Comparison of Introvoxel Incoherent Motion diffusion-weighted MR imaging and Arterial Spin labeling MR imaging in gliomas

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Target Audience: neurosurgeon, oncologist, Radiologist

Purpose: To investigate value of intra-voxel incoherent motion (IVIM) diffusion-weighted imaging(DWI) in glioma grading by comparing perfusion imaging parameters between IVIM and Arterial Spin labeling (ASL) imaging.

Materials and Methods: Twenty-four patients with low (WHO grade I–II) and high (III–IV) grade gliomas underwent Diffusion weighted imaging (DWI) and three dimensional pseudo-continuous arterial spin labeling (3D pCASL) MR imaging before surgery on 3T magnetic resonance (MR) scanner (Discovery MR750 System; GE Medical Systems, Milwaukee, WI, USA). DWI with twenty b values from 0 s/mm^2 to 3,500s/mm^2 (i.e. 0, 10, 20, 40, 80, 110, 140, 170, 200, 300, 400, 500, 600, 700, 800, 900, 1,000, 2,000, 3,000, 3,500 s/mm^2, TR/TE= 3000/87.5ms, field of view (FOV) = 24.0 cm, base resolution = 128 × 128,slice thickness = 5.0 mm, intersection gap = 1.5 mm, and a bandwidth = 250 Hz) were applied and processed by IVIM bi-exponential model to generate parametric images for a fast diffusion coefficient D*, slow diffusion coefficient D, and fractional perfusion-related volume *f*. Cerebral blood flow (CBF) was quantified by three dimensional pseudo-continuous arterial spin labeling (3D Pcasl, background suppression, and a stack of spirals of 3D fast spin echo imaging sequences,512 sampling points on eight spirals, TR/TE = 5327/10.5 ms, post label delay (PLD) = 1.5 s, FOV = 24.0 cm, bandwidth = ± 62.5 KHz, slice thickness = 4.0 mm, number of slices = 36, NEX = 3.0) data. Regions of interests (ROIs) were drawn in tumors and normal white matter (WM) in the contralateral semi-oval center as reference. Imaging parameters of D*, D and *f* from DWI and CBF from were compared between high with low grade tumors, respectively. Values of CBF were further correlated with D* and *f*, respectively, correlation analyses were separately performed in tissues of tumor and contralateral normal WM.

Results: Imaging presentations of each parameters in high grade glioma were shown in figure1, and low grade glioma were shown in figure 2.The *f* and D values of high grade gliomas were lower than those of low grade gliomas($P < 0.05$ and $P < 0.01$, respectively), the CBF values of high grade gliomas were significantly higher than those of low grade gliomas ($P < 0.05$). No difference of D* values (standardization by dividing the contralateral normal WM) was found between high- and low grade tumors (Table 1&2). In tumor tissues, CBF values were positively correlated with D*values (r= 0.712, $P<0.001$) , and negatively correlated with *f* values (r= -0.586,P<0.05). In contralateral normal WM tissues, CBF values were positively correlated with D* values (r=0.561, $P < 0.01$), instead of *f* values ($P > 0.05$). Moreover, bi-exponential model fitted curves shows that signal attenuation characteristics were well fitted b values. Along with increases of b values, group differences of diffusion signal intensities between tumor and normal tissues (Fig. 1g and 2g).

Discussion: This study used more and greater b values in contrast to previous works in gliomas, [1, 2], which might be better to reflect molecular diffusion and perfusion-related diffusion properties [3, 4, 5]. Lower D values were found in the higher grade gliomas, which may reflect limited Brownian motion of water molecules in smaller intercellular gaps in high grade gliomas. *f* partially reflect perfusion property, can demonstrate clearly delineated the edge between tumor and edema. Lower *f* values was found in the high grade gliomas, which was inconsistent with previous report[1]. We speculated that this inconsistence might be induced by different TE. Positive correlation between D* value and CBF implicate that D* can also provide information of perfusion feature of brain tissue.

Conclusion: IVIM has capability for detecting differences of diffusion and perfusion properties between low-grade and high-grade gliomas, and has potential as a non-invasive tool for assessment of brain glioma.

