Purpose: A 2D model of a tumour incorporating the microvasculature environment is developed and used in an iterative manner to model the changing levels of oxygen through its volume over the course of a radiation therapy treatment.
Methods: Tumour vasculature is created by iteration, using published pO2 histograms. A 4 mm2 vessel map is randomly generated then convolved with an oxygen-spreading kernel to generate pO2 map. A cost function is calculated based on the relative square differences between the input and newly created pO2 histograms. Vessel number and spatial position are optimized.
Radiation therapy treatment fractions are modelled by iteration. A linear-quadratic surviving fraction response map is generated incorporating local hypoxia reduction factors (HRFs) that are calculated from the pO2 map. A threshold, dose-dependent response that modifies the microvasculature environment is also introduced. Vessel, pO2, and HRF maps are updated before calculating the i+1 map of tumour response. Parameters for a squamous cell carcinoma were incorporated for the initial testing.
Results: Weighting the cost function allowed us to keep differences in the extremely hypoxic bin (0 - 5 mmHg) and fully oxic bin to less than 1 % of the overall cell count. Differences of as much as 12 % in intermediate bins may indicate limitations of the model to conform to the measured data. The total surviving fraction (TSF) increased by 123% in the vascular response model without any specific vascular dose enhancement compared to the stationary vascular case. Vascular dose enhancement by factors of 1.5 and 2.0 further increased the TSF by 26 % and 50 %, respectively.
Conclusions: This work provides a framework for answering questions relating to tumour vasculature response during radiation therapy. These preliminary results suggest potential for caution in enhancing dose to tumour vasculature.