CHARACTERIZATION OF BRAIN TUMOR USING HIGH ORDER DIFFUSION IMAGING

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INTRODUCTION: Brain neoplasms are typically characterized by contrast enhanced T1 imaging. Depending on the course of treatment, tumor reoccurrence remains a possibility, and can be difficult to distinguish from other enhancing areas, for example post-treatment radiation effects (PTRE), typically necrosis [1]. Further, detailed information about the tumor heterogeneity as detected by standard MR methods is not generally available, but can play a significant role in characterizing and grading the tumor. In this work, a simple multi-b-value DWI sequence has been developed to better understand the heterogeneity and diffusion characteristics of different types of tumors, encountered during routine clinical scanning. The signal decay is fitted with two recently developed diffusion models: a stretched exponential (α-DWI) [2] and a cumulant expansion (DKI) [3] model, where fitted parameters α and K_{app} were shown to correlate the diffusion heterogeneity. We expected to see differences in alpha and K when the multi-b-value DWI sequence directed to the anatomy of interest, primarily due the heterogeneity of the more advanced tumors.

METHOD: Five patients to date meeting inclusion criteria have been scanned, with Institutional Board Approval. Of these, three patients had recurrent glial tumor, one had metastatic disease, and one was a low grade glioma. Echo planar imaging (EPI) sequences were implemented on a GE 3T scanner with 40 mT/m gradients. DWI images were acquired with three gradient directions (X, Y, and Z axes) and six b-values (0, 500, 1000, 1500, 2000, 2500 s/mm^2). Other imaging parameters were: TR/TE = 4000/104 ms, NEX = 6, and slice thickness = 5mm, FOV = 240 × 240 mm^2, and matrix = 128 × 128. Two regions were selected for ROI analysis: Tumoral in areas of contrast enhancemet and peritumoral defined by the region of abnormal T2 signal outside of the enhancing regions. Stretched exponential and second-order cumulant models were fitted to the data using the Levenberg-Marquardt algorithm in MATLAB (Mathworks, Inc.). Data below the noise floor were excluded from the data fitting.

RESULTS: Figure 1 shows the parametric maps of five tumor cases. α and K_{app} maps exhibited a well-circumscribed region in metastasis (1a), suggesting intact neurons around the tumor. The boundary of low-grade gliomas (1b) is relatively well defined by a vasogenic edema, with an increased ADC and reduced heterogeneity (higher α and lower K_{app}). In contrast, a poorly defined boundary in high-grade gliomas (1c-e), suggests infiltration. In particular, the area of increased heterogeneity (lower α) in (1e) demonstrates tumor regrowth on the posterior aspect of the ressected area (arrow). Table 1 shows quantitative analysis, depicting consistently higher average heterogeneity in the tumoral regions than the peritumoral regions (lower α and higher K_{app}) for the high-grade tumors. (1c-e). Lowered ADC reflects the higher cellularity in tumoral regions, except in the metastatic case (1a) where the ADC is much higher suggesting modified cellularity. Additional patient scanning is ongoing.

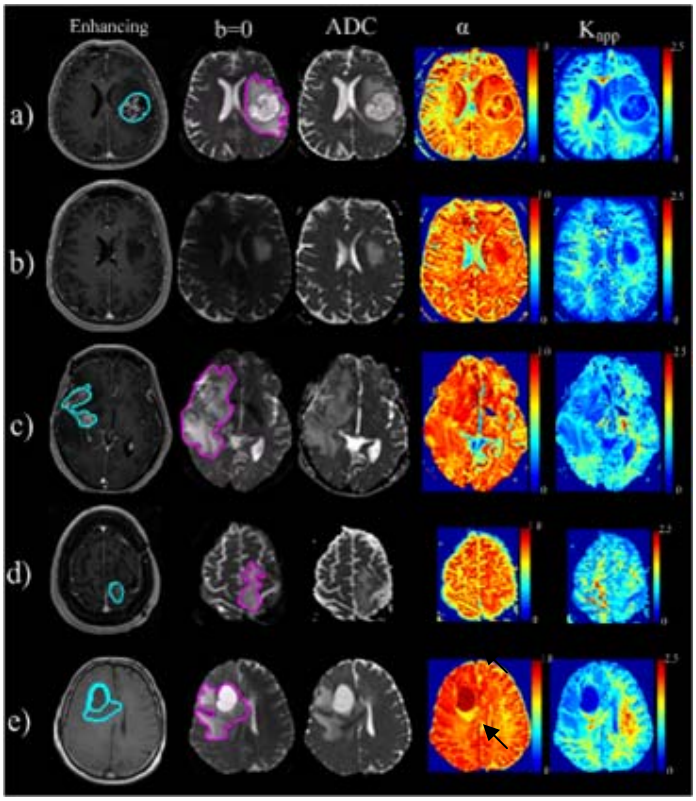

Figure 1 Five cases of brain tumor: (a) metastasis, (b) low-grade gliomas, (c)-(e) high-grade gliomas.

DISCUSSION: This work demonstrated the feasibility of using higher order diffusion models to further understand the brain tumor pathology and differentiation of tumor types. The shown increased heterogeneity in the tumoral region is also consistent with the previous study of animal and human high-grade gliomas [4, 5]. In addition, we found that there exists a mismatch among the regions of heterogeneity by α and K_{app} maps and enhancing regions. This shows the potential of using both the index α and K_{app} together to study brain tumors.

REFERENCE: [1] Provenzale JM,et al, Radiol (239), 632-649, 2006. [2] Bennett KM, et al, MRM (50), 727-734, 2003. [3] Jensen JH, et al, MRM (53), 1432-1440, 2005. [4] Bennett KM, et al, MRM (52), 994-1004, 2004. [5] Kwee TC, et al, NMR biomed, in press, Sep 23, 2009.

Table 1 Values of ADC (×10^{-3}mm^2/s), α, and K_{app} of tumoral and peritumoral regions

Tumor type	Metastasis		High grade Gliomas					
case	a		c		d		e	
ROI	Tumor	Peri	Tumor	Peri	Tumor	Peri	Tumor	Peri
ADC	2.90± 0.50	1.80± 0.40	1.70± 0.70	2.00± 0.20	1.50± 0.15	1.7± 0.46	1.20± 0.34	1.70± 0.35
α	0.78± 0.12	0.77± 0.05	0.76± 0.08	0.80± 0.03	0.76± 0.04	0.77± 0.04	0.73± 0.08	0.79± .0.04
K_{app}	0.36± 0.15	0.58± 0.14	0.55± 0.14	0.46± 0.07	0.60± 0.06	0.55± 0.07	0.84± 0.24	0.55± 0.17