A Brain Resting State fMRI Connectivity Study Using High-Temperature Superconducting RF Coil Platform in A 7T Rat MRI Imager

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Abstract

To improve signal-to-noise ratio (SNR) in MR imaging, a high-temperature superconducting (HTS) radio-frequency (RF) coil platform was implemented in a 7T fMRI study. As the noise reduced, the functional SNR as well as the image SNR were improved. Compared with conventional copper RF coils, this study obtained the image SNR gain of approximately 2 times in both fast spin echo and echo planar imaging (EPI) sequences. Besides, the time-series analysis of the resting state fMRI study showed that not only the functional SNR was raised but also the functional connectivity was improved.

Introduction

The SNR is a crucial factor in fMRI researches. The usual functional SNR of blood oxygen-level dependent (BOLD) signal is between 3~10% and this small change increases the difficulty to distinguish signal from noise. Therefore, to improve the image SNR is essential for the elevation of the functional SNR. A HTS RF coil platform which is regarded as a powerful method to reduce the system noise may be a possible solution. According to theories and previous studies [1][2], the image SNR gain of the HTS RF coil would be about 2 times in a 7T MRI system compared to a 4cm copper RF coil in prediction. Besides, in expectation, the functional SNR would be increased as well as image SNR through the HTS RF coil platform. Furthermore, a better functional connectivity in the resting state fMRI study is anticipated.

Materials and Methods

For comparison, two RF surface coils of 4cm were made of HTS (Bi2223 tinned tape, Innova Superconductor Technology Co., Ltd., Beijing, China) and copper respectively. The experiment setup is illustrated as Figure 1, and the RF signal was inductive-coupled by the pick-up copper coil. Both RF coils were placed inside the longitudinal cryogenic system [1]; however the operation temperature of the HTS and copper RF coils were 77K and 300K separately. A Sprague Dawley rat was anesthetized and scanned in this resting state fMRI study. The EPI sequence was used to collect the time-course data through the Biospec7030 7T animal MRI system (BRUKER, Germany). The EPI sequence parameters were TR/TE = 2000/20 ms, resolution = 312 um, slice thickness = 1mm, and the scan time = 420s. The rat brain anatomical images was acquired by the fast spin echo sequence with TR/TE = 2500/33 ms, resolution = 195 um, slice thickness = 1 mm, and scan time = 320s. In the first part of analysis, we calculated the image SNR by selecting region of interest (ROI) as depicted in Figure 2 where signal region is the red circle and the blue is noise region. Second, we calculated the functional connectivity which was examined on the correlation between the seed time-course and other brain regions. The seed was set at M1/M2 region (Figure 3).

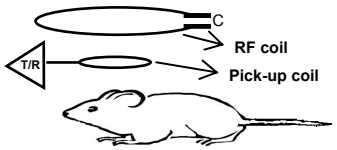

Figure 1. The experiment setup

Results

The comparison of the rat brain anatomical images between HTS and copper RF coils were showed in Figure 2, where Figure 2a represents the image acquired from the copper coil at room temperature (300K) and Figure 2b shows the image acquired from the HTS coil at 77K. By using the HTS RF coil, the SNR was 62.9, 1.94 folds higher than 32.4 by using the copper RF coil. Moreover, the EPI image SNR gain was around 1.9. The time-course sketches from the seed region were presented in Figure 4, where the HTS coil (Figure 4b) performed the smaller variance than the copper coil (Figure 4a) in time-course fluctuation related to the system noise. Further, the HTS RF coil increase the functional connectivity of the resting state data compared with copper RF coil (Figure 3). In a result, the seed region, as well as M1/M2, was correlated to the corpus callosum and contralateral side in the HTS RF coil scanning as Figure 3 shown. It was suggested that, M1/M2 communicate to contralateral side through the corpus callosum.

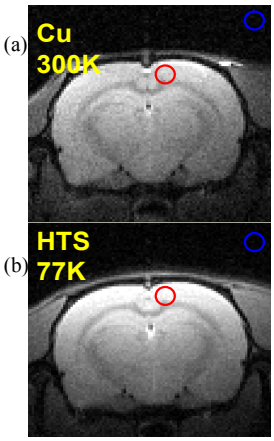

Figure 2. The rat brain anatomical images

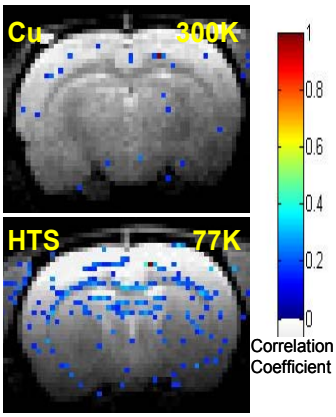

Figure 3. Significant level of the resting state

Conclusions

This study demonstrated the advantages of the HTS RF coil platform on fMRI researches in a 7T MRI system. Both of the anatomy and EPI MR images presented a nearly 2 times SNR promotion compared with conventional copper RF coils. Besides, the functional SNR and the functional connectivity have also been improved by the noise reduction. It was suggested that some information which was covered by noise before would be revealed, and details of the brains will be discovered in the future.

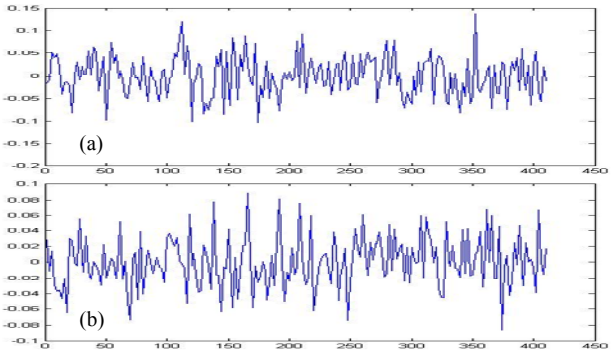

Figure 4. Time course

References

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