MRI Tracked Tumor Physiology in the Hours after 20 Gy Single-Fraction Radiation

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Target Audience: Oncologists and radiologists who are interested in acute tumor response to single high-dose radiotherapy. Medical physicists and others who are interested in MRI measures of tumor physiology.

Purpose: To use MRI measures of tumor physiology, including arterial spin labeling (ASL) and dynamic contrast enhanced MRI (DCE-MRI) to follow the acute response of tumor physiology in the hours after single high-dose radiotherapy (HD-RT). To relate the compression of the mostly normal tissue in the periphery of the tumor to changes in tumor blood flow (TBF).

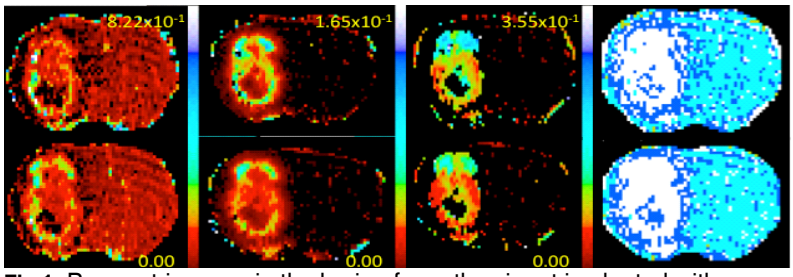

Fig 1: Parametric maps in the brain of an athymic rat implanted with a U251 tumor. From left to right: plasma fractional volume v_p, forward volumetric transfer constant K^{trans} (units in min^{-1}), fractional interstitial volume v_e, Model selection. For the Model map, white is Model 3 acceptance, dark blue is Model 2 acceptance, light blue is Model 1 acceptance, and black is NAN. Two studies, 24 hours apart.

Methods:

A method for using DCE-MRI in the rim of a model tumor to estimate distribution volume (V_D), which is approximately equal to the extracellular volume fraction, has been previously presented (1). In a U251 rat model of cerebral tumor, a model selection paradigm was employed to describe the the region of interest (ROI) of the tumor itself, and of its adjacent outer rim. Using ASL and DCE-MRI methods previously described (2-4), TBF, the DCE-MRI parameters K^{trans} and v_e in the tumor ROI, and V_D in the outer rim, were measured in two sessions on a 24 hr interval, with an intervening exposure to a 20 Gy stereotactic dose of RT. See Fig 1 for the definition of model parameters and an example of test-retest studies, and Ref (5) for a summary of test-retest values in controls. Groups of 5 animals were irradiated at 2, 4, 8, 12, and 24 hrs before the second MR study. Data was plotted as percentage change vs time for TBF, K^{trans}, v_e, and V_D (tumor periphery). In order to avoid bias, the percentage change was calculated as 200(post-pre)/(post+pre) for each parameter, allowing a maximum change of ±200%, but preserving the assumption that the two samples were drawn from the same population.

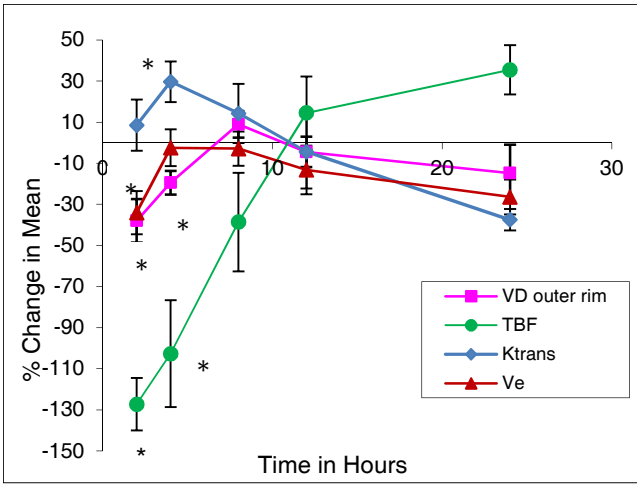

Fig 2: K^{trans}, v_e, and TBF in the Model 3 region, i.e., in the ROI consisting mainly of tumor, and extracellular space (V_D) in the mostly normal ROI surrounding the tumor. A profound decrease in TBF was accompanied by a decrease in extracellular space, both in the tumor itself, and in its periphery. An apparent decoupling of the TBF and extracellular space occurred after the 8 hr time point. Of the parameters related to TBF, the decrease in peripheral extracellular space appears most related to the decrease in TBF. * signifies $p<0.05$.

Results and Conclusion: See Fig 2. Significant changes in vascular parameters were observed 2 hours after 20 Gy HD-RT. In the Model 3 ROI, TBF decreased profoundly, nearly 130%, in concert with a significant decrease in v_e and a similarly significant decrease in peritumoral V_D. Histologically, extensive vacuolization and an increase in apoptosis was evident 2 hours post-RT. Between 8 and 12 hours after the radiation exposure, all vascular parameters including blood flow normalized to near pre-irradiation values. 24 hrs after the radiation exposure, TBF was elevated ~30% over pre-irradiation values, while other vascular parameters including K^{trans} decreased. This points to a decoupling of TBF and extracellular space about 8 hrs post HD-RT. We hypothesize that cellular swelling in the hours after a high dose of radiation led to a decrease in TBF, tumor v_e, and peritumoral V_D, probably through compression of the mostly normal tissue surrounding this embedded tumor.

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References:

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