AbstractID: 13394 Title: Optimization of spot position in intensity modulated proton therapy

Purpose: To develop a method of integrating optimization of spot position into the inverse planning of intensity modulated proton therapy (IMPT), and evaluate the potential improvement of treatment plan quality, particularly in the case of limited intensity levels.

Method and Materials: To obtain the optimal treatment plan with fixed discrete intensity levels, the beam weights and positions are optimized separately in an alternate manner. First, the beam weights are optimized as continuous variables and subsequently rounded to the nearest intensity levels. Then the beamlet, or spot, positions are optimized with this set of weights. This process is repeated until the plan is acceptable. The same objective function is used for both optimizations and is similar to that used in traditional IMPT. The optimization engine uses a sequential quadratic programming method.

Results: The algorithm is evaluated on an ellipsoid water phantom with a spherical target at the center, treated with single field spot scanning. With 10 intensity levels, merely rounding the beam intensities to the nearest levels resulted in homogeneity index (HI = $(D_{2\%}-D_{98\%})/D_{mean}$) increasing from 1.31% to 10.5%. The final optimized plan achieved HI of 1.51%. With 5 intensity levels, severe under-dosage on the PTV (D_{98} at 71.85% prescription dose and HI of 40.7%) is observed if only rounding the beam intensity. Our algorithm yielded a plan of HI of 5.76%.

Conclusions: Incorporating the optimization of proton beamlet positions into the inverse treatment planning system of IMPT offers more flexibility. Our phantom study suggests rounding the beam intensities to the nearest levels can be acceptable with more than 10 levels. In the case of greatly limited number of intensity levels, alternately optimizing the beamlet weights and positions is a feasible solution and can achieve treatment plans of comparable uniformity and conformity to traditional IMPT with continuous intensity levels.