Transient state BOSS fMRI for a further increase in sensitivity

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Introduction

Blood Oxygenation Sensitive Steady-state (BOSS) fMRI is a new method for obtaining functional contrast. Because it is based on refocused SSFP imaging, BOSS has high SNR efficiency and does not suffer from image warping or signal dropout [1, 2]. An early theoretical study demonstrated that the contrast of the SSFP images may depend on the transient-state behavior if approaching the steady state requires a time length comparable to the scan time [3]. It means that the actual image appearance depends on the number of RF pulses experienced by the magnetization prior to data acquisition near the center portion of the k-space. In this study, we apply the transient state phenomenon to BOSS fMRI imaging to further increase the sensitivity of functional signals. Parallel imaging techniques could thus be combined with BOSS to increase transient-state BOSS contrast, speed up acquisition, and without substantial signal loss.

Methods

Imaging was done on a 3.0T Philips Achieva system using an 8-channel head coil. Shimming was targeted to the occipital lobe. The image parameters were 220 mm FOV, 64 by 64 matrix size, 4 mm slice thickness, 5° flip angle and TR/TE = 8/4 ms. To examine the transient-state signal behavior, startup echo in the central k-space was varied from the 5th to the 70th to mimic variations in the number of preparatory RF pulses. The theoretical behavior of MR signal intensity undergoing a continuous train of RF pulses was simulated for the same scanning parameters as described for the imaging experiments. For the investigation on BOSS fMRI combined with parallel imaging, the same parameters were used but with matrix size 128x128. Two sets of BOSS images were acquired, one without SENSE (64 preparatory echoes; steady-state dominant) and the other with two-fold SENSE (32 preparatory echoes; transient-state dominant). The stimulus was an 5 Hz flashing checkerboard visual stimulus in 4 on/5 off blocks (8 frames in each block) for 5/2.76 min separately (one image volume every 2.3/4.3 s, where SENSE provided twice temporal resolution). Analysis was performed using independent component analysis supplied in fMRIlab software package.

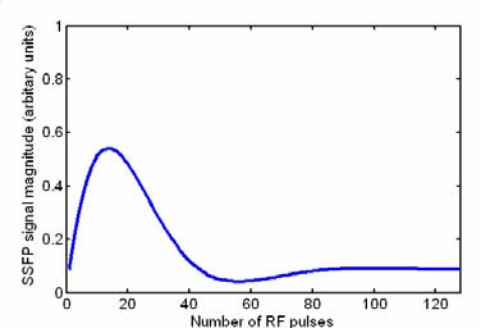

Fig.1 Magnitude of BOSS signal plotted as a function of the number of preparatory RF pulses preceding signal acquisition. Note the stronger transient-state response as compared with steady-state intensity.

Results

Fig.1 shows the theoretical simulation of magnitude change for BOSS, plotted as a function of the RF pulses preceding data acquisition around the center of the k-space. Fig.2 shows brain images acquired with startup echoes from the 10th to the 65th echo. Note the stronger transient-state signal amplitude before approaching steady state, in qualitative accordance with simulation. The activation maps for the fMRI experiments are shown in Fig.3 overlaid on high resolution T1-weighted images without (Fig.3a) and with SENSE (Fig.3b). Fig.3c showed the percentage of the BOSS signal change separately. The percentage signal changes seemed to have similar values. SNR was 153 without SENSE versus 150 with SENSE. Notice that the expected loss in SNR due to SENSE acceleration seemed to be well-compensated by the increase in transient-state BOSS signals. In addition, the activation areas showed good registration on the cerebral cortex (Figs.3a and 3b).

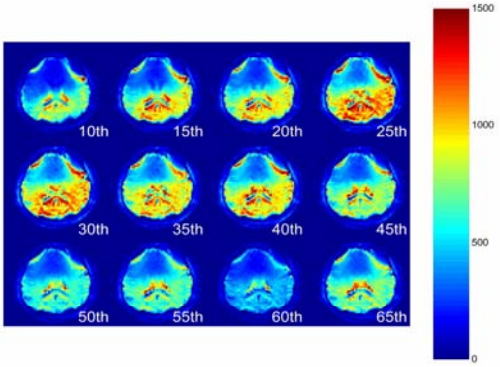

Fig. 2 Brain images acquired with BOSS contrast, showing transient-state behavior with 10 to 65 RF pulses preceding passage around the center of the k-space respectively

Discussion and Conclusion

The results from this study demonstrate that the functional signal sensitivity of BOSS fMRI could be increased by acquiring imaging data in the transient-state. With appropriate setting of the number of RF pulses preceding the center of the k-space, the stronger transient-state functional contrast could be utilized for shorter scan time, increased slice numbers for statistical power, or higher spatial resolution. We therefore conclude that, together with the advantage of no susceptibility-related geometric distortions [2], the transient-state BOSS has strong potential for high-resolution fMRI mapping in the brain.

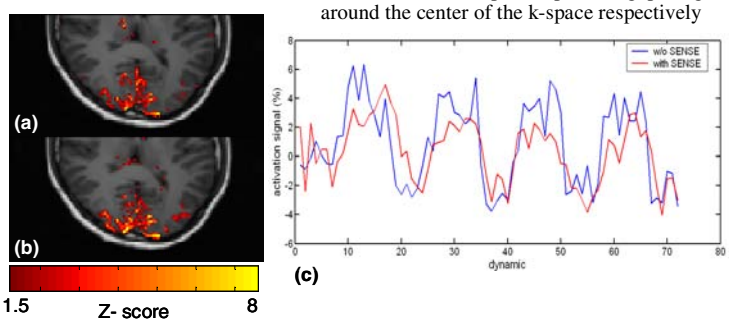

Fig. 3 BOSS functional activation map (a) without SENSE (b) with SENSE and (c) the percentage of signal change.

References

[1] Scheffler, et al. NMR Biomed, 2001; 14: 490-496. [2] Miller, et al. MRM, 2003; 50: 675-683. [3] Huang TY, et al. MRM 2002;48:684-688