Purpose: Respiration-gated radiation therapy delivers the beam at either inhale or exhale phases. To increase the duty cycle of gating and improve the treatment efficiency, we propose delivering radiation at both inhale and exhale windows. This work presents a treatment planning method that enables dual-gated delivery while maintaining plan quality.

Methods: The accumulated dose is a weighted sum of the dose distributions of the two phases. We minimize the least squares difference between the prescribed and computed accumulated doses under a set of dose-volume (DVH) constraints. Optimization produces a single set of beam apertures for delivery at both inhale and exhale phases. We evaluate the optimization framework for our novel delivery scheme using a 4D phantom undergoing 1, 2, and 3 cm periodic motion in the superior-inferior (SI) direction and compare the resultant dose distributions against the IMRT exhale gated distribution.

Results: The dual-gated technique produces highly conformal dose distributions for all testing cases. Compared to gating at exhale, the dual-gated plans exhibit similar adjacent sensitive structure sparing (with the exception of the ipsilateral lung) while providing nearly identical PTV coverage. Indeed, the PTV DVH remains essentially unchanged for increased SI motion. However, the ipsilateral lung receives intermediate doses for large SI translation. For a target prescription of 60 Gy, over 61.7% of the ipsilateral lung receives a dose greater than 10 Gy for 3 cm motion. For 2 cm, 1 cm, and no motion in SI direction, the ipsilateral lung volume receiving a dose higher than 10 Gy is 39.5%, 36.9%, and 32.8%, respectively. The dose to the tissue surrounding the PTV is inversely proportional to the overlap of the inhale and exhale PTVs.

Conclusions: Dual-gated delivery is a promising option for increasing duty cycle and thus improving treatment efficiency for tumors undergoing respiratory-motion.