Purpose: Uncertainties in dose delivery due to setup or motion can be accounted for by robust IMRT optimization. In dose painting, the transformation of functional imaging data to non-uniform dose prescriptions introduces large additional uncertainty, resulting in prescribed dose uncertainty at every voxel. We have developed and tested an optimization method for dose painting treatment plans that is robust to dose prescription uncertainty.

Methods: An optimization method was developed that constrains dose at a voxel to within a range, as opposed to conventional single-dose constraints. Ranges were based on uncertainties in the image-to-dose transformation as determined by a previously presented uncertainty model. Treatment plans for head-and-neck cancer patients were generated using both robust and conventional methods. Mean, deviation, and range in plan quality were compared when different prescribed-dose distributions were sampled. The metric for plan quality was the percent PTV receiving planned dose within ±5% of its prescribed dose (Q(0.95-1.05)).

Results: The pooled standard deviation in Q(0.95-1.05) was significantly lower (p<0.01) for the robust method (SD=19%) than the conventional method (SD=25%), indicating less overall spread in plan quality. The mean Q(0.95-1.05) for all patients was 73% for the robust method and 71% for the conventional method, which was not significantly different (p>0.05). Conventional plans performed better when no prescription uncertainties were introduced (nominal case), and robust plans performed better under large prescription uncertainties.

Conclusions: Robust optimization using dosimetric margins produced significantly less spread in plan quality than did conventional optimization. While the methods yielded similar mean Q(0.95-1.05) values, plan quality under worst-case-scenario dose prescriptions was improved using the robust method. This advantage was more significant for dose-painting plans with high dose-escalation. Eventual incorporation of probability density functions for dose prescriptions into objective functions may enable more precise implementation of dose painting in prospective clinical trials.