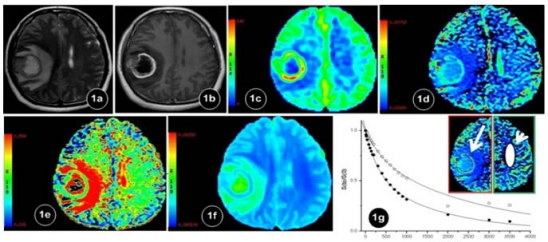

Figure1. An example of high grade glioma *(a* 43-yrs old female, with aglioblastoma of the right parietal lobe, WHO IV). Axial T2WI (a) and gadolinium contrast enhanced T1WI (b). The concrete of tumor shows apparent enhancement. CBF map (c) shows that the tumor with unevenly high perfusion. The D* map (d) demonstrates increased fast diffusion values in the tumor tissue, which is in agreement with the CBF. The *f* map (e) demonstrates clearly the edge between tumor and edema. The D map (f) fails to delineate the tumor clearly, but better describes the scope of peritumoral edema. The logarithmic plot of signal intensity decays as a function of b with a corresponding bi-exponential fit (g): the mass (arrow and solid circles) and contralateral semi-oval center (arrow head and hollow circles).

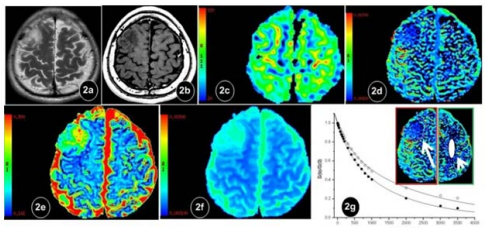

Figure 2. An example of low grade glioma *(a* 33-yrs old male, with an astrocytoma glioma in the right parietal WHO II) The mass was hyperintensive with a fuzzy edge in axial T2WI (a) and without any gadolinium enhancement (b). It shows slight perfusion in the CBF map (c) but fails to distinguish the boundaries of the tumor from normal brain substance. The D* map (d) and *f* map (e) well demonstrate the borderlines of the tumor as an enhancement image. The *f* map also shows an inhomogeneous intrinsic hyperintensity in the tumor. The D map (f) fails to delineate internal details of the tumor, but better describes the scope of peritumoral edema. The logarithmic plot of signal intensity decay as function of b with corresponding bi-exponential fit (g) of the tumor (arrow and solid circles) and contralateral semi-oval center (arrow head and hollow circles).

Table 1. Descriptive statistics of the IVIM - derived parameters in high and low grade gliomas as well as in contralateral healthy semi-oval center of two groups using Student t test or the Satterthwaite approximate t Test.

		HGG	LGG	*P*-value(HGG vs. LGG)
Tumor	D*	4.53 ± 2.96	2.63 ± 0.44	**0.041**
	D	0.66 ± 0.08	0.81 ± 0.09	**0.000**
	f	34 ± 11 %	47 ± 11 %	**0.011**
WM	D*	2.45 ± 0.16	2.47 ± 0.19	0.795
	D	0.38 ± 0.02	0.38 ± 0.02	0.968
	f	28 ± 2 %	29 ± 1 %	0.346
Tumor/ WM	rD*	1.93 ± 1.49	1.09 ± 0.18	0.065
	rD	1.72 ± 0.21	2.12 ± 0.23	**0.000**
	rf	1.20 ± 0.37	1.62 ± 0.38	**0.012**

Significant P values are indicated in bold italics. D*, D in 10^{-3} mm/s, and *f* in percentage. HGG high grade gliomas, LGG low grade gliomas, WM contralateral semi-oval center.

Table 2. Summary of CBF in high and low grade glioma and in contralateral semi-oval center of two groups using the Student t Test.

	HGG	LGG	*P*-value (HGG vs. LGG)
CBF in tumor	102.11 ± 50.49	67.33± 20.17	**0.044**
CBF in WM	23.30 ± 3.77	27.32 ± 8.51	0.138
rCBF (CBF in tumor/ WM)	4.39 ± 2.31	2.76 ± 1.10	**0.044**

Significant *P* values are indicated in bold italics. TBF and CBF are in ml/100g/min. HGG high grade gliomas, LGG low grade gliomas, WM contralateral semi-oval center.

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