Localization of the Resting State Vasomotor Fluctuation with FFT, Cross Correlation, Principal Component and Independent Component Analysis of fMRI data.

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Introduction
Slow vasomotor fluctuation has been localized in the visual cortex of a resting state fMRI dataset of children under thiopental anesthesia (1). The anesthesia was hypothesized to enhance vasomotor fluctuation in the primary sensory areas due to a reduction in the regional cerebral blood flow (1,2). Previously the spatial localization of the vasomotor fluctuation was determined by color encoding the power of the Fast Fourier Transformation (FFT) spectral peaks and by cross correlating a voxel signal time course from the visual cortex (CC) (1). However, the FFT or CC do not clearly separate parenchymal, cerebrospinal fluid (CSF) or vessel sources of fluctuation. A recently developed statistical signal processing technique for separating source signals, namely independent component analysis (ICA), has been successfully implemented for fMRI studies (3-5). For this study the ICA was used to localize voxels that contain statistically independent spatiotemporal features. Principal component analysis (PCA) was used to find brain volumes that explains a maximum amount of variance in the data (6). In this study both the ICA and PCA were applied in the volume domain (4).

The aim of this study was to compare the efficacy of the mentioned four methods in separating the vasomotor fluctuation from other signal sources in the parenchymal regions in the resting state fMRI brain data set.

Methods
15 child subjects aged between 2 to 9.5 years (aver. 5.2) were imaged under thiopental anesthesia with fMRI while spontaneous breathing was ensured. The fMRI scans were performed approx. 30 min from the onset of the anesthesia. The imaging was performed using a 1.5 T GE Signa EchoSpeed MRI scanner with a birdcage head coil. Oblique axial slices covering the primary sensorimotor areas, based on a midline sagittal localizer, were used for each subject. The BOLD sequence of 90 repetitions in 5 slices was imaged with parameters TR=2000 ms, TE=40 ms, flip angle=90°, matrix = 962, FOV = 24x24, slice thickness = 7 mm and 5 mm slice interval. The hearing was protected with ear pads. Center of mass (COM)-analysis showed that none of the subjects exhibited motion greater than 0.9 mm (1).

The FFT spatial localization map of the slow fluctuation was generated by transforming the spectral power map of the chosen frequency into z-scores. Voxels of z-score > 6 were selected to present the chosen frequency. A voxel presenting low frequency signal fluctuation was selected from the visual cortex as a reference time course vector in order to obtain spatial map by cross correlation with a threshold of p < 0.001. The ICA and PCA were done with FastICA (3), in MATLAB. PCA reduced the data dimension from 80 snapshots to 40 principal components, which covered at least 99.99% of the original signal variance. ICA was then calculated based on whitened PCA component data. The resulting components were then transformed into z-scores to obtain spatial localization maps with threshold z > 6.

The data were evaluated by i) by the number of detected areas of fluctuation in the visual cortex, and ii) by the separation of blood vessel or cerebrospinal fluid (CSF) fluctuation from cortical vasomotor fluctuation in regions near sensorimotor cortices. The connectivity of the detected voxels was evaluated by mean correlation coefficient (MCC). MCC was obtained by calculating the mean of the correlation coefficients of each localized voxel on voxel basis.

Results
The FFT, cross correlation and PCA were able to localize the fluctuation in the visual cortex in each subject. However these methods were unable to differentiate fluctuations originating from the neurovascular activity, CSF or blood vessel pulsations in each subject (Fig. 1a-c). ICA was more robust in separating different fluctuation patterns of the distinct sensory cortices from blood vessel and CSF pulsation and various other source signals than other methods.

Discussion
ICA separated the vasomotor fluctuation in the visual cortex more clearly than the other methods. ICA also provided on average 2 other components of slow signal fluctuation in the secondary visual cortices. ICA also seems to detect fluctuation in most if not all the sensorimotor areas from the resting state fMRI data set. At present the disadvantage of the method is the relatively big number of different components and the lack of knowledge on the exact time domain features leading to the selection of each volume. The FFT-guided cross correlation offers a quick and robust analysis of the data quality and results in highly correlative voxels. PCA and FFT-color coding are not as accurate in the anatomical mapping as the rest of the method.

References

Fig.1. The images from a single subject. (a) FFT color encoded map (b) CC map. (c) PCA map (d-f) ICA maps separating functional cortex from blood vessel structures.