Temporal variability of R_2* estimates in single-shot methods

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Introduction

In functional MRI (fMRI), typically a series of images are acquired in rapid succession during a cycle of control and stimulation to detect activity changes in regions of the brain. These activity changes are signified by changes in tissue R_2*, caused by the Blood Oxygenation Level Dependent (BOLD) mechanism. In most fMRI experiments, Δ R_2* is not measured directly, but is inferred from signal changes in serial T_2*-weighted EPI images. A potentially more accurate method of measuring changes in R_2* is the multiple-gradient echo EPI method (MEPI), which acquires separate EPI images at several echo times following a single excitation, allowing an exponential fit to be made to compute R_2*. A recently introduced technique for R_2* measurement, single-shot parameter assessment from signal encoding (SS-PARSE) maps R_2*, frequency (ω) and local magnetization M_0 by modeling the local signal and solving an inverse problem [1]. Because it explicitly models local phase evolution during the signal, it is inherently free of off-resonance geometric distortion. The sensitivity and accuracy of fMRI depend critically on the ability to measure small changes in R_2*. To compare the temporal variability of R_2* estimates using MEPI and SS-PARSE, repeatability studies were performed using phantoms with a range of R_2* values.

Method

The SS-PARSE method uses a model which is based on the local signal from each pixel,

$$s_{n_j} = M_{0_j} e^{-2\pi(k_{xn}x_j + k_{yn}y_j)} e^{-(R_{2j}+i\omega_j)n\Delta t}$$

and determines by conjugate gradient search the set of pixel parameters M_{0j}, R_{2j}, and ω_j (j=1,…,J) best matching the total signal observed to the sum of the local signals, $s_n = \sum_j s_{nj}$. Here the jth pixel is at (x_j,y_j) and k_{xn},k_{yn} represent the k-trajectory at time $n\Delta t$.

Phantom studies for R_2* estimation were performed on a Varian 4.7-T vertical 60-cm-bore scanner. Each study consisted of 4 tubes containing an aqueous solution of agar and different concentrations of sephadex and copper sulphate which gave varying values of R_2*. Initially a series of gradient echo (GEMS) images, 128×128 image resolution, slice thickness = 3mm, TR = 90 ms, and 13 values of TE = 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80 ms, were acquired. The R_2* values obtained through this series were used as standard for comparison. A series of MEPI images, 64×64 image resolution, slice thickness = 3mm, TR/TE = 3000/22.8 ms, each with 4 echoes was repeated 32 times. Next, a SS-PARSE acquisition, thickness = 3mm, TR = 3000 ms, was repeated 32 times. The MEPI and SS-PARSE data sets with 32 repetitions each, were used for the task of evaluating the temporal standard deviation (TSD). All regions of interest selected were 4×4 pixels and were entirely within the tubes.

Results

For pixels within the selected regions of interest, TSD for SSPARSE estimates were significantly lower than TSD for the MEPI method (fig. 1.f). R_2* estimates by both MEPI and SSPARSE occasionally deviated significantly from the actual values, but there was no systematic bias which would affect the TSD values. Note in the R_2* map (fig. 1.h) a rim of apparently elevated R_2* near edges of the phantom with large frequency gradients.

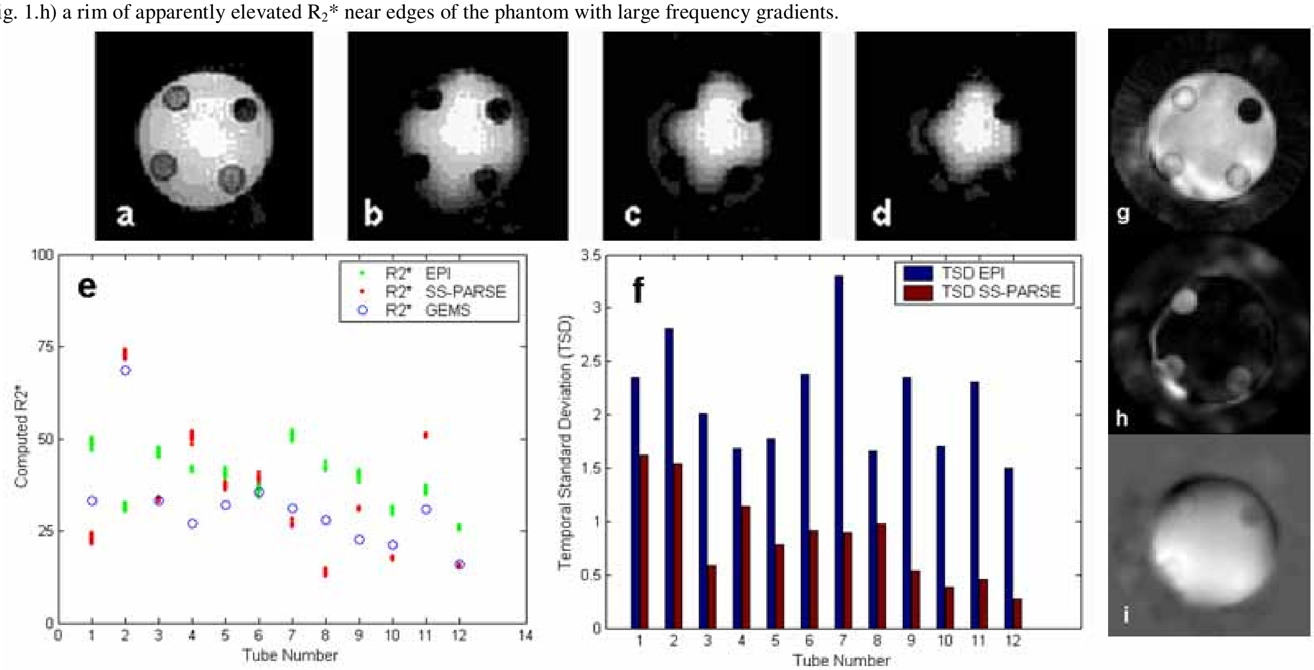

Fig: **1**. **a-d:** EPI intensity images spaced by 22.8 ms echoes; **e**: Computed R_2* values for gradient echo, SS-PARSE (20 frames), and MEPI(20 frames) in each of the 4 tubes from 3 experiments; **f:** Comparison between SS-PARSE and MEPI in terms of their TSD values in 4 tubes from 3 experiments over 20 frames; **g:** Intensity image (M_0 map), **h:** R_2* map, and **i:** Frequency map computed using SS-PARSE technique from a single shot

Discussion

A single-shot method for estimation of R_2* without off-resonance distortion was created and validated with phantom studies. SS-PARSE R_2* estimates matched more closely than MEPI estimates from gradient echo studies. Additional advantages of this method come in the form of magnitude, and frequency information, both of which are obtained using a single-shot. . Since the R_2* values obtained using SS-PARSE show lower variability over time, it appears suitable for fMRI studies which rely on the repeatability of the results within the duration of the designed experiment.

Acknowledgements

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References

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