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Mathematical Modeling of Tumor Dynamics and Radiotherapy for Early Glioma

Glioblastomas are very aggressive brain tumors with a poor prognosis. These highly vascular and invasive tumors exhibit a high degree of cellular heterogeneity that accounts for their resistance to standard therapies. To estimate the amount of cellular destruction through radiotherapy, we use mathematical models such as the linear-quadratic model. In this work the growth of glioma is simulated in conjunction with the effects of radiotherapy on a microscopic scale. Furthermore, we consider the variability of the radiation sensitivity of individual cells as a function of the cell cycle phase.

We propose a hybrid approach for modeling tumor progression on a cellular scale. The spatio-temporal model consists of reactiondiffusion equations that describe interactions between cancer cells and the microenvironment. The movement of tumor cells, the distribution of the nutrients and the density of the extracellular matrix is covered by partial differential equations. Additionally, the cell cycle is incorporated to allow for a more accurate modeling of biological processes. The simulation of radiotherapy is based on the linear-quadratic model. Here, the effects of irradiation are influenced by the administrated dose and two parameters representing the radiosensitivity of tissue with respect to the cell cycle.

A qualitative evaluation of first results shows an initial exponential growth of the tumor. During therapy, after each fraction of radiation the population of tumor cells decreases steadily. During treatment breaks, an increase of the population can be observed. The model was also used to study the effects of the radiation dose and a direct dependence between the dose and the tumor cells can be observed.

The simulations depict plausible results for both, the progression of tumor and the effect of radiotherapy on individual cells. By introducing molecular and/or macroscopic components into this model, a multiscale approach describing the effects of radiotherapy is possible.