Connectivity and Perfusion Analyses with Simultaneous MultiSlice (SMS) Resting-State fMRI

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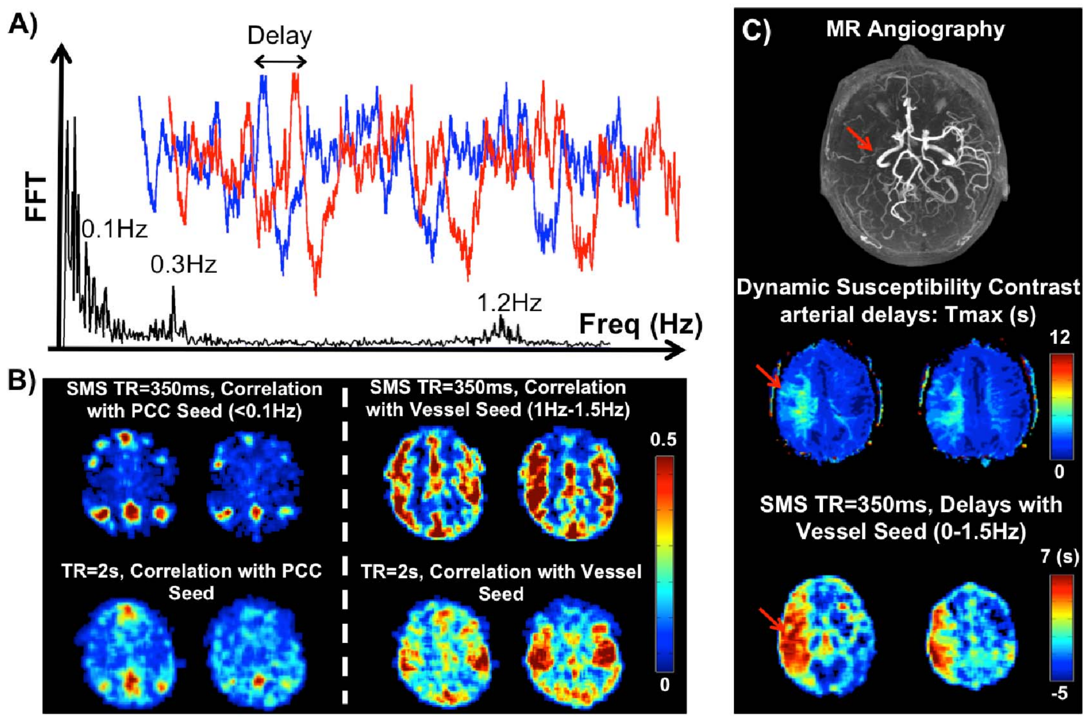
Introduction: Spontaneous fluctuations of the MR BOLD signal are usually acquired to explore the brain's functional organization through the resting-state BOLD fMRI (rsfMRI) analysis. Yet, a few recent reports have suggested that rsfMRI could also be used for perfusion related measurements [1-2]. The origins of this phenomenon remain unclear, and their study is limited by the long TR (>2s, and corresponding frequencies aliasing) used in most of the rsfMRI studies. In this work, we used the Simultaneous MultiSlice (SMS) EPI with blipped CAIPI method [3] to achieve a high-temporal resolution in rsfMRI. By achieving full brain coverage with a TR = 350ms, we were able to investigate the influence of different parts of the frequency spectrum on connectivity and perfusion measurements. Acquisitions were performed in healthy volunteers and patients with cerebrovascular disease.

Materials and Methods: The local IRB committee approved all studies. 3 volunteers (1 woman; mean age 30yrs; range 27-32yrs) were scanned at 3T (Discovery MR750 scanner, GE Healthcare Systems, Waukesha, WI) with a 32-channel head coil (NOVA Medical). 4 patients with diagnosed Moyamoya disease (3 women; mean age 40yrs; range: 24-52yrs) were scanned with an 8-channel GE head coil. A gradient echo SMS-EPI with blipped CAIPI sequence (TE=30ms, TR=350ms, 5 slices, SMS acceleration factor of 6 (32ch coil)/ 3 (8ch coil), CAIPI FOV shift of 3, FOV=20x20 cm, ST=5mm, matrix size=70x70) with 1000 repetitions was used for resting-state acquisitions. A standard non-SMS resting-state EPI acquisition with TR=2s and the same spatial resolution and coverage was also acquired for comparison. Data from the scanner were imported into MATLAB (MathWorks Inc., Natick, MA, USA). Resting-state data were corrected for head motion (least squares approach, 6 parameters). The first ten time points were discarded to avoid transient signal changes before the magnetization reached steady state. The time series were filtered in 3 frequency domains (0.01-0.1Hz, 0.1-0.5Hz, 1-1.5 Hz) to reflect functional connectivity, respiration, and cardiac contributions respectively. ***For Connectivity measurements,*** the Default Mode Network (DMN) was probed using a seed ROI centred in the precuneus/PCC. ***For Perfusion related measurements,*** a seed ROI was placed in superior sagittal sinus vein. The cross correlation analysis was performed with the reference signal shifted from +/-30TR, and the delay maps were created by taking the maximum of the correlation coefficient over the time lag [1-2]. In the Moyamoya patients, MR angiography and Dynamic Susceptibility Contrast (DSC) maps were obtained as part of the routine clinical protocol.



Results: Figure (A) shows whole brain signal in one volunteer (as well as a shifted version to illustrate the delays analysis). In the corresponding frequency spectrum, 3 domains with significant power can be identified. Results from the same volunteer are shown in Figure B. High correlation values (>0.5) were found using the PCC seed when the signal was filtered under 0.1Hz and correspond to the default mode network. The correlation coefficients were lower when the high frequency filters (>0.1Hz) were used (not shown). On the contrary, correlation analyses using the vein seed provided the highest coefficients when the signal was filtered above 1Hz. In that case, the correlation pattern resembles blood volume maps. It is interesting to note that – although no large delays were found in volunteers – the introduction of small lags in the analysis (<1.5s) was necessary to obtain the full vascular structure. In all cases, using SMS-EPI acquisitions with proper frequency filters provided better results than the standard EPI (TR=2s) acquisition (see bottom row in Fig B). In the Moyamoya patients, large delays (>5s) were found in the affected hemisphere. As seen in figure C, these delays correspond to arterial arrival times found with bolus perfusion analysis using the contrast agent (Tmax maps). In the delay maps, the highest SNR was found when the whole frequency spectrum (0-1.5Hz) was incorporated.

Conclusion: The study suggests that connectivity and perfusion maps can be created using a single resting state fMRI acquisition. The high temporal resolution allowed by the SMS-EPI approach permits one to focus on different parts of the frequency spectrum, and this increases the quality of the maps.

References: [1] Lv et al., Ann Neurol, 2013. [2] Christen et al., JMRI, 2014. [3] Setsompop et al., MRM, 2012. **Acknowledgements:** Supported in part by (NIH 1R01NS066506, NIH 2RO1NS047607, NCRR 5P41RR09784) and GE Healthcare. Authors also want to thank Atsushi Takahashi (MIT Martinos Imaging Center) for helping with the pulse sequence.