Reducing Physiological Noise in fMRI using Simultaneous Echo Refocusing Sequence with 8 Slices (SER-8)

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Introduction

Physiological noise, defined here as cardiac and respiratory pulsation, is the bane of fMRI brain activation studies. One well-known problem states that physiological noise will negate the signal to noise advantage of high field strength beyond 3T systems because physiological noise, unlike random noise, grows in step with the brain activation signal that investigators are interested in. Reducing physiological noise should in principle free up the advertised contrast-to-noise potential of higher field machines like the 7T. We are extending the Simultaneous Echo Refocusing (SER) EPI sequence [1] from its original 2 slice single-shot acquisition into a new sequence (SER-8) which can acquire up to 8 slices at one-shot. Since SER-8 is currently only installed at a 1.5T system, we will focus on demonstrating how SER-8 with a TR of 150ms can be used at 1.5T to remove physiological noise in brain activation. A short 150ms is chosen because the first and second harmonics of cardiac oscillation still have a fair amount of signal. It is true that any conventional EPI scan can acquire one or two slices with short TR to reduce physiological noise. However, SER-8 makes physiological noise removal into a more meaningful exercise because 8 slices may cover enough portion of the brain to be of interest to many investigators.

Since a 150ms TR may have signal to noise too low for some type of studies, cardiac gated imaging with TR~1sec can be used to reduce cardiac noise (but not its harmonics) and respiratory noise (at ~0.25Hz is below the Nyquist rate of TR~1sec). We also took advantage of the simultaneity of SER-8 in cardiac gated imaging. Unlike conventional cardiac gated EPI which normally ends up with each slice having a different cardiac phase which in turn gives each slice a different T2* signature, SER-8 collects all 8 slices at the same cardiac phase.

In addition to the T2* problem associated with different cardiac phase in conventional cardiac imaging, there is also in general a T1 variation problem (for both conventional and SER-8) due to irregular TR. It seems that we would just be replacing the ungated cardiac noise with another type of noise. Besides, the possibility of the aliasing T1 signal, just like the ungated cardiac signal, may reduce any benefit of low passing to remove respiratory signal. However, there is a known T1 [2] based correction which we will apply in this report. With the T1 variation out of the way, it then makes sense to use a low pass filter to remove respiratory noise.

Materials and Methods

Studies were performed on four healthy subjects (30-45 years) on a 1.5 Tesla Siemens Avanto whole-body MR system. Each subject performed a visual task in the fMRI experiment. A blocked paradigm consisting of activation and fixation blocks was used. Each block lasted for 16 seconds. Visual stimulus consists of a black/white radial checkerboard inverted in intervals of 500ms projected onto a screen. A series of BOLD fMRI images were acquired using SER-8 sequence (TR/TE=150ms/57ms, flip angle=30 degrees) while the subject performed the visual task. Another series of BOLD fMRI images were acquired using the same SER-8 sequence and visual paradigm but with cardiac gating, with an average TR~950ms. For the gated BOLD images, T1 based correction was applied in post-processing. Activation maps were constructed separately on the short TR (TR=150ms) and gated BOLD images before and after low pass filtering at 0.12Hz, using t-test for the contrast of visual stimulus versus fixation. Comparisons were done on the t-value maps derived from the image data with and without low pass filtering, and, in the cardiac gating case, with and without T1 correction.

Results and Discussion

Fig.1 shows that the contrast to noise ratio was increased for more than 100% in the brain activation (t-value) maps derived from short TR data after low pass filtering at 0.12Hz. A large extent of physiological noise can be removed effectively by a simple low pass filter on image data acquired with SER-8 sequence. Fig.2 shows that physiological noise was reduced after T1 correction and low-pass filtering in the gated image data. The contrast to noise ratio in the brain activation derived from gated image data was increased for more than 50%. The present findings imply that physiological noise can be effectively separated from BOLD fMRI images acquired with either short TR or T1-corrected cardiac gated SER-8 sequence.

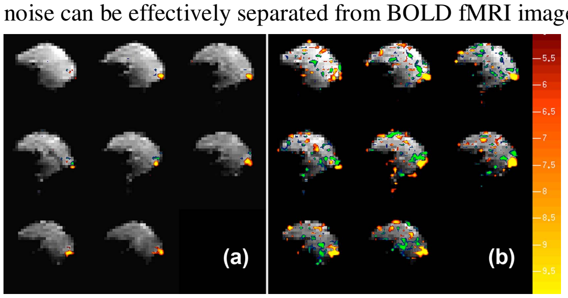

Fig.1 T-value maps derived from short TR image data (a) before low pass filtering at 0.12Hz; (b) after low pass filtering at 0.12Hz. Stronger brain activations at visual cortex and higher contrast to noise ratio with an increase more than 100% were seen with low-pass filtering.

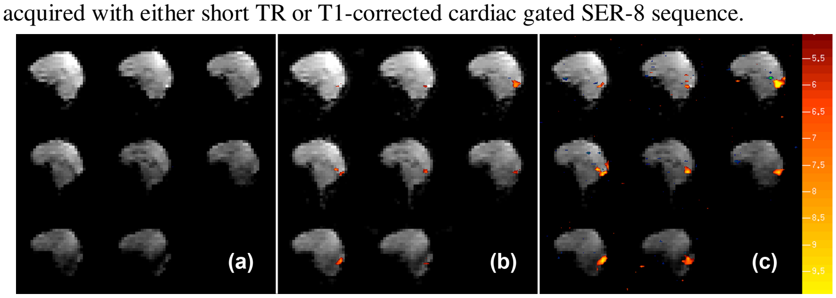

Fig.2 T-value maps derived from cardiac gated image data (a) without T1 correction and low pass filtering; (b) with T1 correction but without low pass filtering; (c) with T1 based correction and low pass filtering at 0.12Hz. Increased brain activations at visual cortex and higher contrast to noise ratio (more than 50%) were noted with T1 correction and low pass filtering.

References

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2. Guimaraes, A.R., et al., Hum Brain Mapp, 1998. **6**(1): p. 33-41.