Impacts of Single Carrier Wideband Gradient-Echo Sequence in BOLD Contrast

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Target Audience

Investigator who has interests on physiological mechanism in BOLD contrast and the application of Wideband technology.

Purpose

Since discovered by Ogawa et al.[1], blood-oxygenation-level-dependent (BOLD) fMRI is widely applied to brain science by detecting the T_2^* signal. However, the BOLD contrast still suffers the low temporal resolution and low sensitivity. Recently, the Single Carrier Wideband (WB) MRI technique was introduced to accelerate the scan time by simultaneous acquisitions of different locations [2], which enhances the temporal resolution, and possibly enhances sensitivity as well, in fMRI studies. In this study, we applied this novel technique in animal fMRI study and to test the influence of WB on BOLD sensitivity. Stemming from the additional separation gradient, we hypothesize that WB-based GRE enhances the BOLD contrast for higher T_2^* sensitivity.

Methods

In this study, two Sprague Dawley (male, 250g~350g) rats were studied under the isoflurane anesthesia (1.5%~2%) condition. We applied 2 different combinations of inspired gas (Oxygen: 100% O_2 and Mixed: 20% O_2+ 5% CO_2 + 75% N_2) using two different kinds of multi-echo sequences: GRE and WB-GRE. The respiration rate was controlled within the range of 45~50 bpm. All images were acquired on Biospec 70/30 7T animal MRI system (BRUKER, Ettlingen, Germany) with a phased array coil. Multi-echo GRE image was used to evaluate the T_2^* effect during different inhaled gases. The multi-echo GRE imaging protocol was listed below: single slice with FOV: 2.5 x 2.5 cm^2, Voxel Size: 130 x 130 x 1000 um, TR: 100 ms, 12 TE various from 4 ms to 59 ms, NEX=10, and the total acquisition time is 192 s. On the other hand, multi-echo WB-GRE experiments had the same protocol as GRE, except that W=2 acceleration, NEX=10, and the total acquisition time is 96 s. We reconstructed the extended FOV (5 x 1.25 cm^2) of WB-GRE into the same FOV of GRE through specific regridding technique [2]. Subsequently, we fitted the T_2^* values under the 4 conditions (GRE-Oxygen, GRE-Mixed, WB-Oxygen, WB-Mixed) and assumed the simulated BOLD contrasts (Oxygen vs. Mixed) to compare the BOLD sensitivity between GRE and WB-GRE.

Results

Figure 1 demonstrates the results of BOLD contrast, reflected in fitted T_2^* values and T_2^* maps. The fitted T_2^* values resembled each other while the WB-GRE required only half the acquisition time. Bottom-left panel of Fig. 1 shows the signal decay of T_2^* signal in the right somatosensory (S1) and Bottom-right shows larger T_2^* when inspiring O_2. On the other hand, when comparing the two sequence, estimated T_2^* was larger in GRE than WB-GRE. At last, we used the four contrasts to simulate the BOLD contrast-to-noise ratio (CNR) curves, considering the T_2^* decay of signal intensity. We found that the optimal signal change occurred in TE of 20.7 ms in GRE and 18.7 ms in WB-GRE. When TE was set to 20ms, the BOLD contrast of GRE could be increased from 2% to 2.3% changing the used sequence to the WB-GRE (Fig. 2).

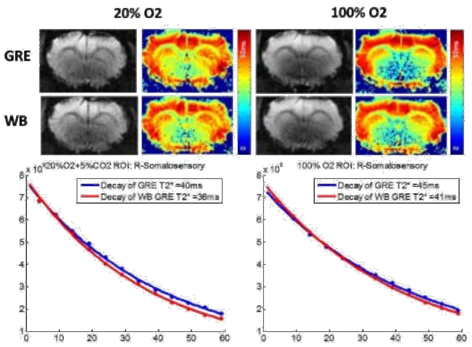

Figure 1. The BOLD contrasts acquired by GRE and WB-GRE under different inhaled gases. Gray- scale shows the GRE images and color maps are fitted T_2^* results. Bottom-left shows T_2^* decay in right S1 by inspiring Mixed gas. Bottom-right shows the same by inhaling pure oxygen.

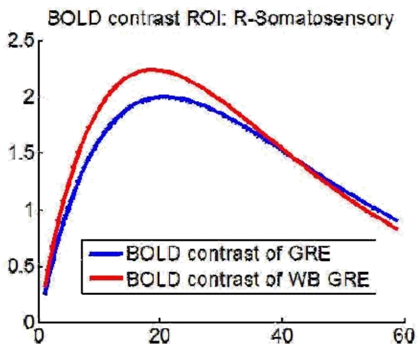

Figure 2. Simulated BOLD CNR using GRE and WB GRE. The optimal TE appears at 20.7 ms for GRE and 18.7 ms for WB-GRE. It shows that WB-GRE demonstrates the higher sensitivity than GRE.

Discussion

Using the old-fashioned mixing-gas examination, our preliminary results demonstrated the applicability of using WB-GRE to study fMRI. WB technique can either speed up the scan time, or increase the spatial resolution, which benefits the temporal resolution of fMRI study. In this study, we found that the WB technique does not affect the BOLD contrast; instead, it improved the BOLD sensitivity (increased from 2% to 2.3%) based on our simulated BOLD contrasts. Such phenomenon could be contributed from the reduced T_2^* values based on WB technology, imposing additional separation gradient and accelerate the dephase effect based on BOLD contrast.

Conclusion

The WB technique not only reduced the acquisition time, but also enhances the BOLD contrast due to the reduced T_2^* values. We expect that the enhanced BOLD sensitivity of WB technique could help to discover the subtle functions in the deep brain.

References

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[2] Huang, Y.A. et. al., "W=2 Acceleration Single carrier Wideband MRI Technique and Blur Mitigation Method". Proc. of the 21th ISMRM Annual Meeting, Salt lake City, U.S.A., 2013.