Ultra fast BOLD fMRI Using Single Shot Spin-Echo EPI With SENSE at 3 Tesla

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Introduction

Functional magnetic resonance imaging (fMRI), based on the blood oxygenation level-dependent (BOLD) contrast, has become a powerful tool for neuroscientists to investigate the functional organization of the human brain. The selection of MRI method may however, impact on localization accuracy by affecting image quality and the degree of BOLD contrast achieved (1). As a means of improving time efficiency in MRI, parallel acquisition techniques (e.g. SENSitivity Encoding (SENSE) (2)) have been used to shorten readout train in single-shot gradient echo, echo planar imaging (EPI), thereby reducing artifacts and improving spatial resolution (3).

SENSE together with single-shot spin-echo EPI imaging may further reduce off-resonance artifacts thus improving the anatomical localization and delectability of the functional signal. The goal of this work was to investigate the BOLD response of a SENSE-adapted single shot spin echo EPI using a motor task on a 3 Tesla scanner and optimize the sequence parameters for detection of the activation induced signals.

Materials and Methods

fMRI studies of 7 healthy right hand dominant volunteers were carried out in a 3 T scanner (Philips Medical Systems) using the body coil for rf-excitation and a 6-element head coil (MRI Devices Corporation) as receiver. Whole brain fMRI was performed using a single shot spin echo EPI sequence (24 axial slices, 4 mm thick, 0.4 mm slice gap, FOV of 240 mm, 128x128 recon matrix, TR 2400 ms, flip angle 90°).

For 30-60 ms echo times increments of 5 s were performed. A SENSE factor of 2.75 was used to reduce the number of phase encoding steps. The subjects performed a self-paced (~1.5Hz), simple motor task with the dominant hand for 30 seconds alternating with rest in a block design for 3 minutes (72 time points). The functional experiment was performed twice for each echo time. All data underwent identical post-processing, including rigid body motion correction (4), and an improved cross-correlation analysis (5). Only pixels with a statistically significant correlation (P<0.001) were considered as activated areas. Average and maximum BOLD contrast were determined for the cluster of activation in the M1 motor area in each subject.

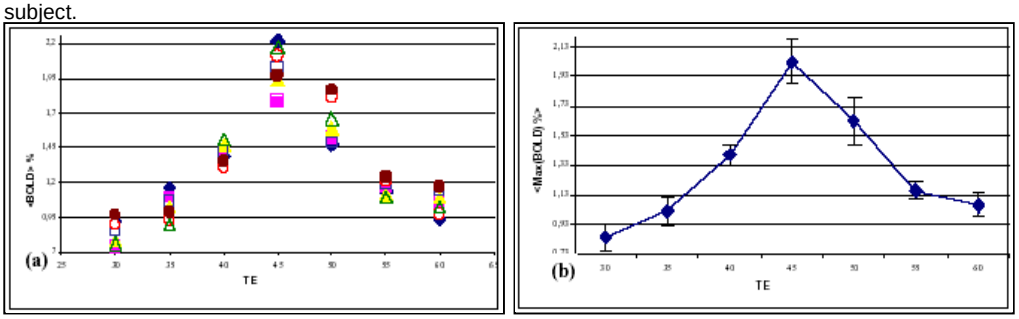

Figure 1: (a) Individual average BOLD signal (<BOLD>) over seven subjects as function of echo time, and **(b)** maximal BOLD signal (<Max(BOLD)>) averaged over seven subjects as function of echo time. Both evaluation were done in motor area.

Results and Discussion

Both maximal, average signal changes and peak BOLD signals occurred an echo time of 45ms (Figure 1). At very short echo time (TE= 30ms) the sequence was still sensitive to BOLD effects. At higher echo times (e.g. TE= 60ms), although a smaller BOLD effect is observed, a larger volume of activation was seen (Figure 2). At all echo times studied, susceptibility artifacts did not destroy the BOLD signal. Quadrature ghost artifacts that are associated with higher field strengths, which are typically seen in single shot EPI, were not visible and, the distribution of activation in the motor, pre-motor and sensory region (Figure 2) was consistent with previously reported studies for this motor task (6).

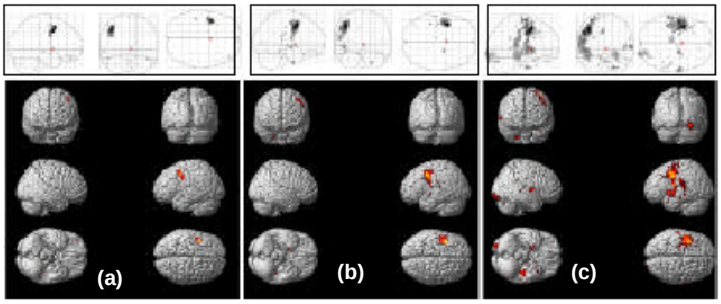

Figure 2: Rendering on a standard brain of motor contrasts of normal brain subjects averaged over seven volunteers and, projections in the stereotactic space of Tailarach. The sets correspond respectively to **(a)** TE= 35ms, **(b)** TE= 45ms, **(c)** TE= 55ms.

Echo Time in ms	Mean size of the activated area in number of voxels	Standard Error
35	81	13
45	117	18
55	196	29

Table 1: Results representing the average number of the activated voxels obtained through group analysis of the 7 healthy subjects at the echo times 35, 45 and 55 ms.

Conclusion

We have found that single shot spin-echo using SENSE at high magnetic fields is robust algorithm for obtaining functional maps of neuronal activity in the motor system. Susceptibility artifacts associated with higher field fMRI can be reduced by the use of SENSE. With the use of the appropriate imaging parameters single shot SE-EPI at higher field systems produces robust maps of activity with reduced suceptibility artefacts and better localization of BOLD signal at the cortical microvascular bed.

We have studied single shot SE-EPI with SENSE scans in the context of their sensitivity to BOLD signals and their vulnerability to susceptibility-induced artifacts at 3 Tesla. BOLD imaging can be achieved using single shot SE-EPI with SENSE scanning, with improved BOLD contrast and reduced susceptibility artifacts. Functional experiments with sensorimotor activation on normal subjects demonstrated the advantages of single shot SE-EPI with SENSE scanning.

References

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