Comparison of T1 to T2* Derived Parametric Maps in Brain Tumor Patients

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INTRODUCTION:

Assessment of regional blood volume and blood brain barrier integrity can be very useful in identifying brain tumors and lesions. Specifically, intravenously injected gadolinium (Gd) has been used in MRI to probe brain tissue vascularity due to its effects on T1 and T2*. Assessment of Gd's effects on each MR relaxation constant has proven very helpful in patient care. This study asks which property is more important in assessment of brain tumor grade. That is, are assessments based on dynamic changes in T2* or T1 more likely to benefit brain tumor characterization?

METHODS:

Dynamic contrast enhanced MRIs (DCE-MRI) were performed on a GE Signa 3T scanner with an 8-channel phased array head coil for 18 patients with gliomas of grades varying from 2 to 4. In each patient, two dynamic imaging sequences were used, each with an injection of 20 ml Gd-DTPA. The first dynamic sequence used a T1-weighted 3D spoiled gradient echo (SPGR) sequence (N=12, FOV=26x26x8.4cm^3, res=1.02x1.02x3mm^3, TR=5ms, TE=1.2ms, flip angle = 30°, TA=6:24sec) followed by a post Gd 3D fast (FSPGR) sequence. The second Gd injection was performed during T2*-weighted dynamic echo-planar imaging (EPI) (N=80, FOV=26x26cm^2, res=2.03x2.03mm^2, 15 4mm slices, TR=1500ms, TE=54ms, flip angle = 35°, TA=2:00).

Each T2* and T1 data set was analyzed by fitting a model describing Gd concentration over time to the data in each voxel with nonlinear least squares regression. T1-weighted analyses used an automated technique to select and model voxels representing intravascular space for normalization of parameter values. A two compartment exchange model was then fit to each voxel in the dynamic sequence, with the vascular parameters held fixed as a forcing function [1]. In each voxel, the T1 model output parameters represent the fractional blood volume (f_{BV}: ml blood 100cc^{-1} tissue) and endothelial transfer coefficient (K^{PS}: ml blood 100cc^{-1} tissue sec^{-1}), approximating the permeability surface area product (PS) [1]. The change in MR signal intensity from pre to post Gd injection was assumed proportional to concentration in the T1 model. T2* analyses used an automated gamma-variate model fitting procedure to produce multiple parametric maps [2]. Similar to T1 derived parameters, T2* parameters used here are representative of cerebral blood volume (CBV), as calculated by area under the concentration-time curve, and percent recovery to pre contrast baseline signal. Regions of interest (ROIs) representing contrast enhancing lesion and normal appearing white matter (NAWM) and gray matter (NAGM) were drawn on the FSPGR image, resampled to 1.02x1.02x3mm^3 resolution for direct registration. CBV and recovery maps were resampled to this same resolution. A relative CBV (rCBV) was also calculated by normalizing CBV values from the NAWM mean ROI value.

Parameters representative of tissue vascularity (f_{BV} and CBV) and vascular permeability (K^{PS} and recovery) were directly compared across all patients to assess how well the parametric maps represented the disease state as determined by the histologic tumor grade. Tissue vascularity parameters were also tested for validity by comparing ratios of NAGM and NAWM to published cerebral blood volume ratios of approximately 1.9 – 2.1 [3,4].

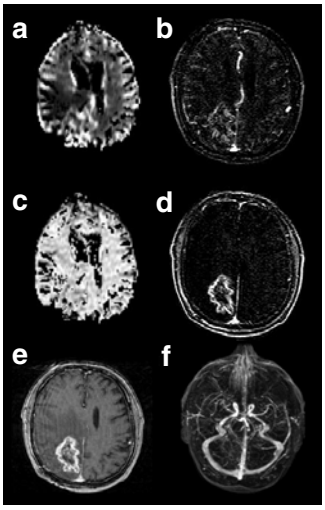
Table 1. ROI averages for T1 derived f_{BV} values (ml blood 100cc^{-1} tissue) in NAGM and NAWM and their ratios are shown. T2* derived GM:WM ratios, or rCBV in NAGM, are also displayed. (* - Data not available for these patients)

