Assessment of the Reproducibility of BOLD signal-based Hemodynamic MRI

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TARGET AUDIENCE: People interested in clinical application of resting-state fMRI to cerebrovascular diseases.

PURPOSE

Mapping of temporal delay in resting-state brain fMRI (rs-fMRI) signal has been proposed as a potentially useful biomarker in vascular diseases [1, 2]. Recent works suggest that the draining veins or sinuses would provide optimum seed voxels for reference signal to create "venodynamic" or drainage MRI, a contrast agent-free counterpart to perfusion MRI[3, 4]. Here we conducted a test-retest reliability study of several rs-fMRI-based measurements.

METHODS

Day-to-day reproducibility experiment was conducted with seven participants. Inside a Siemens 3T scanner, whole-brain, multiband gradient-echo images were acquired with following parameters: 64 × 64 pixels, interleaved 28 slices, 224mm FOV, 4-mm slice thickness, TR/TE = 500/35ms, multiband factor of 4. From each experimental session, two five minute-runs (624 volumes) were subjected to the analysis.

Data processing: The first 22 volumes were discarded. Motion correction and band-pass filtering (0.008-0.1Hz) was applied prior to the analyses below. Anatomical normalization and spatial smoothing was done at the final stage.
1) ***Time-lag and magnitude analysis:*** We followed an earlier study[4] except for the size of the SSS seed. The lag maps (Lag) were created by taking the time shift relative to the SSS signal that gives maximum of the correlation coefficient for each brain voxel. We also created maximum correlation coefficient maps (Zmax) and BOLD magnitude maps (Mag, temporal standard deviation) to examine their stability.
2) ***Seed-based correlation mapping:*** PCC region of interest defined by AAL template was used. White matter and cerebrospinal fluid signals were regressed out. Individual correlation maps were converted to Z score-map to create DMN maps[5].
3) ***ICA-based denoising*** was done using MELODIC-FSL and an in-house Matlab script for automated IC classification. Following an earlier study[6], the individual ICs were classified as artifact by a simple heuristics based on (1) the fraction of time-series power above 0.2Hz, (2) the fraction of the component's spatial map overlaying low-intensity voxels. The artifactual components' time series were regressed out of the individual 4D data.

Finally, normalized mutual information (NMI) and voxel-wise correlation coefficient were calculated to evaluate similarity between every possible pair of intra- and inter-individual measurements.

RESULTS

Grand mean images and the similarity (NMI) between measurements are shown in the figure. Compared with the DMN, all of Lag, Mag, and Zmax maps had significantly higher inter-individual consistency (P<0.001, two-tailed paired T) even after the ICA denoising. Intra-individual (day-to-day) reproducibility was also higher as appears in the bar graphs and statistically significant (P<0.03 in Lag map), while it was significant only by correlation coefficient in DMN map. The ICA denoising was effective in improving the stability of Mag maps (P<0.001) but failed to significantly affect the reproducibility of other measurements.

DISCUSSION & CONCLUSION

We found higher reproducibility of the BOLD rs-fMRI-based hemodynamic mapping relative to the seed-based connectivity. Particularly the striking intra-individual stability encourages use of this technique for longitudinal observation in patients. Further study is necessary to understand the mechanisms underlying these venodynamic maps as well as their relationship with the brain neuronal activity.

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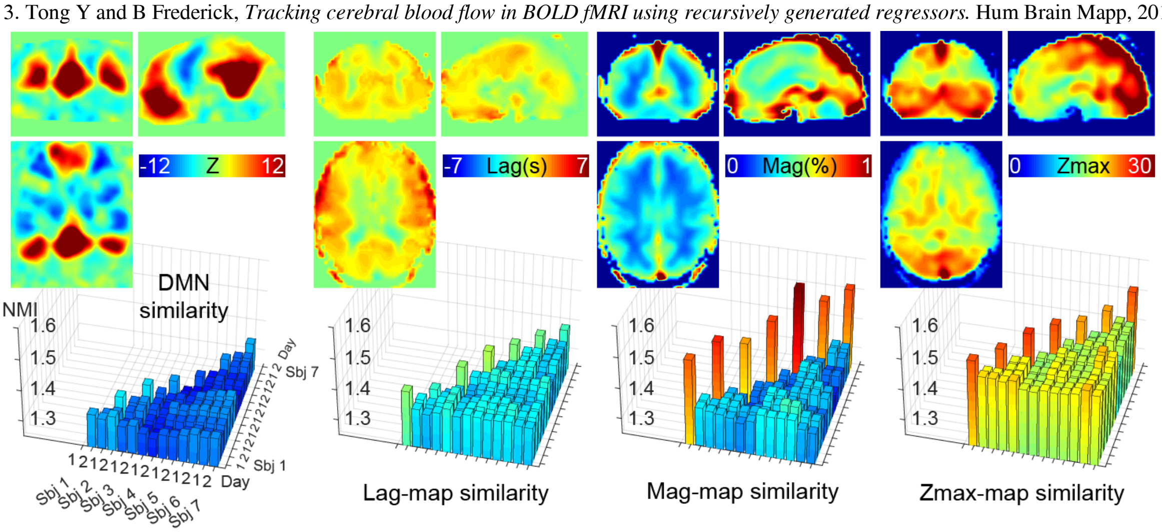

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