Resting Fluctuations in Volumetric Arterial Spin Labeling

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Introduction: Spontaneous signal fluctuations in resting brain have been studied widely using blood oxygenation level-dependent (BOLD) functional magnetic resonance imaging (MRI) (1-7). BOLD signal fluctuations are a combination of blood oxygenation, cerebral blood volume, cerebral blood flow (CBF) and metabolic rate of oxygen (8) and provide relative magnitude of signal fluctuations. In contrast, CBF-based measurement can provide a quantitative measure of signal fluctuations and may provide better localization of functionally connected regions (9-10) and better characterization of low temporal frequencies than BOLD (11). The presence of correlated resting fluctuations within motor regions has been reported with arterial spin labeling (ASL) (12-13). However, large-scale organized networks of perfusion fluctuations during the resting state have not been extensively studied. We report measurements of spatially correlated fluctuations using a volumetric ASL sequence with strong background and vessel suppression.

Methods: Five healthy volunteers were imaged on a GE 3 Tesla scanner using an 8-channel head coil receive array. Pulsed-continuous arterial spin labeling (PCASL) (14) images were acquired with a 3D stack of spirals RARE sequence: 40 axial slices with slice thickness of 4 mm, field of view of 24 cm and TR of 5 s. Each acquisition was performed with three interleaves and one average, producing a spatial resolution of 3.64 mm. Background suppression was used to minimize the BOLD contribution and to reduce motion and other instabilities. The timing of background suppression pulses (15) was optimized to achieve 0.3% of the background tissue signal. The PCASL difference images were acquired consecutively for 39 times with labeling duration of 2 s and post-labeling delays of 1.8 s. The post-labeling delay of 1.8 s was chosen to minimize the arterial transit time effects. A vessel suppression (VS) preparation pulse (16) was applied to minimize the effect from vessels although minimal vessel signals are expected for this post-labeling delay. Thirty-nine 3D images were collected in 20 minutes.

Standard group independent component analysis (ICA) was performed using probabilistic ICA (PICA) (17) as implemented in FSL's Multivariate Exploratory Linear Decomposition into Independent Components (MELODIC) Version 3.10. Default group PICA processing steps were applied to the data sets. Subsequently, thirty-nine 3D images from each volunteer were concatenated in time to create a single 4D data set. Each data set was head-motion corrected and normalized to the standard template space. The data sets were decomposed into the independent components (18) with the dimensionality automatically estimated from the software. The resulting estimated component maps were divided by the standard deviation of the residual noise and thresholded at a posterior probability threshold of p>0.5 (i.e. an equal loss is placed on false positives and false negatives) by fitting a Gaussian/Gamma mixture model to the histogram of intensity values (17). Each independent component describes spontaneous signal fluctuations across temporal and spatial domain.

Results & Discussions: Seven resting state independent components (ICs) were found using group PICA analysis (Fig 1). All 7 resting state networks are very similar to those reported in BOLD fmri (19-20). This demonstrates that ASL perfusion MRI technique has the ability to detect the resting state networks and provides a compensatory mechanism to analyze the brain rest state. Moreover, resting state networks are structured non-modeled noise in perfusion (and BOLD) MRI. The temporal and spatial correlation of noise can cause false positive or negative biases in any application of the technique if not taken properly into account. Due to the quantitative nature of ASL perfusion, the magnitude of perfusion fluctuating components in the resting state can be quantified and may be used in the noise compensation of the perfusion studies.
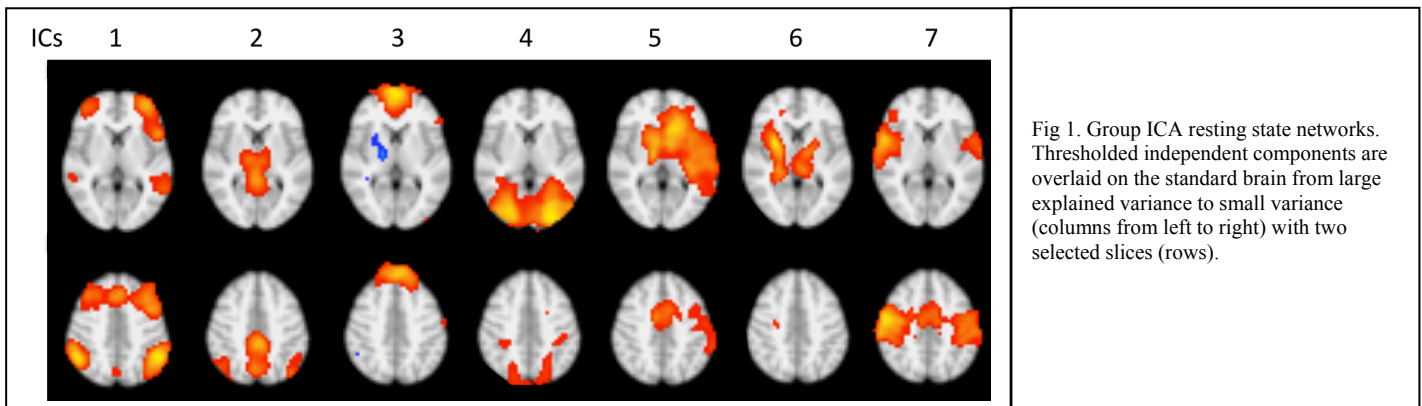

Fig 1. Group ICA resting state networks. Thresholded independent components are overlaid on the standard brain from large explained variance to small variance (columns from left to right) with two selected slices (rows).

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