First Demonstration of SS-PARSE in Detecting the BOLD Effect in Humans

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INTRODUCTION

Functional magnetic resonance imaging (fMRI) using echo planar imaging (EPI) is subject to difficulties arising from physically inaccurate assumptions underlying conventional MR image reconstruction methodology. These difficulties include geometric distortion and signal loss arising in regions of high susceptibility gradient. The Single-Shot Parameter Assessment by Retrieval from Signal Encoding (SS-PARSE) method[1-3] acknowledges the time-dependence of the MR signal on local gradients and signal decay, and discards the Fourier transform reconstruction model in favor of a nonlinear optimization for the inverse solution to the MR signal equation. This eliminates off-resonance geometric distortion. A rosette k-trajectory is used since the frequent crossing of k=0 improves the conditioning of the solution. The optimization process produces maps of magnetization (M_0), signal decay rate (R_2*), and frequency (ω). In this report we present the first detection of the BOLD effect in humans using SS-PARSE.

METHODS

A block design visual stimulus protocol was used in which an 8Hz flashing checkerboard stimulus was delivered to alternating hemifields, with contrast levels of 100%, 25%, and 6%. Scanning was performed using a 3T clinical scanner. Parameters were: FOV=192mm, reconstruction matrix=64^2, slice thickness=3mm, 4 slices, TR=2000ms. An EPI scan was also acquired (TE=30ms) for comparison of activation location. For the rosette scans, defined as $k(t)=k_{max}\cos(\omega_1 t)\exp(i\omega_2 t)$; ω_1=3577 rad/s, ω_2=3968 rad/s, k_{max}=1.67cm^{-1} giving a peak gradient slew rate of 140T/m/s. The rosette k-space trajectory was calibrated using the method of Zhang et al[4]. The stimulus protocol consisted of 6 TR of baseline (no stimulus) followed by 12 blocks of 6 TR periods each in which stimuli were delivered. Hemifield alternation occurred every block, with one no-stimulus block at the end of the series. A normal volunteer viewed the stimuli (projected onto a screen at the back of the scanner bore) using a periscope device attached to the 8-channel head coil. For the rosette/SS-PARSE data reconstruction, a nonlinear optimization was used to provide an inverse solution to the MR signal equation: $s(t_n)=\iint M_{xy0}e^{-(R_2^*(\vec{x})+i\omega(\vec{x}))t_n}e^{-2\pi i\vec{k}_n\cdot\vec{x}}dx$ where k_n is the calibrated k-trajectory. A progressive length conjugate gradient search was used to minimize the cost function defined as $C=\sum_n(s_n-s_{est})^2$ where s_n is the acquired signal and s_{est} is the estimated signal generated using the current parameter maps.

RESULTS

Figure 1 shows a time series example for 6% contrast flashing checkerboards from one subject taken directly from the R_2* map. Decreases in R_2* can be seen to be synchronized with the delivery of the visual stimulus for the single ROI plot shown on the left. The plot on the lower right shows ΔR_2* from the series mean for 3 pixel ROIs in the left and right hemispheres from the locations shown in the correlation map (based on a fit to a hemodynamic function). Activation locations corresponded to those found in the EPI data.

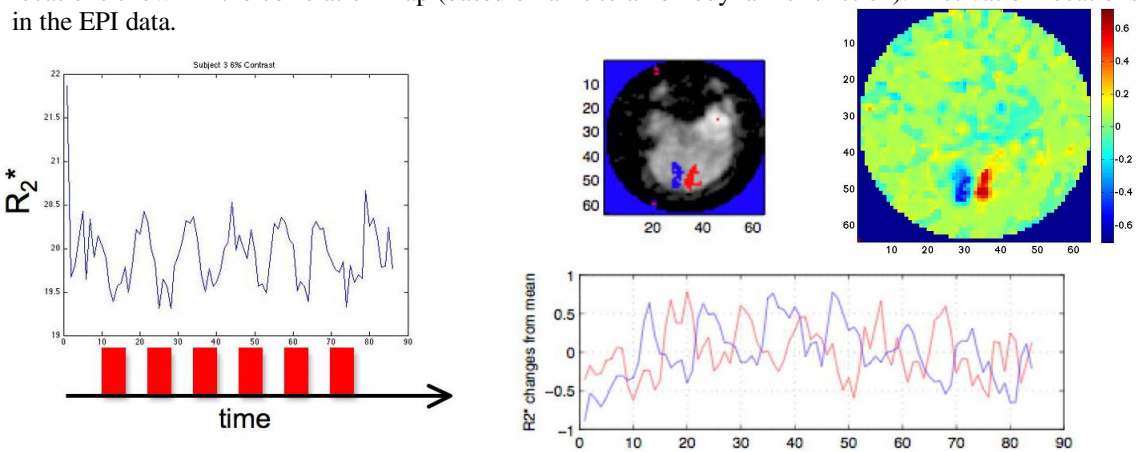

Figure 1. Time series examples. Left: Plot from 3 pixel ROI of the R_2* map in visual cortex. Vertical scale in units of s^{-1}. horizontal scale is image frame number. R_2* decreases with activation (corresponding to T_2* increase). Upper Middle: Activated regions detected using R_2* maps. Upper Right: correlation map. Lower Right: R_2* changes for both hemifields. Vertical scale in units of s^{-1}, horizontal scale is image frame number.

DISCUSSION

In this first demonstration of SS-PARSE in humans, successful identification of activation was identified based on changes in R_2* as derived from the parametric map resulting from the inverse solution to the MR signal equation. A detailed comparison study with EPI and spiral imaging will be carried out to provide a more detailed assessment of SS-PARSE performance.

REFERENCES

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