MR PERFUSION IMAGING USING HIGH-TEMPORAL-RESOLUTION RESTING-STATE FUNCTIONAL MAGNETIC RESONANCE IMAGING

Tianyi Qian[1], Yinyan Wang[2,3], and Tao Jiang[2,3]

[1]MR Collaborations NE Asia, Siemens Healthcare, Beijing, Beijing, China, [2]Beijing Neurosurgical Institute, Beijing, China, [3]Beijing Tiantan Hospital, Capital Medical University, Beijing, China

Target audience: Those interested in resting-state fMRI and brain perfusion imaging.

Introduction: A recent study found that time series in lesion areas of stroke patients during rest period showed a time-shift pattern that has a similar topography as a perfusion image[1]. However, in previous resting-state functional magnetic resonance imaging (rs-fMRI) studies, the global signal (the averaged time series of BOLD signal across the whole brain) has always been treated as the background noise and is typically regressed out[2]. Also the physiological source and quantitative characteristics of the global signal have not been fully studied. In this study, an iterative algorithm was used to extract the time-shift-corrected global signal. By calculating the time delay and weight with respect to the corrected global signal in each voxel, we were able to measure the transient time of the whole brain. Simultaneous multislice acceleration acquisition combined with rs-fMRI was used to acquire the dataset used in this study to further improve the temporal and spatial resolution of this method.

Materials and method: The simultaneous–multislice-accelerated EPI-based (non-product) rs-fMRI (SMS rs-fMRI) dataset we used in this study was obtained from the INDI repository (http://fcon_1000.projects.nitrc.org/indi/pro/eNKI_RS_TRT/FrontPage.html). Eleven healthy subjects (4 females, age 30.2±9.6 yrs.) were included in this study. SMS /rs-fMRI data was obtained on a MAGNETOM Trio Tim (Siemens AG, Erlangen, Germany). For each subject, there was one SMS rs-fMRI scan (TR=645ms, TE=30ms, flip angle=60°, 40 slices, SMS acceleration factor=4, FOV=222×222mm^2, voxel size=3×3×3mm^3, 900 scans) and one rs-fMRI scan in each session (TR=2500ms, TE=30ms, flip angle=80°, 38 slices, FOV=216×216mm^2, voxel size=3×3×3 mm^3, 120 scans). A standard pre-processing method for analyzing resting-state fMRI was applied to the SMS /rs-fMRI data[1]. After pre-processing, the perfusion map could be obtained using the following steps: 1) Averaging the time series of the whole brain to create the global signal. 2) For each voxel, we shifted the time course from -10s to +10s (e.g. TR=2500ms, shifted from -4 TR to +4 TR, TR=645ms, shifted from -16 TR to + 16 TR) and correlated it with the global signal at each TR. Each voxel was then assigned the value of time shift resulting in the maximal correlation coefficient value to create the time-shift map. 3) Recalculating a new global signal based on the time-shift map. The new global signal is the average of the time series of each voxel after shifting number of TRs determined by step 2. 4) Repeating step 2 and 3 until the number of voxel, who had changed their time-shift value between two iterations, is less than 100. 5) Computing the amplitude of global signal in each voxel using linear regression (the coefficient value b was defined as the amplitude of each voxel).

Results: The averaged time-shift map of the rs-fMRI data over 11 normal subjects (TR=2500 ms, voxel size=3x3x3 mm^3) is shown in Fig.1. As expected, the ventricle area shows the longest transit time and the area supported by the middle cerebral artery (MCA) shows significant shorter ransit time. The transit time of the area supported by the vertebral artery has earlier arrival time than that including the ventricle and slower than the area covered by the MCA. Compared with the standard rs-fMRI data, the results calculated from high-temporal-resolution resting-state fMRI (SMS rs-fMRI, TR=645 ms) are consistent with rs-fMRI. Furthermore, the SMS rs-fMRI has a better temporal resolution and could show more details of the transient process in different anatomical structures (Fig.2).

The averaged amplitude map of rs-fMRI and SMS rs-fMRI (Fig. 3) show that the amplitude of global signal is very small in the ventricle and white matter. Brain grey matter has larger amplitude than white matter which might be partially related to the oxygen metabolism of cortical neural activity. The venous sinus shows the greatest amplitude because it represents the highest concentration of deoxyhemoglobin after oxygen exchange. The different amplitudes between adjacent brain tissues can be better distinguished by SMS rs-fMRI as compared to standard rs-fMRI.

Discussion and Conclusion: By using the iteration time-shift correction method in this study, the weight of the global signal in each voxel could indirectly reflect oxygen-metabolism function. Both the time-shift and signal-weight patterns obtained from SMS rs-fMRI data can provide perfusion imaging information non-invasively with high temporal and spatial resolution. The current findings provide a new method to assesse hemodynamics in brain disease.

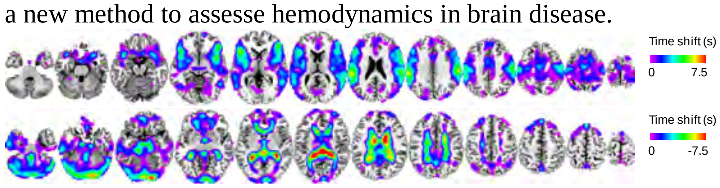

Figure 1. Averaged time-shift correction analysis results obtained from R-fMRI (TR = 2500 ms)

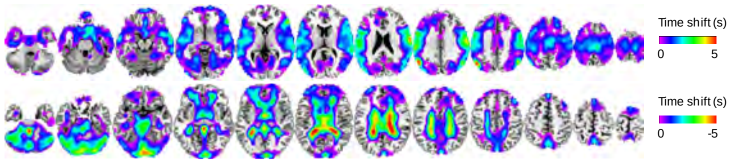

Figure 2. Averaged time-shift correction analysis results obtained from mR-fMRI (TR = 645 ms)

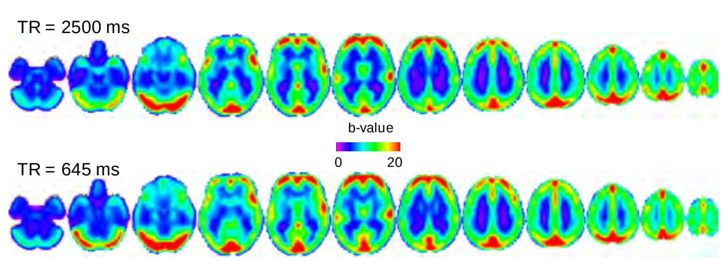

Figure 3. Averaged amplitude map of the global signal.

References:

1. Lv Y, et al., Annals of neurology, 2013;73(1), 136-140. 2. Fox M., et al., J. Neurophysiol. 2009;101, 3270–3283.