The orbitofrontal fMRI experiment with correction of the susceptibility artifact

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Introduction

The signal loss by the susceptibility artifact makes it difficult analyze the fMRI data of the orbitofrontal region of the brain. In addition, an EPI sequence, which is used in many fMRI experiments, has the geometric distortion and Nyqust ghosts. For the fMRI experiment with correction of these artifact and distortion, we used a flat RF pulse which provides nearly constant signal intensity against the magnetic susceptibility and a gradient echo sequence. In the result, it is shown that the signal loss in the orbitofrontal region of the brain is recovered without geometric distortion and Nyquist ghosts and the activation in that region was analyzed successfully.

Methods

The flat RF (F-RF) pulse is made by adding bilinear ($a_1|z|$) and quadrature (a_2z^2) phase terms along the slice selection direction (z-direction) in equation (1) for compensation of the phase dispersion due to the field variation that is induced by the magnetic susceptibility. It is assumed that the susceptibility effect on the spins in the slice selection direction introduces a linear phase. [1]

$$S = \sqrt{\left[\int_{-z/z_o}^{z/z_o} M_o \cos(a_1|z| + a_2 z^2 + P_{sus} z)\, dz\right]^2 + \left[\int_{-z/z_o}^{z/z_o} M_o \sin(a_1|z| + a_2 z^2 + P_{sus} z)\, dz\right]^2} \qquad (1)$$

where z_o is the slice thickness, M_o is the magnetization, γ is the gyromagnetic ratio, TE is the echo time, and G_{sus} is the field gradient caused by the magnetic susceptibility. We used a_1 ($=b\times\pi/z_o$) and a_2 ($=q\times 2\pi/z_o^2$), where $b(=0.001)$ and $q(=8)$ are parameters to modulate bilinear and quadrature phase terms.

The fMRI experiment related to the compassion is performed for the activation on the orbitofrontal cortex related to the compassionate emotion. As shown in Fig.1, a subject looked at pictures with neutral or sad facial expressions passively or compassionately (four stimulus blocks: at neutral facial expressions passively, at neutral facial expressions compassionately, at sad facial expressions passively, and at sad facial expressions compassionately). Looking passively and looking compassionately were crossed on regardless of the facial expression. In addition, the reference block (30sec) was added between two stimulus blocks for relaxing the blood oxygen level dependent (BOLD) signal. Each stimulus block consisted of 8 facial expression pictures (3.75sec x 8 = 30sec) and was repeated for three times. Total scan time was 13min 24sec including the dummy time (12sec) and the pre-information picture for each stimulus block (6sec).

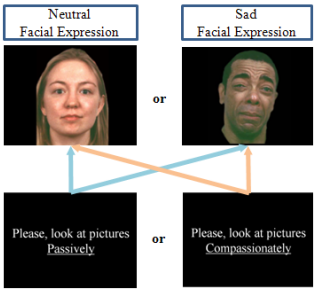

Fig. 1 Combination of stimulus blocks

Results and Conclusions

We performed in-vivo experiments using 3T MR system using, where the imaging sequence were the echo planar imaging (EPI) and gradient echo multi slice (GEMS) sequences with the conventional slice selection RF pulse and F-RF pulse. In the experiment, TR and TE were 3000msec and 35msec respectively, the matrix size was 64×64, the slice thickness was 5mm, the flip angle was 10°, and FOV was 256mm×256mm. In the GEMS sequence, the sensitivity encoding (SENSE [2]) technique with an acceleration factor of about 2.67 was used using an 8-channel RF coil and three slices were obtained. In the EPI sequence, a birdcage RF coil was used and 30 slices were acquired. The data was analyzed by SPM2.

In Fig. 2(a), the image was obtained using EPI sequence with the Sinc RF pulse and has the susceptibility artifact, geometric distortion and Nyquist ghost in the orbitofrontal region. The image in Fig. 2(b) shows that the signal loss from the susceptibility artifact was reduced. However, the geometric distortion makes a problem in analyzing the activation on the orbitofrontal cortex. The Nyqust ghosts are still remaining. On the other hand, the image obtained by GEMS sequence with F-RF pulse shown in Fig. 2(c) has no geometric distortion and Nyqust ghosts. Therefore, it becomes possible to analyze the activation in the orbitofrontal region of the brain by removing the susceptibility artifact.

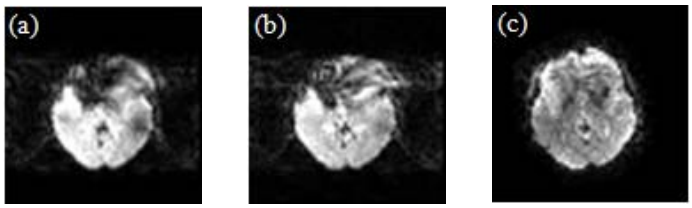

Fig. 2 Images obtained using EPI and GEMS with Sinc RF and F-RF pulses: (a) EPI with Sinc RF pulse, (b) EPI with F-RF pulse, and (c) GEMS with F-RF pulse

The activation results for each fMRI experiment are shown in Fig. 3. The order of sequence and RF pulse used in each result are same as that in Fig. 2. The result in Fig. 3(a) is hard to show the activation by the susceptibility artifact. Although the susceptibility artifact is reduced by F-RF pulse, the geometric distortion still remains and disturbs the analysis of the result in Fig. 3(b). However, the result in Fig. 3(c) shows the activation in the orfitofrontal region of the brain clearly because the signal intensity in orbitofrontal region is corrected by the F-RF pulse and the geometric distortion is removed by using the gradient-echo sequence. Therefore, the fMRI experiment using F-RF pulse and gradient-echo sequence has better analysis quality.

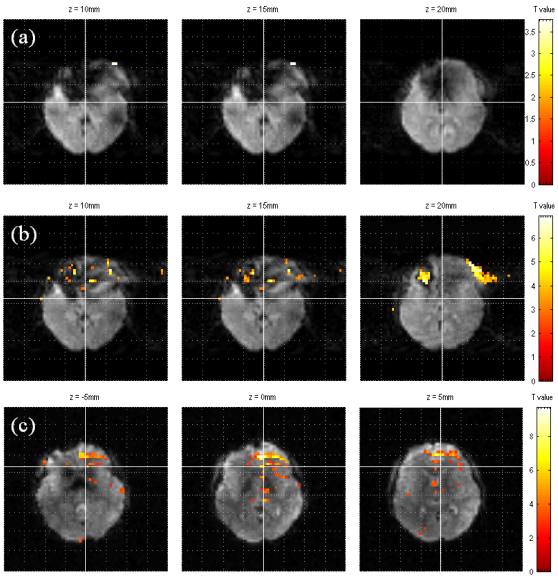

Fig. 3. The activation results in the orbitofrontal region of the brain for each fMRI experiment: (a) EPI with Sinc RF pulse, (b) EPI with F-RF pulse, and (c) GEMS with F-RF pulse

References

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[2] Pruessmann KP et al., Magnetic Resonance in Medicine **42**:952-962, 1999.