Tissue characterization of Gliomas: Initial clinical experience with Magnetic Resonance Fingerprinting (MRF)

Chaitra Badve[1], Dan Ma[2], Yun Jiang[2], Alice Yu[3], Jeffrey Sunshine[1], Vikas Gulani[1,2], and Mark Griswold[1,2]

[1]Radiology, Case Western Reserve University and University Hospitals Cleveland, Cleveland, Ohio, United States, [2]Biomedical Engineering, Case Western Reserve University, Cleveland, Ohio, United States, [3]School of Medicine, Case Western Reserve University, Cleveland, Ohio, United States

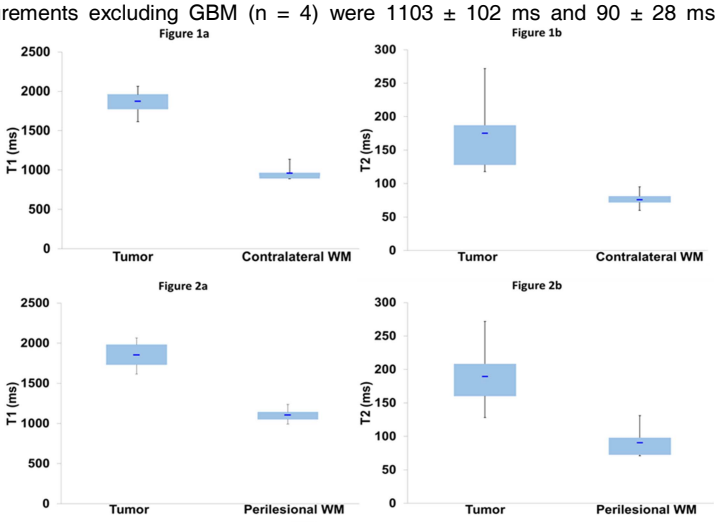
Target Audience: For those who are interested in quantitative imaging and advanced tumor neuroimaging

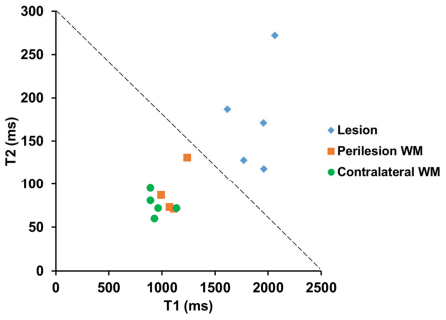
Purpose: Magnetic Resonance Fingerprinting (MRF) allows simultaneous, non-invasive, and rapid quantification of multiple important tissue properties *in vivo*[1]. It allows robust multi-parametric data acquisition, which can be translated into quantitative maps as well as qualitative images designed to match traditional contrast images. Gliomas are the most common primary brain tumors and consist of heterogeneous tumor types ranging from grade I to grade IV tumors (glioblastoma; GBM). This study shows initial clinical experience with the MRF technique for quantitative analysis of gliomas.

Methods: Five patients with gliomas ranging from Grade I to IV; 3 low-grade gliomas (LGG- grade I, II) and 2 high-grade gliomas (HGG- grade III, IV) were scanned using the MRF technique. T_1 and T_2 quantification of solid tumor parenchyma, perilesional white matter signal abnormality, and contralateral white matter was performed. The two tailed Student's t-test for paired data was performed to compare T_1, T_2 values between different locations across the subjects.

