Modelling the Progression of Brain Metastases

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Introduction

The present work is devoted to model the progression of brain metastases. Without any treatment, the prognosis for patients with brain metastases is poor. Radiosurgery has shown to significantly increase the average survival of patients. To this end, maximization of tumour control while minimizing normal tissue toxicity necessitates an accurate knowledge about the tumour infiltration.

Mathematical models of tumour progression potentially provide valuable and complementary information for physicians about the non-detectable part of metastatic lesions. Ultimately, this information could enable the possibility to improve treatment strategies.

Methods

The progression of brain metastases is described on a macroscopic scale by means of a reaction-diffusion equation. In addition to proliferation and random motion cell migration due to adhesive forces is considered. To account for the expansive nature of the tumour, the tumour cell density is linked to a parametric deformation model.

Results

Simulation of metastatic progression was performed by using a brain atlas with an isotropic resolution of 1 mm. The mathematical model was applied to a patient with brain metastases from small-cell lung cancer. The metastatic lesion calculated with the model was compared to the lesion measured on contrast-enhanced T1 weighted images at three different time points prior to radiosurgery. The results show that the progression of the brain metastases can accurately be recovered in space and time.

Conclusion

A novel mathematical approach is presented that allows for simulating the progression of brain metastasis. First results for a patient diagnosed with brain metastasis strongly suggest that this model can reproduce the visible part of the lesion. Incorporation into clinical planning systems could ultimately help radiation oncologists to select the appropriate safety margin for radiosurgery. Avenues for future research include further validation as well as an extension to simulate the effects of radiosurgery.