PAPER

Fast robust optimization of proton PBS arc therapy plans using early energy layer selection and spot assignment

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Abstract

Objective. Proton pencil-beam scanning arcs (PBS arcs) have gained much attention during the past years, due to its potential for increased clinical benefit compared to conventional proton therapy. Previous studies on PBS arcs have primarily been focused on plan quality, and lately efforts have been made to reduce the delivery time. However, the methods presented so far suffer from slow optimization processes. *Approach.* We present a new method for fast robust optimization of PBS arc plans. The new method assigns a single energy layer per discretized direction prior to spot weight optimization and reduces the number of initial spots considerably compared to conventional methods. We used the new method for three prostate cancer patients with a prescribed dose to the CTV of 77 Gy_{RBE} in 35 fractions. For each of the patients, four plans were created: 2-beam IMPT (2IMPT), 1-beam PBS arc (1Arc), 1-beam PBS arc without focus on reducing upward energy jumps (1Arc_unseq) and two-beam PBS arc (2Arc). *Main results.* All PBS arc plans show a reduced integral dose compared to their respective 2IMPT plans. In the nominal case, the average CTV D98 and D2 metrics over the three patients were best for the 2Arc, followed by 2IMPT ($\bar{D}98/\bar{D}2$: 7523/7986 cGy_{RBE} (2IMPT), 7478/7984 cGy (1Arc), 7486/7951 cGy (1Arc_unseq), 7531/7951 cGy_{RBE} (2Arc)). The average robust target coverage in terms of V95 of the voxelwise minimum dose distribution (evaluated over 42 scenarios) was: 98.0% (2IMPT), 88.6% (1Arc), 92.5% (1Arc_unseq), 97.3% (2Arc). The optimization time, including spot selection and spot dose computation, is longest for the 2Arc plan, but is below 6 min for all patients. The maximum estimated delivery time for all types of arc plans is just above 5 min *Significance.* The ability for efficient treatment planning constitutes an important step towards clinical introduction of proton PBS arcs.

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