TABLE 1	Tumor	Perilesional WM	Normal WM
MRF (Grade 1 to 4)	T_1 = 1873 ± 178.7 T_2 = 175 ± 61	T_1 = 1273 ± 390 T_2 = 101 ± 33	T_1 = 961 ± 102 T_2 = 76 ± 13
Oh et al[2] (Grade 3, 4)	T_2 = 159.5 ± 30.6	T_2 = 203 ± 32.8	T_2 = 78 ± 4.3
Newman et al[3] (Mean range Grade 1 to 4)	T_1 = 1592–3001 T_2 = 111–339	Not reported	Not reported

Results and Discussion: The mean T_1 and T_2 values of the solid tumor parenchyma (n = 5) were 1873 ± 179 ms and 175 ± 61 ms, respectively. The necrotic and cystic foci within the tumor parenchyma were excluded to avoid erroneously high measurements. The mean T_1 and T_2 values of perilesional white matter (PWM) including GBM (n= 5) were 1273 ± 390 ms and 101 ± 33 ms respectively whereas the measurements excluding GBM (n = 4) were 1103 ± 102 ms and 90 ± 28 ms respectively. Similarly, the mean T_1 and T_2 measurements for (n= 5) contralateral normal white matter (CWM) were 961 ± 102 ms and 76 ±13 ms. Few data on *in vivo* T_1 and T_2 relaxometry of tumors are available[2,3] and comparison with previously published data is summarized in Table 1. The obtained results are in good agreement with the limited published literature. The T_1 and T_2 values of solid tumor components were significantly different than T_1, T_2 of contralateral white matter (n=5, $p<0.001$, $p<0.05$) (Fig. 1a, b). Except for GBM, T_1, T_2 values of tumors were significantly different than the T_1, T_2 values of PWM (n=4, $p<0.02$, $p<0.05$) (Fig. 2a, b). GBM measurements were excluded from tumor versus PWM comparison, as this grade IV tumor is always associated with peritumoral neoplastic infiltration, which would yield different T_1, T_2 values compared to non-infiltrated white matter surrounding lower grade lesions. In line with this hypothesis, we found that in our case of GBM, the T_1 and T_2 values of PWM (which showed FLAIR hyperintensity) were nearly identical to the solid tumor component (which showed post contrast enhancement) (peritumoral T_1 = 1953 ms, tumor T_1 = 1958 ms; peritumoral T_2 = 143 ms, tumor T_2= 118ms respectively). There was a trend towards significance for the comparison between T_1 and T_2 values of perilesional and contralateral white matter (n=4, $p<0.17$, $p<0.18$) after excluding measurements in GBM. Figure 3 is a scatterplot of distribution of T_1 and T_2 values for all tumor grades. As seen, the tumor tissue characteristics are distinct from the PWM and CWM, suggesting that it may be possible to quantitatively distinguish normal from neoplastic tissue using this technique. Previously published tumor data are limited either due to lack of T_1 measurements or lack of evaluation of surrounding white matter[2,3]. Our data use a novel precise technique to perform simultaneous T_1 and T_2 quantification of tumor and surrounding white matter regions. The preliminary analysis shows promising results in defining the tumor tissue and further comprehensive analysis on larger dataset to differentiate tumor types (glioma versus metastasis) and types of peritumoral edema (vasogenic versus infiltrative) is being pursued.





Conclusion: This initial clinical experience with MRF demonstrates that relaxation parameter mapping with quantitative analysis can distinguish glial tumors from peritumoral white matter changes and uninvolved white matter. Preliminary evidence also suggests that MRF helps to identify and distinguish regions of infiltrative tumor in higher-grade lesions. Although studies with different types of tumors and larger patient populations are necessary for further exploration of the capabilities of MRF, the present results suggest applications in tumor grading, tumor delineation, pre-treatment and post-treatment evaluation.

Acknowledgement: Supported by NIH grant 1R01EB017219 and Siemens Healthcare

Reference: 1. Ma D, Gulani V, Seiberlich N, et al. Magnetic resonance fingerprinting. *Nature.* 2013; 495:187-192.

2. Oh J, Cha S, Aiken A, et al. Quantitative Apparent Diffusion Coefficients and T2 Relaxation Times in Characterizing Contrast Enhancing Brain Tumors and Regions of Peritumoral Edema. *JMRI.* 2005; 21:701-708.

3. Newman S, Haughton V, Yetkin Z, et al. TI, T2 and proton density measurements in the grading of cerebral gliomas. *Eur Radiol.* 1993; 3:49-52.