Resting State fMRI using Multi Echo EPI (ME-EPI): a Study of Echo Time Dependence of Sensitivity

Deqiang Qiu[1], Thomas Christen[1], Jae Mo Park[1], Michael E Moseley[1], and Greg Zaharchuk[1]
[1]*Radiology, Stanford University, Stanford, CA, United States*

Introduction: Analysis of the spontaneous physiological fluctuations [1] of the brain in resting sate has attracted significant interests, due to its potential for studying functional connectivity between different brain regions. However, the relative sensitivity of resting state fMRI (RS-fMRI) with respect to echo time has not been characterized. In this study, we developed a multi-echo EPI (ME-EPI) sequence with parallel imaging to study the dependence of RS-fMRI sensitivity on echo time. We also propose the use of combining multiple echoes for increasing the sensitivity and reducing the signal dropout in regions close to air-tissue interface.

Materials and Methods: MR imaging was performed at 3T with an 8-channel head coil (MR750, GE Healthcare, Waukesha, WI). Three subjects were scanned with the following protocol: A 3D T1-weighted inversion recovery spoiled gradient echo (IR-SPGR) sequence covering the entire brain was acquired. A multi-echo 2D EPI was acquired (FOV=24cm, Matrix = 64x64, slice thickness/gap = 4 mm/1mm, number of slices = 21, TR=2s, parallel imaging factor =2, five echoes: TE = 14ms, 28.7ms, 43.3ms, 58ms and 72.7ms, 250 temporal frames, total scan time was 8min20s). Image processing was performed using FSL, AFNI and home-written scripts. Image pre-processed included slice timing and motion corrections, spatial smoothing with 6mm FWHM, lowpass filtering at 0.1Hz, quadratic detrending and nuisance regression with 6 parameters of motion estimators and mean signal intensities from white matter and cerebrospinal fluid. Seed based analysis was performed, and a ROI with a radius of 3mm was placed in the posterior cingulate cortex (PCC) in the standard space to study the functional connectivity of the default mode network (DMN). To compare the relative sensitivity of RS-fMRI at different echo times, the correlation map was calculated in the native space and the number of voxels with correlation coefficient larger than an arbitrarily selected threshold of 0.45 was calculated. ROIs were placed to include bilateral PCC and angular gyrus (AG) and the mean correlation coefficients were calculated.

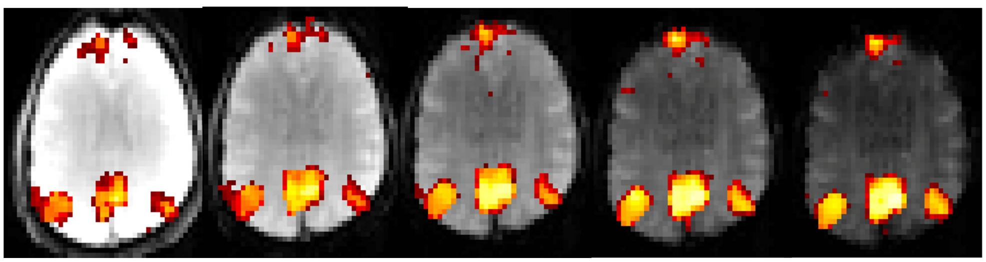

Fig 1: Correlation map with posterior cingulate cortex to detect default mode network at different echo times (from left to right: TE=14ms, 29ms, 43ms, 58ms and 73ms). Correlation coefficient increased with TE until 58ms and no significant increase was observed when further increasing TE to 73ms.

Results and Discussions: Figure 1 shows correlation maps with PCC acquired at different echo times. Visually, the correlation coefficients increase with TE up to 58ms. Further increasing the TE did not significantly change the correlation coefficients. Quantitative analysis (Table 1) confirmed this observation, showing similar trend with different metrics including the number of suprathrehold voxels, mean correlation coefficients in the PCC and angular gyrus. Since the T2* value of gray matter is approximately 50ms, it was expected that increasing TE beyond 58ms would substantially reduce the sensitivity. However, this was not observed. This is likely due to the fact that fluctuations caused by respiration and cardiac pulsation also change with TE in a similar way as spontaneous neural activity [2]. It was also found that at increasing TE, the signal drop-out at the frontal region near air-tissue interface became more severe. Combination of the different echoes for optimal performance may be performed taking into account the relative sensitivity information obtained in this study and the amount of signal drop-out. The use of parallel image in our implementation shortens the EPI readout train and hence reduces the image distortion. The reduction in static signal-to noise-ratio with the shortened readout time can be compensated by combining different echoes.

Echo	CC in PCC	CC in AG	#voxels with CC>0.45
1	0.67 (0.01)	0.58 (0.06)	711.3 (152.7)
2	0.75 (0.02)	0.63 (0.08)	978.0 (103.1)
3	0.77 (0.05)	0.62 (0.16)	882.0 (242.2)
4	0.82 (0.04)	0.69 (0.09)	978.0 (265.1)
5	0.83 (0.04)	0.71 (0.07)	918.7 (271.7)

Table 1. shows the number of voxels with correlation coefficient (CC) larger than 0.45, and the mean CC in posterior cingulate cortex (PCC) and angular gyrus (AG).

Conclusion: In this study, we developed a multi-echo EPI sequence to study the echo time dependence of RS-fMRI sensitivity. The RS-fMRI sensitivity increases with increasing TE until 58ms and does not change significantly when further increasing TE to 73ms. Different echoes from multi-echo EPI sequence can be combined for optimal sensitivity and this is being investigated.

References: **[1]**Biswal B. 2010. PNAS. 107:4734-9. **[2]**Qiu D. 2012. Neuroimage. 2012 Sep;62(3):1726-31. **Acknowledgements :** National Institute of Health (2RO1NS047607, 1R01NS066506, 5P41RR09784), Lucas Foundation and Oak Foundation