Nested multi-echo EPI Acquisition Technique for Oxygen Extraction Mapping

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Introduction

Following a model of tissue structure, proposed by Yablonskiy [1], oxygen extraction fraction from blood (OEF) can be calculated by measuring blood volume fraction (λ) and reversible relaxation rate (R'_2). In this work, a new nested multi-echo EPI acquisition technique is proposed to map these parameters. This approach is promising due to the superior SNR per time interval of EPI compared to other techniques. A phantom study shows that a significant reduction of measurement time can be achieved.

Methods

To measure the reversible relaxation rate, the signal arround a spin echo at t_{SE}=150ms was sampled with multi-echo EPI trains on a 1.5T MAGNETOM Symphony scanner (Siemens, Germany). Each train consisted of six consecutive single-shot EPIs (64x64 matrix, FOV=192x192x8mm, t_{ADC}=25.2ms), optimized for the scanners gradient system and acquired employing partial Fourier sampling in order to minimize readout time. A spin echo was acquired at the 3rd EPI (bold triangle in Fig 1).

The acquisition was repeated three times with a starting time shifted by ¼ of the echo spacing t_{ADC}, resulting in 24 echoes in total. This nested acquisition of contrasts (cf. Fig 1) overcomes the technical limit of the minimal possible sampling interval given by the readout length of a single EPI. By doing so, we achieved a sampling point spacing of $t_{ADC}/4$=6.3ms.

A phantom study was performed to demonstrate the feasibility of R'_2, λ measurements using the proposed technique. The phantom was custom-built and resembles the tissue properties of statistically distributed capillaries in a homogeneous medium as required by the model used for parameter evaluation. It consists of four compartments containing randomly coiled nylon strings of different diameters (64-240µm) with a relative volume fraction of $\lambda \cong 5\%$ in a $NiSO_4$ solution. The acquisitions were repeated with TR=2000ms and 32 averages, leading to a total acquisition time of 4:16min. Data evaluation was conducted using the theory of Yablonskiy [3].

Results

The developed sequence design is shown in Fig 1. The four multi-echo EPI trains, depicted in a vertical order, were acquired sequentially with a TR of 2000ms. Fig 2a shows the log-timecourse of the signal taken from a representative ROI as shown in Fig 2b. The time scale is centered around the spin echo. The measurement shows the expected signal behaviour and results in reasonable values for the reversible relaxation rate (R'_2=3.4Hz) and the relative volume fraction (λ=7.0%).

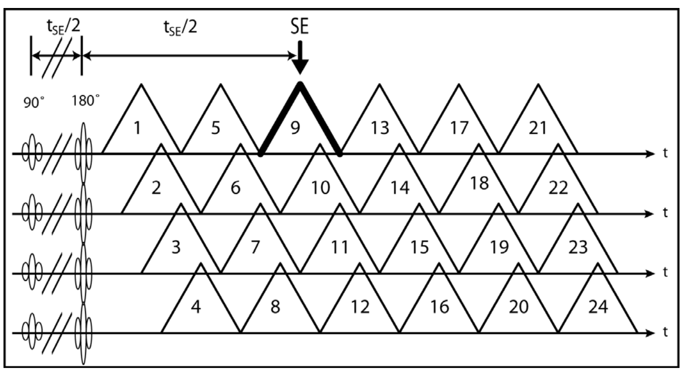

Fig 1. Timing table of the developed sequence with all iterations. Each triangle represents a single-shot EPI readout; contrast numbers are indicated within them. Spin echo (#9) is highlighted.

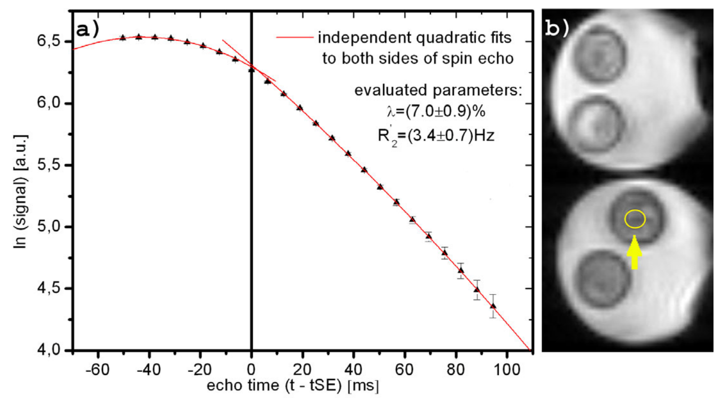

Fig 2. a) Signal-timecourse within in a ROI (logarithmic scale) with quadratic fits to both sides of spin echo; b) First image of the timecourse with ROI marked in 2nd compartment.

Discussion

In this work, a new EPI-based technique for OEF mapping is proposed. By shifting the starting time of multi-echo trains, time resolution is increased by a factor of 4 compared to a simple multi-echo EPI and thus comparable to the time resolution of multi-GE techniques. It is shown that a high sampling rate combined with EPI´s superiour SNR per time interval can be achieved. Due to the short repetition time between two independent measurements, quantitative fMRI experiments might become possible with this technique.

In contrast to multi-GE techniques it is not possible to define an exact echo time for EPI acquisitions. This might cause differences in the measured relaxation rates from both techniques and has to be investigated in the future. Nevertheless the aproach proposed in this work seems to be reasonable since the main signal is acquired in the k-space center. A general drawback of R'_2 techniques is the very high sensitivity to dephasing due to macroscopic field inhomogeneities. To achieve exact quantitative results, these must be corrected. In this work this was accomplished within data evaluation. The stability of the fitting algorithm could be improved by correcting phase distortions as a preprocessing step before data evaluation (as described e.g. by Chiou [4]).

References

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