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 the fMRI studies of brain activation as well as baseline brain oscillation at the resting state. 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. The cardiac and respiratory signals would also alias onto the low frequency bandwidth of interest (below 0.15Hz) in resting state brain oscillation studies (Birn, Diamond et al. 2006). Reducing physiological noise should free up the advertised contrast-to-noise potential of higher field machines and reduce any possible contamination to particular regions of interest in resting state oscillation research. We are extending the Simultaneous Echo Refocusing (SER) EPI sequence (Feinberg, Reese et al. 2002) 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 and in resting state. 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 more useful 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). There is a T1 variation problem for cardiac gated images due to irregular TR. However, T1 correction (Guimaraes, Melcher et al. 1998) can be applied. With the T1 variation out of the way, it then makes sense to use a low pass filter to remove respiratory noise.

In resting state, we used short TR but not cardiac gated SER-8 because we are interested in the role of cardiac frequencies. We ask the simple question: Are there at least some human subjects whose MR signals at the cardiac or respiratory frequency ranges show a correlation of pixels at the visual cortices? As long as there are some, and there need not be all, subjects who show such a correlation, the pixel correlation reported for low frequencies below 0.15Hz stands a chance of being contaminated.

METHOD

Studies were performed on four healthy subjects (30-45 years) on a 1.5 Tesla Siemens Avanto whole-body MR system. Three series of BOLD fMRI images were acquired using SER-8 sequence (TR/TE=150ms/57ms, flip angle=30 degrees) in brain activation and resting state studies.

Brain Activation Study

Two series of BOLD fMRI images were acquired with and without cardiac gating using SER-8 sequence while the subject performed the visual task. For the series with cardiac gating, the average TR was around 950ms. T1 based correction was applied in the post-processing of gated BOLD images.

Activation maps were constructed separately on the short TR (TR=150ms) and gated BOLD images before and after low pass filtering below 0.15Hz, 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.

Visual Task

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.

Resting State Study

A series of images were also acquired with the subjects in resting states with TR=150ms.

Fuzzy cluster analysis (FCA) (EvIdent, Institute for Biodiagnostics, NRC of Canada) was used to measure correlation of pixel time courses. Frequency ranges are defined as -- low frequency range: below 0.15Hz; respiratory range: 0.15Hz to 0.85Hz; cardiac range: above 0.85Hz.

RESULTS

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 below 0.15Hz. 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.3 shows that an example of the fuzzy cluster map of low frequency oscillation matching the fuzzy cluster map of visual cortex activations induced by flickering chekerboard.

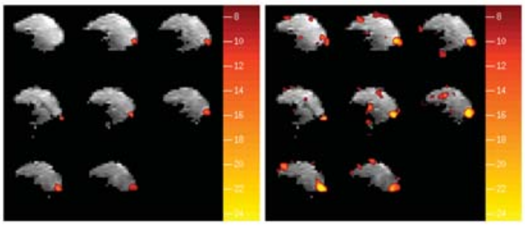

Fig.1 T-value maps derived from short TR image data (left) before low pass filtering below 0.15Hz; (right) after low pass filtering below 0.15Hz. Stronger brain activations at visual cortex and higher contrast to noise ratio with an increase more than 100% were seen with low-pass filtering. All the positive activations shown are significant with p<0.01.

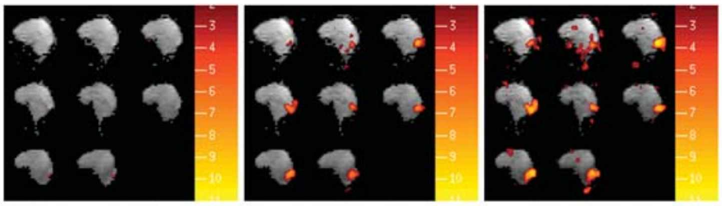

Fig.2 T-value maps derived from cardiac gated image data (left) without T1 correction and low pass filtering; (middle) with T1 correction but without low pass filtering; (right) with T1 based correction and low pass filtering below 0.15Hz. Increased brain activations at visual cortex and higher contrast to noise ratio (more than 50%) were noted with T1 correction and low pass filtering.

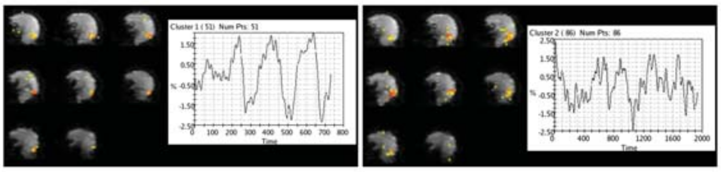

Fig.3 Frequency components derived from (left) image data show activations at visual cortices while subject was performing visual task; (right) image data showing low frequency brain oscillations at visual cortices while subject was in resting state.

DISCUSSION

While our small sample of 4 subjects would be sufficient to show the effectiveness of the fast acquisition of SER-8 sequence in the reduction of physiological noise, it also alerts us to the problem of physiological noise aliasing. A much larger sample size would be needed to study carefully the algorithms for the reduction of the physiological noise and the correlation of pixels at low frequencies onto the images acquired with SER-8 sequence.

CONCLUSION

Fast acquisition SER-8 sequence is effective to reduce the physiological noise. Short TR or cardiac gated algorithm with the low-pass filtering is able to improve the signal-to-noise ratio. The physiological noise and the low frequency brain oscillations at the resting state can also be separated in the images acquired with the SER-8 sequence.

References:

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