Tissue Mapping in Brain Tumors with Partial Volume Magnetic Resonance Fingerprinting (PV-MRF)

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AUDIENCE: Those interested in quantitative imaging, parameter mapping, MR Fingerprinting, pre-surgical and advanced tumor imaging.

PURPOSE: Magnetic resonance imaging is a standard method used in diagnosing brain tumors and for planning their surgical resection. The recently introduced Magnetic Resonance Fingerprinting (MRF) framework [1, 2] for quantitative imaging provides the ability to perform rapid simultaneous mapping of multiple parameters including, but not limited to, relaxation rates (T_1 and T_2) and proton density. Preliminary clinical studies indicate that MRF parameter maps can be used to quantitatively differentiate between solid tumor parenchyma, peritumoral white matter (PWM), and contralateral white matter (CWM) in patients with gliomas [3]. MRF sequences generate magnetization evolutions which never reach steady state, and as such, different tissue types exhibit different signal evolution behavior in MRF. It was previously demonstrated that modeling single voxel MRF signals as a weighted sum of evolutions from known tissue types can be used to quantify subvoxel tissue fractions in the brain and perform grey matter/white matter/cerebrospinal fluid (GM/WM/CSF) segmentation [1] and that this subvoxel decomposition can provide information which is unique from standard relaxometry parameters [4]. Here we demonstrate that modeling mixed voxel MRF signals as a weighted sum of signal evolutions originating from free (bulk) fluid, intra/extracellular water (IEC water), and myelin water can be used to generate tissue maps in heterogeneous tumors including glioblastoma multiforme (GBM) and metastases of various origins (lung and colon) and may provide information not visible in standard clinical imaging sequences.

MATERIALS & METHODS: In this IRB-approved study, all subjects provided written informed consent prior to participation. Six patients with GBM and 4 patients with tumor metastases in the brain were scanned (3T, Siemens Verio or Skyra; Siemens Medical, Erlangen, Germany) prior to any treatment using an IR-bSSFP based MRF sequence [1, 3] in addition to standard clinical imaging. Later surgical resection and subsequent pathology confirmed tumor type and grade. Tissue fractions were computed pixel-wise from reconstructed MRF images using a 3-component decomposition as described in [4] with the following relaxation parameters set *a priori*: free fluid (T_1=4700ms, T_2=500ms), IEC water (T_1=1300ms, T_2=130ms), myelin water (T_1=130ms, T_2=20ms) [5]. Tissue fractions were normalized such that they summed to 1. Fraction maps were generated to display each component tissue fraction on a scale from 0 to 1. Regions of interest approximately 3mm x 3mm were drawn by a fellowship trained neuroradiologist inside the solid tumor parenchyma, PWM, and CWM. Free fluid fraction, IEC water fraction, and myelin water fraction were compared using a Student's t-test assuming unequal variances.

RESULTS: Representative fraction maps from a glioblastoma patient are shown in Figure 1. Free fluid appears both in the CSF and in regions of severe edema. IEC water fraction is high in healthy cortical GM and near the tumor core. Myelin water fraction appears in normal-appearing CWM but is reduced inside the tumor region. Significant differences in free fluid and IEC water fractions were found in PWM between those with metastases and those with GBMs (Figure 2). Mean free fluid, IEC water, and myelin water fractions in CWM were not found to be significantly different between patients with metastases and those with GBMs.

DISCUSSION: The quantitative partial volume results represent relative abundance of tissues which behave similarly to each fluid component included in the model. The findings suggest relatively more free fluid in the extracellular space of PWM of GBMs compared to that of metastases. Previous studies have also reported less restricted diffusion in regions of edema surrounding high grade gliomas, likely due to destruction of the native extracellular matrix by infiltrative tumor cells [6]. The ability of PV-MRF to detect pathological deviations from normal appearing tissue is a promising technology for diagnosing, monitoring and planning treatment for brain tumor patients.

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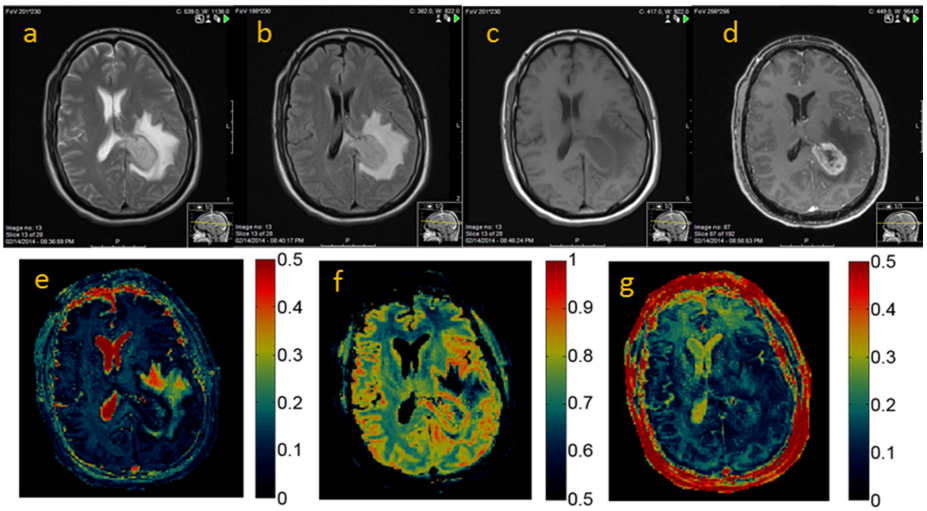

Figure 1 Clinical images & MRF partial volume maps from patient with GBM. T2 weighted (a) FLAIR (b) T1-weighted (c), T1 post-contrast (d), MRF free fluid map (e), MRF intra/extracellular water map (f), and MRF myelin water map (g). Note the reduction of myelin water and increase in IEC water anterior to the tumor that is not seen on any of the conventional imaging sequences.

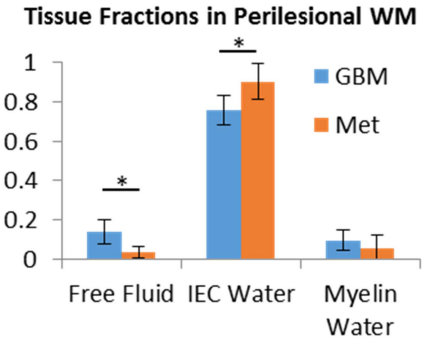

Figure 2 Tissue fraction comparison in perilesional WM. Star indicates p<0.05.