Simultaneous EEG and ASL Perfusion fMRI during Resting and Mental Calculation: A Preliminary Study

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Introduction The combination of EEG and fMRI offers the potential for multi-model neuroimaging with both high spatial and temporal resolutions (1). Recent studies have demonstrated the feasibility of simultaneous EEG and (blood-oxygen-level-dependent) BOLD fMRI (2-3). However, the cognitive domain that can be studied with EEG/BOLD fMRI is limited to transient processes due to the baseline drift effects in BOLD fMRI. Arterial spin labeling (ASL) perfusion contrast offers an alternative approach to BOLD fMRI especially for imaging sustained behavioral states. Concurrent recording of EEG and ASL perfusion fMRI may provide several potential advantages. Firstly, ASL scans include inherent RF/gradient quiet periods (e.g., delay time) with reduced interferences for EEG recording. Secondly, resting perfusion can be well linked to EEG power spectrum during specific behavioral states (e.g., sleep) without the need to perform task activation. Finally, EEG/ASL studies are less demanding in terms of signal processing, since event-related potentials (ERP) are generally not required. The present study explored the feasibility of simultaneous EEG and ASL perfusion fMRI during two resting states of eyes closed (EC) and eyes open (EO), along with a cognition task of mental calculation (MC).

Methods Five subjects (4 male, age 23-27 years) were scanned on a Siemens 3.0T Trio scanner, using the standard volume head coil. EEG data were simultaneously recorded using a 64-channel Neuroscan MagLink System. BOLD images were acquired during the two resting states of EC and EO with a typical gradient echo EPI sequence [60 acquisitions, 25 slices, 4mm thk/interleave, TR: 3s (1.5s image acquisition and 1.5s interval), TE: 30 ms, FOV: 22×22cm2, Matrix: 64×64]. Perfusion images were acquired during EC, EO and a mental calculation task of serial subtraction (eyes closed), using an amplitude-modulated continuous ASL technique [60 acquisitions, 12 slices, 6mm thk/1.5mm sp, TR: 5s (2s labeling, 1s delay, 0.5s image acquisition and 1.5s interval), TE: 17 ms, FOV: 22×22cm2, Matrix: 64×64]. SCAN 4.5 (Neuroscan) was used to analyze the interleaved EEG data recorded during the scan interval of BOLD fMRI and during the delay time of CASL perfusion fMRI thus no EPI noise was involved. BOLD and perfusion fMRI data were analyzed by SPM99. For each subject, raw EPI images were corrected for head motion, followed by pair-wise subtraction of label and control acquisitions and conversion to quantitative CBF images based on the single-compartment perfusion model (4). Voxel-wise population comparisons were then conducted on the BOLD and CBF images. Areas of significant activation were identified for uncorrected P value smaller than 0.005 and cluster size larger than 30 voxels (voxel size 2x2x2 mm^3).

Results Fig.1 illustrates the CBF activation differences between the three states overlapped on the mean CBF images. High quality perfusion images were obtained in each subject, with a mean global CBF value of 43.6 ml/100g/min. Consistent with the neuroimaging literature (5-6), perfusion fMRI revealed greater visual activation for EO than EC, and greater frontal and parietal activations for MC than EC. However, no visual activation was found by BOLD data, which may be attributed to the long blocks and unoptimizable experimental design for BOLD fMRI used in this study. Fig.2 illustrates the differences between the three states from EEG spectral analysis. Consistent with the EEG literature (7-8), EEG revealed greater alpha component over 8-11Hz in posterior brain for EC than EO, greater delta and theta components over 1-6Hz in frontal areas for MC than EC.

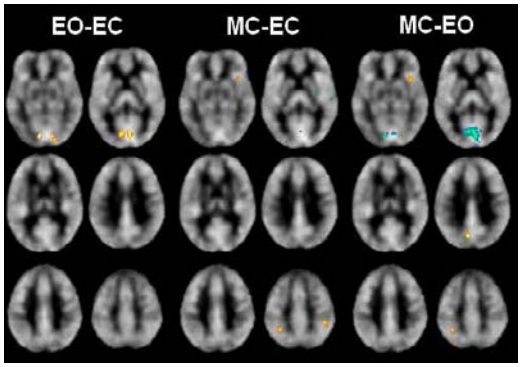

Fig.1. CBF activation differences between three states.

Discussion These preliminary results demonstrate the feasibility of simultaneous EEG and ASL perfusion fMRI for imaging brain activity during both resting states and cognition tasks. Compared to EEG/BOLD fMRI studies, concurrent EEG and perfusion fMRI is more suitable for tracking gradual state changes in brain function (e.g. sleep) with characteristic markers in both hemodynamic and neurophysiology.

References

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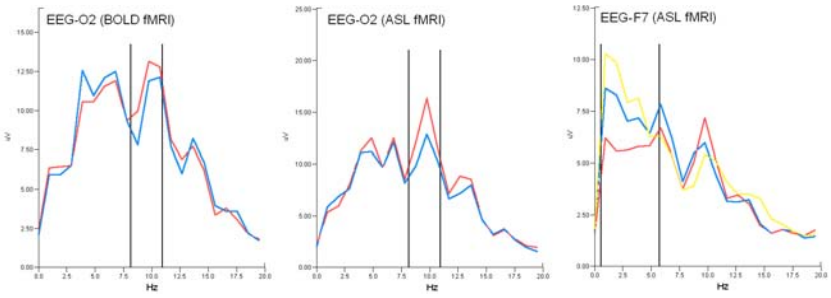

Fig. 2. Spectrum of concurrent EEG during EC (red), EO (green), and MC (yellow).