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Optimised cancer treatment using cell cycle synchronisation with heavy ion irradiation

Cancer is a leading cause of death worldwide. As a consequence a multitude of experimental and mathematical studies on cancer growth and a diversity of treatments are being developed. Among these is tumour irradiation with heavy ions. While this novel methodology was restricted to research institutes for a long time, this treatment became a full part of clinical reality now.

We present an agent-based approach to the modelling of cellular dynamics within tumour spheroids that is based on experimentally accessible parameters and thus is able to take advantage of experimental data from irradiation experiments. As the model architecture is lattice-free and average-free, it can be considered to be a realistic representation of tumours. The model grows a tumour from a single malignant cell and the dynamics of tumour growth in response to irradiation protocols can be tracked. As the model is single cell based we are able to provide an in depth analysis of all possible observables ranging from the cell cycle phase, pressure inside the spheroid, nutrient supply and limitations, up to genetic expression profiles for the intracellular network. Target of our study is a detailed examination of the dynamical reaction of tumours to heavy-ion irradiation treatment.

It is found that irradiation treatment induces a variety of dynamical reactions within a tumour. Reoxygenation of the tumour volume and a decrease in pressure due to cell death lead to excessive regrowth after irradiation. As expected fractionation of the radiation dose changes the degree of tumour control considerably depending on the applied fractionation scheme. A pronounced resynchronisation of the cell cycle within the tumour after irradiation is found which could be exploited in order to administer follow-up treatments in accordance to the cell's most radiosensitive phases. This result has direct implications for experimental studies and eventually for clinical trials.