Towards clinical implementation of IVIM analysis in brain tumors: Influence of cerebrospinal fluid contamination on the perfusion fraction

Sotirios Bisdas[1], Christian Braun[2], Ulrike Ernemann[1], and Uwe Klose[1]
[1]*Neuroradiology, Eberhard Karls University, Tübingen, Germany,* [2]*Neurology, Eberhard Karls University, Germany*

Target Audience: Researchers & clinicians working in the field of quantitative MRI, diffusion-weighted brain MRI, and brain tumor imaging

Purpose: Recent reports on the intravoxel incoherent motion (IVIM)-based DWI analysis stressed out the potential of the method to estimate perfusion in brain tumors.[1,2] However, the IVIM-modeled DWI in brain has a major inherent shortcoming: the partial volume of CSF induces a non-uniform pattern similar to blood. We sought to examine whether the influence of CSF signal on the calculated perfusion fraction (f*)* in brain tissue and tumors can be estimated, if measurements with two different echo times were performed.

Methods: We performed DWI experiments with multiple b-values and with two echo times. Eight patients (4 women, 4 men; median age, 58 years) with brain tumors underwent DWI prior to any treatment. Imaging was performed in a 3T MR scanner (Magnetom Verio; Siemens, Germany). DWI was performed twice with two different TEs based on standard single-shot DW SE-EPI using monopolar Stejskal-Tanner implementation with the following parameters: TR/TE1/TE2 of 3300/60/150 ms. slice thickness 7 mm, FOV 250 mm, matrix 128*128. The axial, 3-scan-trace DW-images were acquired with 7 b-values ranging from 0-150 s/mm^2 and 3 b-values from 700-1300 s/mm^2. In all patients ROIs with 5*5 pixel extension were placed in tumor tissue and gray and white matter. Data evaluation was performed with a 2-step fitting procedure: a monoexponential fit was performed using the signal acquired with the three larger b-values. The difference of all signal intensities to the fitted line was again fitted by monoexponential decay. The f-values were calculated from the signals at b=0 from both fits.

Results: Examples for the selected ROIs are shown in Fig.1. With both echo times, the evaluated mean signal intensities could be fitted by the two-step fitting procedure (Fig.2). The calculated f-values are shown in Tab.1. The f in gray matter was higher in the TE2 measurements indicating that the fast decaying signal component had long T2, as expected for CSF. In tumor tissue, the calculated f value showed a slight decrease.

Discussion: The T2-value of blood is slightly higher than the T2 of white matter and shorter than the T2 of tumor tissue (the transverse relaxation rate of blood, which is proportional to the fraction of deoxyhemoglobin, increases in tumor due to hypoxia).[3] This explains the slight increase of the f in white matter and the slight decrease in tumor. The influence of CSF in white matter and tumor tissue seems to remain small. On the other hand, the increase of f in gray matter indicates a strong signal contribution of CSF. Therefore, the IVIM method seems to be inadequate for the evaluation of gray matter ROIs with considerable CSF contribution, but it is sufficient for ROIs in white matter and tumor tissue.

Conclusion: The described effects are important for the clinical implementation of IVIM analysis for the primary tumor diagnosis as well as for the longitudinal follow-up of the treated brain lesions.

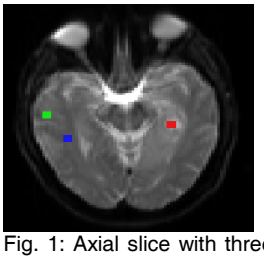

Fig. 1: Axial slice with three selected region within tumor (red), white matter (blue) and gray matter (green)

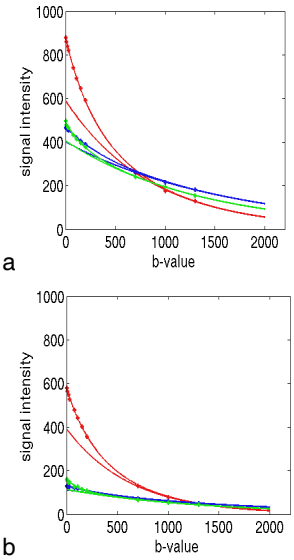

Fig.2: Biexponential signal decay in the selected regions. Symbols show the measured mean signal intensity, lines the fitting of the slowly decaying component and the result of the sum of both fits after an additional fit of the remaining fast decaying component, for TE = 60 ms (a), 150 ms (b).

TE	white matter	gray matter	tumor tissue
60 ms	0.13 ± 0.03	0.25±0.13	0.16±0.10
150 ms	0.15 ± 0.03	0.36±0.15	0.15±0.15
p-value	0.09	0.0011	0.09

Tab.1: f values with both TEs

References:

1. Bisdas S, Koh TS, Roder C, et al. Intravoxel incoherent motion diffusion-weighted MR imaging of gliomas: feasibility of the method and initial results. Neuroradiology. 2013. doi:10.1007/s00234-013-1229-7.
2. Federau C, Meuli R, O'Brien K, et al. Perfusion Measurement in Brain Gliomas with Intravoxel Incoherent Motion MRI. AJNR Am J Neuroradiol. 2013. doi:10.3174/ajnr.A3686.
3. Meyer ME, Yu O, Eclancher B, et al. NMR relaxation rates and blood oxygenation level. Magn Reson Med. 1995;34:234-41.