Reduction of onset variability of event-related BOLD responses with Diffusion-weighted Spin-echo EPI

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Introduction

Gradient-echo (GE) BOLD-fMRI using bipolar diffusion gradient has been studied by several groups (1, 2) and the results demonstrated that the significant amount of signal arise from macrovascular intravascular component far away from the exact neural firing site. Yacoub et al (3) and Thulborn et al (4) demonstrated increasing the extravascular weighted BOLD by using high magnetic field and spin-echo (SE) sequence can improve spatial specificity. Further, Hulvershorn et al (5) compared the time to peak (TTP) of GE and SE BOLD-fMRI in response to brief visual stimuli and the results illustrated TTP of SE precede that of GE. Because BOLD signal in response to neural activity occur earlier in microvasculature and later propagate into the vein, we hypothesize that better spatial specificity would lead to improved temporal variability. In this study, we evaluated the temporal variability of BOLD signals measured within the same cortical area, using diffusion-weighted SE (DWSE), SE and GE EPI. Comparisons were based on the same contrast-to-noise ratios (CNRs) which were controlled by averaging different number of repeated single-trial responses.

Method

Six normal volunteers participated in this study. All the experiments were performed on a 1.5T Magnetom Vision MRI scanner. The paradigm consisted of 40 repeated trials for DWSE and 30 trials for GE and SE, with each trial consisting of 1-sec brief visual stimulation followed by 13-sec fixation. The GE images were acquired by using a single-shot EPI sequence, with TR/TE/FA= 1000ms/60ms/75° and in-plane resolution=3.3×3.3 mm^2. An oblique slice with thickness 8 mm was imaged to cover the visual cortex. SE EPI sequences were used to measure DWSE and SE BOLD-fMRI signals with TR/TE=1000ms/80ms. For DWSE experiments, bipolar diffusion gradients (6) were incorporated into the SE EPI sequence with b values of 50 ($DWSE_{50}$) and 200 s/mm^2 ($DWSE_{200}$) in slice-selection direction. For image data processing, significantly activated voxels (p<0.005) were detected by correlating with a gamma variate function. After selecting the regions-of-interest within the visual cortex, the time series were extracted for each pixel and averaged randomly across 30, 20,10,1 repeated single trials for $DWSE_{50/200}$ and 20,10,1 for SE and GE experiments. By employing curve fitting method using a gamma variate function, the onset times were determined at the time to first half maximum and CNRs were determined as the contrast of the fitted curve divided by the the standard deviation of the differences between the fitted curves and the raw time series.

Results

Fig. 1 showed the activation maps attached to T1w images. Decreased sensitivities were noted for the SE and DWSE experiments, as compared the number of activated voxels with GE results. Fig. 2 demonstrated the relationship between CNR and standard deviation of the onset times. As expected, variance of the onset time decreased with increasing CNR. At the same CNR, we observed remarkably smaller onset variances for SE and $DWSE_{50/200}$ compared to GE. No difference was found between $DWSE_{50}$ and $DWSE_{200}$. Table 1 illustrated the time to half maximum (TTHM) and TTP. Compared to GE, the decreases of TTHM and TTP in SE and $DWSE_{50/200}$ sequences were statistically significant (*** p<0.005, ** p<0.01 and * p<0.05).

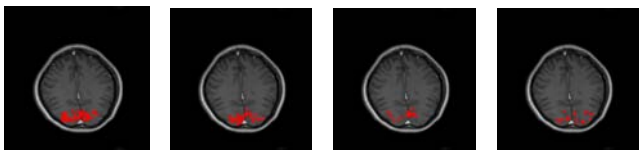
Discussion

We observed earlier onset times and smaller variances of onset time in DWSE than those in GE BOLD. Since DWSE technique is able to null the intravascular signal and is more sensitive extravascular signal around small vessels, we suggest that it could more accurately detect the onset time related to neuronal events. From Fig. 2, the curve profiles in both GE and SE techniques showed a good correlation with exponential decay curve (r^2=0.9967 and r^2=0.9897) and those in $DWSE_{50}$ and $DWSE_{200}$ correlated well with linear decay curve (r^2=0.9983 and r^2=0.9907) with greater slopes. In other words, at higher CNR the onset time variance may approach constant for GE and SE but continue decreasing for DWSE. Further, the curves of $DWSE_{50}$ and $DWSE_{200}$ overlapped nicely, which suggests that the b value of 50 s/mm^2 may be sufficient to eliminate the large vessels' contamination on the determination of the onset of BOLD fMRI responses.

References

1. Boxerman J. L., et. al., *Magn. Reson. Med.*, 1995, 4-10
2. Song A. W., et. al., *Magn. Reson. Med.*, 1996, 155-158
3. Yacoub E., et. al., *Magn. Reson. Med.*, 2003, 655-664
4. Thulborn K. R., et. al., *NMR Biomed.*, 1997, 183-190
5. Hulvershorn J., et. al., *NeuroImage*, 2005, 216-223
6. Stejskal E. O.,et al., *J Chem Phys*, 1965, 288-292

Fig. 1



GE SE $DWSE_{50}$ $DESE_{200}$

Fig. 2

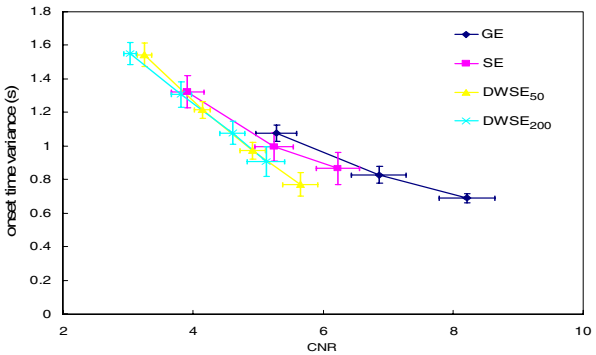


Table 1

Sequence	TTHM(sec)	TTP (sec)
GE	2.92±0.08	4.97±0.19
SE	2.40±0.07***	4.50±0.17**
$DWSE_{50}$	2.44±0.11**	4.54±0.15**
$DWSE_{200}$	2.23±0.11***	4.62±0.07*