High resolution 3D spiral trajectory BOSS fMRI

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Introduction

Blood Oxygenation Sensitive Steady-State (BOSS) fMRI is a new technique that obtains the functional contrast using small tip angle balanced Steady-State Free Precession (balanced-SSFP) imaging [1]. The sharp phase transition near on-resonance combined with the frequency shift of deoxy-hemoglobin creates strong functional contrast near on-resonance frequency. As a result, increased activation level has been observed compared to conventional fMRI [1,2]. The spiral imaging technique is a validated fast imaging technique that covers k-space efficiently. With BOSS fMRI combined with a 3D stack-of-spirals sequence, the whole visual cortex was covered with high spatial resolution.

Methods

Imaging was done on a 1.5T GE EXCITE system (40 mT/m, 150 mT/m/msec) using a standard GE transmit/receive head coil. A 3D stack-of-spirals trajectory, 16 interleaves with 18 slice encodings, was incorporated into a 4 degree flip angle balanced SSFP sequence. The first moment nulling in each gradient was done to remove flow artifact [2]. TR was chosen to be 8.7 ms. The voxel size was isotropic 2 mm with a temporal resolution of 2.5 sec. The FOV was 24 x 24 x 3.6 cm^3. The reconstructed image matrix size was 120 x 120 x 18.

A back-projected 10 Hz reversing annulus grating visual stimulus was presented in 15 sec on/off blocks for 2 minutes. Forty-eight high-resolution 3D images were taken during the 2 minutes.

Since BOSS generates functional contrast only near on-resonance, to cover the whole 3D region, the experiment was done at four different center frequencies in 4 Hz intervals. Combining the maximum activation level obtained from the four different center frequencies generated the final activation map. To generate the individual activation map, analysis was performed using FSL [4]. The images were registered and processed using FEAT with cluster thresholding (cluster threshold $Z > 2.6$ and cluster significant threshold $p < 0.005$).

Results

Figure 2 shows three different cross sections (axial, sagittal and coronal) through the three-dimensional activation map. The activation map is shown with the maximum intensity combined original images. In all three slices significant activation in the visual cortex region can be observed. The maximum signal change was 25.9 %. Previous study on BOSS has also shown increased signal changes (15.7%) at smaller voxel size [2]. Conventional fMRI has also reported increased signal change at smaller voxel size due to reduction of partial volume effects [5,6].

Discussion

Using the 3D high resolution imaging technique, very significant functional contrast was observed at the visual cortex in the low field with standard head coil. This technique also has the advantage that it covers the whole visual cortex region with high SNR due to 3D volumetric coverage. Providing isotropic 3D coverage nearly doubled the contrast.

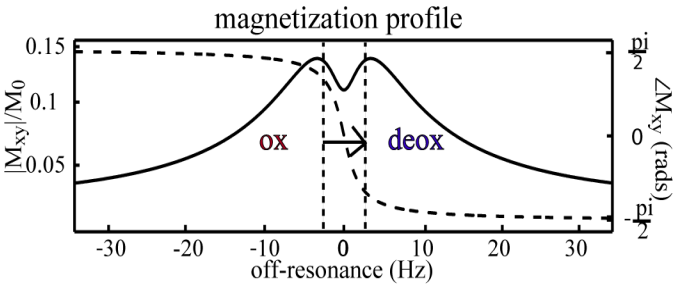

Figure 1. BOSS contrast mechanism. The frequency difference in oxygenated and deoxygenated blood create phase shift.

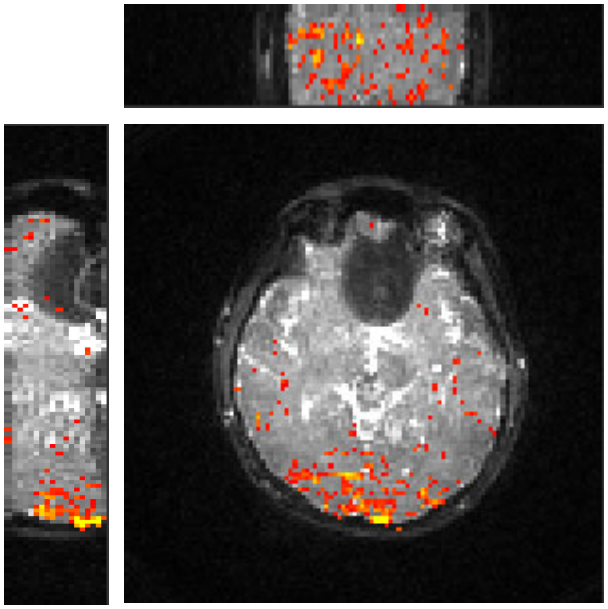

Figure 2. Functional activation map through the 3D data set (Sagittal: 66th Slice from the left, Coronal : 29th Slice from the posterior end, Axial: 7th Slice from the bottom)

References

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