INTRAVOXEL INCOHERENT MOTION MR IMAGING AND DYNAMIC CONTRAST-ENHANCED MRI IN BRAIN TUMORS: CORRELATION OF QUANTITATIVE AND SEMI-QUANTITATIVE PARAMETERS

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Target Audience: MR physicists and radiologists.

Purpose: Intravoxel incoherent motion (IVIM) MRI can be used to obtain information about tissue microcapillary perfusion properties based on diffusion-weighted acquisitions.[1] The validity and physiologic interpretation of this information remains controversial due to technical and methodological issues. Therefore, we compare perfusion-related parameters obtained by IVIM measurements with cerebral blood volume and flow (CBV,CBF)[2] as well as semi-quantitative parameters retrieved from dynamic-contrast-enhanced (DCE) MRI in tumorous and normal-appearing white matter.

Materials and Methods: 9 patients with (multiple) gliomas were examined on a 3-Tesla whole-body MRI system. IVIM measurements were performed with a single-shot EPI sequence (spatial resolution 1.7×1.7×3mm³ (20 slices), TR/TE=5000/60ms, 3 averages, 10 b-values (0-1000s/mm²)). Afterwards, the patients underwent DCE-MRI using an view-sharing 3D gradient-echo sequence (TE/TR=0.86/2.29ms) acquiring 200 volumes after double-bolus injection of 0.1mmol/kg Gadobutrol (temporal resolution 2.1s, spatial resolution 2×2×3mm³). Regions of interest (ROIs) were drawn in tumorous tissue (excluding necrosis) and normal-appearing white matter, resulting in a total of 26 ROIs. The IVIM parameters *D* (tissue diffusivity), *f* (perfusion fraction) and *D**(pseudo diffusivity) were determined by fitting the signal attenuation to a biexponential model.[1] DCE data was quantitatively analyzed with a 2-compartment exchange (2CX), uptake (2CU), and Tofts (2CT) model;[2,3] for each ROI, the most appropriate model was selected with the Akaike information criterion.[3] Additionally, semi-quantitative area-under-the-curve (AuC) and maximum signal enhancement (SE_{max}) values were obtained from DCE measurement. Taking the different relaxation times of white matter and blood [5,6] and the water content fraction of white matter into account, CBV_{IVIM} was calculated from our median *f* value in white matter.[4] Using this CBV_{IVIM}, the median *D** in white matter, and values for the capillary geometry in the cat brain cortex [7], CBF_{IVIM} was estimated.[4] Pearson's correlation coefficients between IVIM and DCE MRI parameters were calculated.

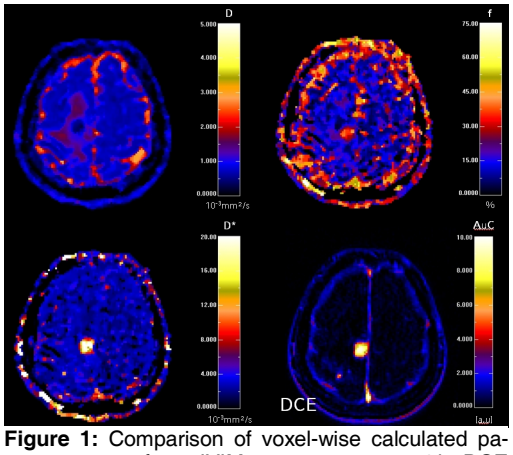

Figure 1: Comparison of voxel-wise calculated parameter mapsfrom IVIM measurements with DCE area-under-the-curve map

Results: Median values and standard deviations of IVIM and DCE parameters are summarized in Table 2. Table 1 lists Pearson's correlation coefficients between IVIM and DCE-MRI parameters as well as their respective p-values. IVIM parameter maps show similar features as DCE-MRI AuC maps (Fig. 1). CBV_{IVIM} = 4.58 ml/100ml and CBF_{IVIM} = 23.60 ml/100ml/min are of the same order as the calculated DCE values and in good agreement with literature values.[2]

Table 1: Median values(±standard deviation) of IVIM and DCE parameters

	f[%]	*D*[mm²/10³s]	*D*[mm²/10³s]	CBV[ml/100ml]	CBF[ml/100ml/min]	AuC	SE_{max}
Tumorous tissue	18.82±4.60	0.95±0.18	3.63±0.71	5.72±3.16	49.87±36.05	14379±5212	60.10±30.13
Normal-appearing white matter	10.68±2.10	0.67±0.7	3.09±0.40	1.02±0.36	15.60±29.07	1364±285	7.90±2.10

Table 2: Pearson's correlation coefficients (and p-values) between IVIM and DCE parameters

	D		*f*		*D**		*D**×*f*	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*
CBV	***0.548***	***0.0038***	***0.686***	***<0.0002***	*0.298*	*0.1395*	***0.743***	***<0.0001***
CBF	***0.563***	***0.0028***	***0.588***	***0.0016***	*0.266*	*0.1895*	***0.649***	***<0.0004***
SE_{max}	***0.747***	***<0.0001***	***0.792***	***<0.0001***	*0.348*	*0.0812*	***0.848***	***<0.0001***
AuC	***0.788***	***<0.0001***	***0.804***	***<0.0001***	***0.423***	***0.0314***	***0.888***	***<0.0001***

Conclusions: The IVIM perfusion fraction *f* correlates well with CBV and CBF (Table 2) as well as with AuC and SE_{max} (Fig. 2), indicating that IVIM yields perfusion-related information. The fact that there is no significant correlation between *D** and CBF suggests that the CBF increase in the examined tumors is rather due to a higher capillary count than increased blood velocity. All of the DCE parameters correlate best with the product *D**×*f* (Table 2, Fig. 2), which reflects a "makeshift flow" [4] and is therefore likely to be the best indicator for tissue-perfusion changes.

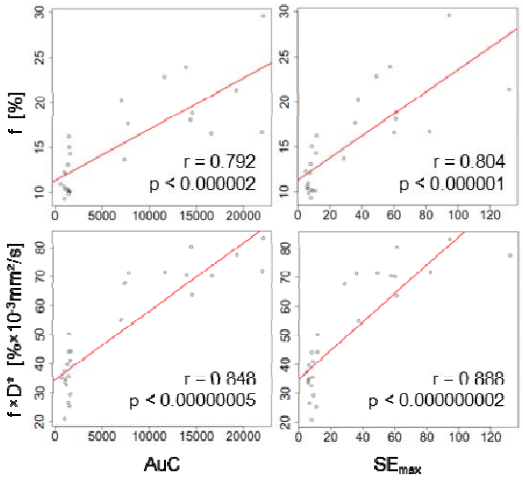

Figure 2: Correlations between *f* and AuC, *f* and SE_{max}, the product *f*×*D** and AuC, as well as between f×D* and SE_{max}

References: [1] Le Bihan D et al. Radiology 1988;168:497-505,[2] Sourbron et al. MRM 2009;62:205-217,[3] Ingrisch M et al. Invest Radiol 2012;47:252-258,[4] Le Bihan&Turner MRM 1992;27:171-178, [5] Lemke et al. Magn Reson Med 2010;64:1580-1585, [6] Stanisz et al. Magn Reson Med 2005;54:507-512, [7] Pawlik et al. Brain Res 1981;208:35-58