Patient	NAGM f_{BV}	NAWM f_{BV}	T1 GM:WM ratio	T2* GM:WM ratio
1	3.97	2.58	1.54	1.10
2	4.63	2.25	2.06	5.43
3	4.54	1.74	2.61	*
4	2.90	1.07	2.71	2.90
5	4.17	1.91	2.18	1.47
6	3.33	2.28	1.46	2.12
8	2.60	1.13	2.30	1.81
9	3.38	1.78	1.90	*
10	2.95	1.88	1.57	*
11	3.56	1.85	1.92	2.22
12	4.02	1.95	2.06	1.15
13	4.38	2.45	1.79	1.12
14	8.70	3.63	2.40	2.67
15	2.26	1.39	1.63	1.51
16	5.12	3.18	1.61	*
17	5.56	2.54	2.19	2.53
18	3.28	1.76	1.86	2.14
average	4.08	2.08	1.99	2.17
SD	1.49	0.67	0.38	1.15

RESULTS:

Figure 1 shows representative images of a grade 4 glioma. T2* derived CBV maps (Figure 1.a) show values that do not contrast greatly between NAGM and tumor, while T1 derived f_{BV} maps (Figure 1.b) show a strong distinction between tumor (and blood vessels) and other tissues. A maximum intensity projection (MIP) of the 3D f_{BV} map is shown in Figure 1.f. The resolution allows the sagittal, transverse, and straight sinuses to be readily apparent, as well as smaller vessels in the brain. The T2* signal recovery maps (Figure 1.c) do not seem to show any visible differences from healthy to diseased tissue, yet the K^{PS} maps (Figure 1.d) clearly highlight the tumor. The post Gd FSPGR image (Figure 1.e) was used to draw representative ROIs. T2*-weighted images also showed a varying amount of image warping artifacts due to the EPI technique. This artifact was not seen in the T1-weighted images.

Measured f_{BV} values correlate well with published results [3]. This is seen in Table 1 along with GM:WM ratios that correlate well with literature in both T1 and T2* techniques [3,4]. K^{PS} was the only parameter to show a significant correlation with histologic tumor grade, shown in Figure 2.



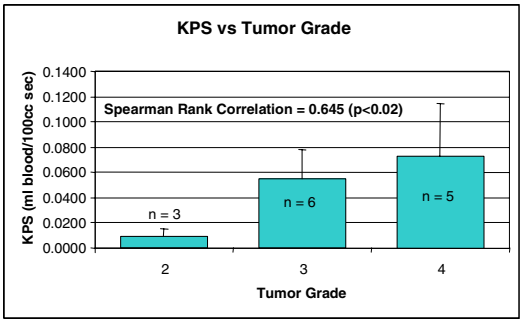


Figure 1. (left) Representative images of our results in a grade 4 tumor: **a.** and **c.** are the T2* derived CBV and recovery maps, ranging from 0 to 6000 and 0 to 100%, respectively; **b.** and **d.** are the T1 derived f_{BV} and K^{PS} maps, ranging from 0 to 25 and 0 to 0.15, respectively; **e.** is the post Gd FSPGR image used for ROI designation; and **f.** is a MIP of the f_{BV} map, ranging from 0 to 100.
Figure 2. (top) Spearman rank correlation of ROI average K^{PS} versus histologic tumor grade.

DISCUSSION:

This study shows that T1 derived parametric maps can be very useful in assessing brain tumor patient disease state. A significant correlation between K^{PS} and tumor grade is an extremely important finding for early treatment planning of brain tumors. In addition, compared to T2* techniques, T1 weighted images can be acquired with improved resolution (and thus less partial-volume effects), greater coverage, and less image distortion.

It is also important to note that parameter values for f_{BV} have absolute units that correlate very well with previously published values, which is a strong point of validation for this technique. T2* derived GM:WM ratios also correlate well with literature, implying a valid comparison across these two methods.

CONCLUSION:

This study shows that while T2* derived parameters are a valid tool to aid in brain tumor characterization, T1-weighted techniques are also useful. In fact, due to improved resolution, greater volume of coverage, less image warping artifacts, and increased specificity (as shown by the significant correlation of KPS and tumor grade), T1 derived vascular parameters may be more useful than T2* derived parameters in the clinical assessment of brain tumors.

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