Quantitative OEF Determination by Separate T2 and T2* Mapping

M. B. Mie[1], and L. R. Schad[1]
[1]Computer Assisted Clinical Medicine, Heidelberg University, Mannheim, Germany

Introduction:

The knowledge about tissue oxygen supply provides important information about the viability of the tissue. In oncology, the measurement of oxygenation is of great interest, because tumor oxygenation is an indicator of aggressiveness and affinity to metastazation [1]. Moreover, the chance of success of a radiation therapy or chemo therapy depends on the oxygen partial pressure of the tumorous tissue [2]. That is the reason why hypoxia is a large obstacle to tumor therapy [3]. In this study, a model of static dephasing magnetization [4] can be used to measure the oxygen extraction fraction (OEF) by using a gradient echo sampled spin echo (GESSE) sequence. This model has already been tested with promising results [5,6]. A disadvantage of this technique is, that the reversible relaxation rate R_2', the irreversible relaxation rate R_2 and the deoxygenated blood volume λ are determined simultaneously with one fit. This results in an uncertainty of the fitted parameters. Here, the parameters R_2 and R_2^* are determined independently by separate measurements, resulting in much more stable fit parameters.

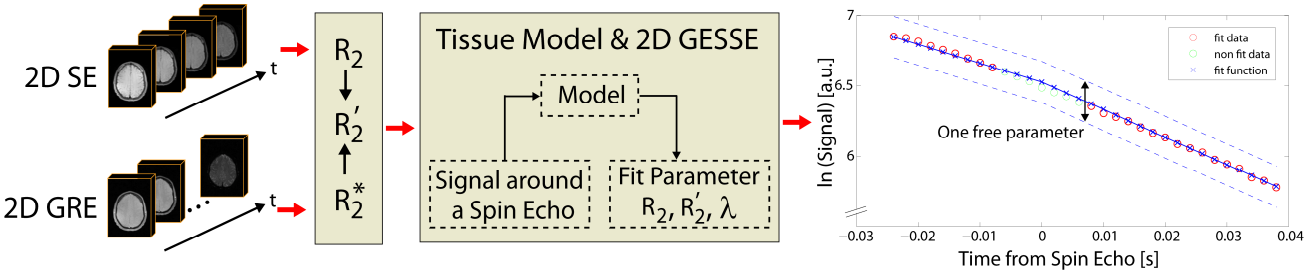

Figure 1. *Experimental Setup. At first, echo trains of a spin echo sequence and a gradient echo sequence are acquired to calculate a R_2- and a R_2^*-map of the investigated slice. These parameters are used as an input for a tissue model, that samples a spin echo with many gradient echos. The former three fit parameters are then reduced to only one fit parameter, resulting in a robust fit.*

Methods:

In this study, three different sequences were used. All measurements were performed with the same voxel dimensions: FoV=256x192mm^2, matrix size=96x128, slice thickness=6mm. The first sequence was a spin echo sequence (TR=2000ms, FA=90°, Phase partial Fourier=6/8, BW=200Hz/Px, averages=2, TA=4:48min), which has been applied four times with the echo times TE=20ms, 35ms, 50ms, 65ms; The second measurement was a multi-echo gradient echo sequence (TR=100ms, FA=20°, BW=500Hz/Px, averages=4, TA=1:16min) with 12 echoes was applied. The first echo time was TE_1=5ms and the time interval between the echoes was Δt_E=5ms. Subsequently, a GESSE sequence (TR=2000ms, FA=90°, BW=1400Hz/Px, averages=8, TA=25:36min, contrasts=32, GE number for SE=14, Δt_E=2ms, TE(SE)=66ms) was applied. All measurements were performed on a 3T Magnetom Tim Trio (Siemens, Erlangen, Germany). The spin echo and the gradient echo measurements enable a calculation of the R_2-map and the R_2^*-map, respectively. With this information, a R_2'-map could be calculated and was used for the signal fit of the GESSE sequence. The remaining free fit parameter was the deoxygenated blood volume λ, which could be easily determined and the OEF value depending on R_2' and λ was calculated pixel-by-pixel.

Results & Discussion:

Figures 2a and 2b show the R_2- and R_2^*-maps of the spin echo and the gradient echo experiment, respectively. Subtracting R_2^* from R_2 yields the R_2' map, presented in Figure 2c. The values of the R_2' in white and grey matter are well between 1Hz and 5Hz, corresponding to reversible relaxation times T_2' between 1000ms and 200ms. Figure 2d shows a T_2-weighted image of the investigated slice. Application of the static dephasing model and the GESSE sequence enables a determination of λ and OEF. The values are well between 0% and 10%, while the corresponding OEF values are between 0% ad 40%, which is in agreement with literature values. The corresponding maps are presented in Figures 2e and 2f. In regions close to interfaces (tissue-air, tissue-ventricle) macroscopic inhomogeneities falsify the results. A correction by high resolved phase mapping could likely solve this problem. This study shows a trustable determination of R_2 and R_2' because of the one-parameter-fit in spin echo and gradient echo experiments. Moreover, the fit of the signal progress in a GESSE experiment becomes robust, because there is only λ as a free parameter left. One disadvantage of this technique is the additional measurement time compared to the three parameter fit, where only the GESSE measurement is performed. Nevertheless the robustness of the three-sequence-technique causes reliable parameters.

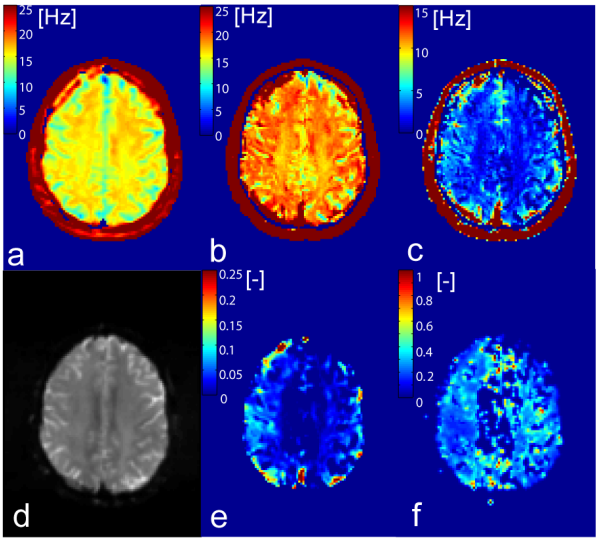

Figure 2. *The first two sequences measure the signal decay of a spin echo and a gradient echo. Here, the resulting R_2-map (a) and R_2^*-map (b) are presented. Subtraction of $R_2^*$and R_2 yields the R_2'-map (c). On the T_2-weighted image, the anatomic structure of the brain can be seen (d). In this work, R_2 and R_2' are used to calculate the deoxygenated blood volume λ (e), which is an output parameter of the tissue model, that enables the determination of the OEF (f).*

References:

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