Monitoring Brain Tumor Response to Radiation by Sodum MR Imaging

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Introduction: High-grade brain tumors have a grim prognosis with a mortality rate of 80% at 2 years post diagnosis. Despite aggressive treatment, this outcome has not changed in 30 years. Tumor control does not appear to be established during initial treatment despite surgery, radiation and chemotherapy. Vital time is lost until recurrence is recognized with poor consequences for the patient. We demonstrate that sodium MR imaging can be quantified as a tissue sodium concentration (TSC) map that is a direct measure of cell volume fraction that is sensitive to the voxel-wise cell kill during fractionated radiation treatment. This parameter allows simulation of tumor response as regional cell kill and may potentially be used to modify initial treatment to improve response.

Methods: Human imaging protocols were approved by the IRB. Sodium imaging was performed on a clinical 3.0 Tesla scanner (GE Healthcare, WI) equipped with multi-nuclear capabilities with a single-tuned birdcage RF coil and using a modified flexible twisted projection imaging pulse sequence. This sequence allowed choice of resolution and minimized TE to less than 0.31ms. Typically, 5 mm isotropic acquisition resolution was used and quantified using a calibration phantom with three sodium concentrations (30, 70, 110mM) covering the biologically important range acquired under the same conditions as the patient. Imaging was performed weekly during the 6 weeks of radiation treatment across three patients. Images were aligned in post processing and the transformation was applied to the k-space data for reconstruction without further blurring after the gridding of the time domain projection data. The quantitative TSC maps were examined on a voxel-wise basis to classify the temporal response of each voxel into one of 5 groups: normal TSC (A), decreasing edema (B), no response at elevated TSC (C), cell kill with increasing TSC (D) and elevated TSC that decreases inadequately (E).

Results: Figure 1 shows the representative temporal responses for TSC in the surgical bed of a partially resected glioma multiforme of one patient during radiation treatment. Voxels were classified by response. In this patient who showed recurrence of tumor at two months after treatment, group C voxels were extensively present and in the region of recurrence. The group D responses could be simulated in a standard radiobiologic model to derive the cell kill as 6% per Gray radiation dose as shown in **Figure 2**.

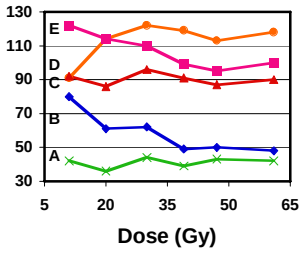

Figure 1. Temporal responses of TSC (mM) in the radiation portal as a function of the accumulated radiation dose (Gy). The C pattern indicates a lack of radiation response and was the site of recurrence.

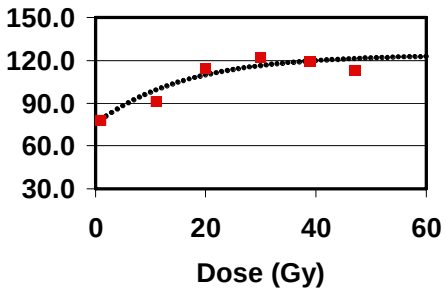

Figure 2. Radiobiologic simulation of the D pattern of response of TSC estimates the cell kill as 6% per Gy that saturates at half way through the treatment.

Conclusions: Quantitative sodium imaging can be performed on a clinical service to follow radiation response of brain tumors and may be predictive of the location of tumor recurrence thereby allowing modification of treatment protocol to improve outcome.

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Reference:

1. Boada FE, et al. Fast three dimensional sodium imaging. Magn Reson Med 1997;37:706-15.