Quantitative OEF Determination in Tumor Patients Using Additional DSC Measurements

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Introduction:

A very important parameter for investigating tissue viability is the local oxygen consumption. A model of static dephasing magnetization [1] can be used to measure the quantitative fraction of oxygen, which is transferred from the arterial blood into the tissue. This model has already been tested with promising results [2]. In this study, a GESSE sequence [3] is applied for *in vivo* measurements in brain tumor patients, to examine the tissue viability inside and outside the tumor region. Furthermore, a 3DGRE sequence is used to remove macroscopic field inhomogeneities. One specific feature of this work is the combination of the method mentioned above and a dynamic susceptibility contrast (DSC) measurement used to measure the cerebral blood volume (CBV).

Methods:

Measurement of the oxygen extraction fraction (OEF) of brain tissue was performed by a gradient-echo sampled spin-echo sequence (GESSE, resolution: 2x2x6mm^3, TR/TE$_1$=1500ms/55ms, Δt_E=3.5ms, FoV=256x208 mm^2, B_0=3T). Hereby, the signal around a spin echo is sampled by a number *n=31* of gradient echoes. A tissue model by Yablonskiy [1] enables simultaneous determination of the CBV, the irreversible relaxation rate R_2 and the reversible relaxation rate R_2'. To remove macroscopic field inhomogeneities originating e.g. from air/tissue-interfaces, multiple slices of high-resolved phase images were acquired within the thicker GESSE slice, using a multi echo 3D gradient-echo (GRE) train (resolution: 1x1x2 mm^3). Following a 3D phase unwrapping, a non linear least square curve fit was calculated to create the gradient field maps in three dimensions. Thereby, correction of acquired data was performed under the assumption that the presence of macroscopic linear gradients results in a, on the signal super positioned, time- and gradient-dependent *sinc*-funtion. In a three parameter OEF-model two parameters (R_2' and CBV) were used for further analysis. If these parameters are determined using two different methods, the likelihood of reaching an accurate result is larger. Therefore, an additional invasive perfusion measurement with Gd-DTPA as a contrast agent was performed to determine CBV independently of R_2'. An echo train of 50 T_2*-weighted pictures was recorded during contrast agent injection and the Mean Transit Time (MTT) and the Cerebral Blood Flow (CBF), which are input parameters for CBV calculation, have been calculated.

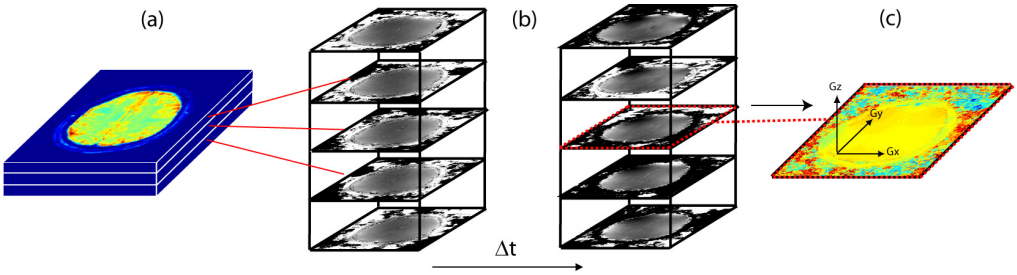

Figure 1. *Measurement method: GESSE-slice (a), set of phase images acquired at different times (b), resulting ΔB-Map and the gradients for one GRE-slice (c), the resulting relevant GRE gradient maps are averaged and downscaled to the GESSE resolution before used for further analysis.*

Results:

Figure 2a shows a transversal slice of a patient who has an acoustic neuroma. The DSC perfusion measurement implies stable CBV values of the tissue (Figure 2b). It can be seen that there is a significant increase of the CBV value in the affected region (TR) compared to that of the healthy region (HR). The mean CVB values are 4.2% (HR) and 8% (TR). Using Yablonskiy's tissue model with both CBV and R2' as input parameters shows that in the brain-tumor-affected area the OEF value is strongly decreased (Figure 2c). In the healthy brain area, the calculated mean OEF value adds up to 38%, while a reduction by a factor of 1.34 can be seen in the tumorous brain area, resulting in an average value of 28%.

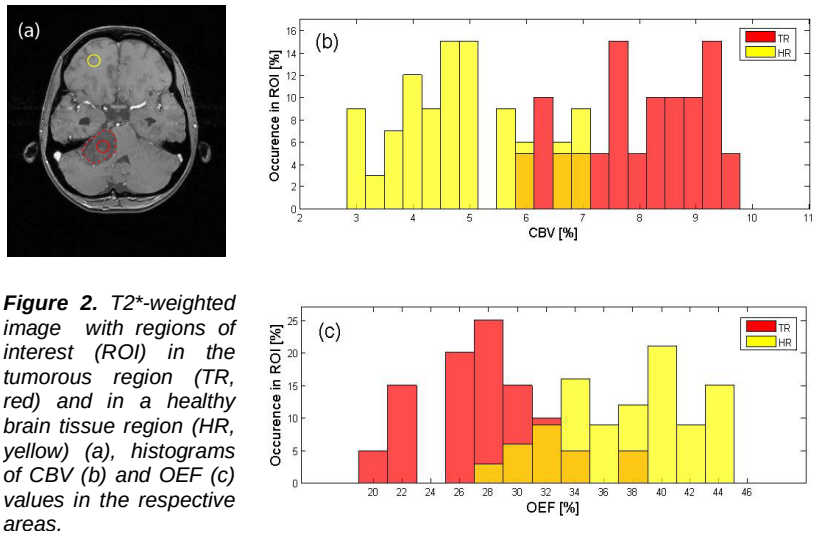

Figure 2. *T2*-weighted image with regions of interest (ROI) in the tumorous region (TR, red) and in a healthy brain tissue region (HR, yellow) (a), histograms of CBV (b) and OEF (c) values in the respective areas.*

Discussion:

In this study a new approach for *in vivo* OEF measurement is used. The problems that occur with simultaneous estimation of CBV and R_2' are avoided by an additionally invasive CBV measurement. This reduces the number of fitting parameters by one, which leads to a much more stable parameter fit. The investigated area of the brain tumor shows a significant different OEF value than a healthy region of the brain. The development of a technique for verification of the oxygen extraction fraction is of high interest particularly in the field of neuroradiology, since tissue with decreased OEF is less viable. This new technique based on a macroscopic inhomogeneities corrected determination of the reversible relaxation rate R_2' and on an external DSC-determination of the cerebral blood volume, enables a new possibility of stable *in vivo* OEF determination.

References:

[1] Yablonskiy et al. *Magn Reson Med*, 32, 749-63 (1994)
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[3] Yablonskiy *Magn Reson Med*, 39, 417-428 (1998)