf motion was constrained by the maximum leaf velocity between control points in terms of monitor units and between phases and between leaves for tumor motion parallel and perpendicular to the leaf travel direction, respectively, in terms of phases. Without loss of generality, due to the computational burden, 4D optimization was performed with two phases, end inhale and exhale. For comparison and a starting point for the 4D optimization, 3D optimization was performed on each of the phases.

Results: 4D treatment plan score improved during 4D optimization by 34% for Patient 1 and 50% for Patient 2, indicating 4D optimization generated a better 4D plan than the sum of individually optimized phase plans. The DVHs for each phase remained similar, indicating robustness of the 4D plan to respiratory variations expected during treatment delivery.

Conclusions: 4D optimization for respiratory phase-dependent treatment planning with dynamic MLC motion tracking improved the 4D plan score by 42% on average compared with 3D optimization. 4D treatment plans generated changed from phase to phase to account for anatomic motion, but showed similar dose distributions in each phase.

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