AbstractID: 10485 Title: The role of hypoxia in radiation treatment planning. A simulation study

Purpose: To assess the importance of hypoxia imaging for radiation treatment planning by evaluation of the effectiveness of modulated radiation treatments targeting hypoxia with increased doses.

Method and Materials: Starting with a two-dimensional diffusion model of tissue oxygenation, a planar tumor model was developed to simulate chronic and acute hypoxia as well as oxygenation/reoxygenation effects on the microscopic scale. Tumor cell radiation response was evaluated using linear quadratic model taking into account individual cell oxygenation levels. Cell repopulation/tumor shrinkage was not considered, as to represent a slow-growing tumor. Using this model, we evaluated the effectiveness of intensity modulated radiation therapy treatments targeting hypoxia with increased radiation doses. We compared different approaches to targeting hypoxia, including fixed dose modulation based on the pre-treatment imaging of hypoxia and adaptive dose modulation based on interfraction imaging of hypoxia. Furthermore, to study the importance of hypoxia imaging resolution we compared two scenarios: 1. microscopic, where cell-by-cell imaging of hypoxia and dose delivery is possible, 2. macroscopic, where both imaging and irradiation can be conducted with 1mm resolution.

Results: For a total tumor dose of 30Gy, the adaptive hypoxia-targeting therapy provided the best tumor control for the microscopic scenario with $SF_{30}=4.46\cdot10^{-5}$ compared to $SF_{30}=9.44\cdot10^{-5}$ for the treatment with uniform dose of 2Gy per fraction. However, for a more realistic macroscopic scenario, the finite resolution of hypoxia imaging and dose delivery significantly reduced the therapeutic advantage of adaptive hypoxia targeted therapy resulting in $SF_{30}=4.85\cdot10^{-5}$ compared to $7.09\cdot10^{-5}$ for the uniform dose treatment.

Conclusion: We have demonstrated that the adaptive dose modulation based on oxygenation map acquired before each fraction does results in slightly better tumor control compared to uniform dose delivery. However, the tumor control improvement is yet to be proven significant enough to justify the clinical implementation of hypoxia-targeting dose modulation.