Reliable Detection of Default Mode Network in Resting-state Perfusion fMRI using pCASL 3D GRASE with Background Suppression

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Introduction:

Resting-state functional connectivity (RSFC) has received much attention in clinical neuroscience applications. The majority of studies investigating resting-state networks are based on spontaneous fluctuations of BOLD signal which represent combined changes of cerebral blood flow (CBF), cerebral blood volume (CBV) and metabolic rate of oxygen. Recent studies have exploited the use of ASL perfusion fMRI for RSFC since perfusion fMRI may improve our understanding of the biophysical mechanism of resting-state connectivity and may provide a quantitative alternative to resting-state BOLD fMRI [1, 2]. However, the main limitations of resting state perfusion fMRI are the relatively low sensitivity, low temporal resolution and potential BOLD contamination. In this study, we report the use of pseudo-continuous ASL 3D GRASE (a hybrid of gradient and spin echo) [3] with background suppression (BS) to reliably detect RSFC arising from CBF fluctuations.

Methods:

Data acquisition: 13 healthy volunteers participated in this study on a Siemens 3T TIM Trio system with the product 12 channel head coil. Pseudo-continuous ASL (pCASL) with single-shot 3D BS GRASE was used for resting state perfusion fMRI. The imaging parameters were: FOV=22cm, matrix size=64x64, TE=22ms, TR=3s, partial Fourier=4/8, labeling time=1.5s, post-labeling delay (PLD)=1s, a 3D slab of 26 slices with 5mm thickness, 160 acquisitions with 8min scan time. To investigate the effect of BS, the pCASL 3D GRASE scan was repeated with compromised BS (PLD shifted 200ms from the optimal TI). For comparison, a resting-state BOLD fMRI scan was performed using gradient-echo EPI and the parameters were: FOV=22cm, matrix size=64x64, TE=30ms, TR=2s, 26 slices with 5mm thickness, 240 acquisitions with 8min scan time. During all scans, subjects were instructed to rest quietly and look at a blank screen.

Data analyses: Preprocessing steps included motion correction, normalization and smoothing (FWHM=8mm) were done using SPM8. Independent component analysis (ICA) was performed on both pCASL GRASE and BOLD fMRI data using the GIFT software. ICA was also performed on the label and control only image series of the pCASL 3D BS GRASE scan. The default mode network (DMN) component of each subject was converted to Z score, and a one sample t-test was applied on the Z score components of all subjects to produce the group map of DMN.

Results and Discussion:

The DMN was reliably detected by pCASL 3D GRASE with BS and BOLD fMRI in all subjects. Figure 1 shows the group t maps of the DMN based on BOLD (Fig 1a) and perfusion (Fig 1b) contrast, respectively, which include posterior cingulate cortex/precuneus, medial prefrontal cortex, and bilateral parieto temporal cortex. However, the perfusion DWN includes ventromedial prefrontal and orbitofrontal cortex which are not detected by BOLD fMRI, likely due to reduced susceptibility effects using GRASE. With compromised BS, the DMN cannot be reliably detected by pCASL 3D GRASE (Fig 2a), suggesting that BS effectively enhances the sensitivity of perfusion fMRI for detecting spontaneous CBF fluctuations. To further identify the source of perfusion based RSFC, ICA analysis was performed on the label and control only image series of the pCASL BS GRASE scan, respectively. The DMN can be detected in the label only series (Fig 2b), whereas no obvious pattern of DMN is observed in the control data (Fig 2c). This result further indicates that there is minimal BOLD effect in the raw GRASE images acquired with BS. Therefore, the detected DWN using pCASL BS GRASE reflects true spontaneous fluctuation of resting-state CBF with no or minimal BOLD effects. The mean CBF in the ROIs of the DMN from perfusion and BOLD data are 56.90 and 52.20 mL/100g/min, whereas it is 42.01 and 43.08 mL/100g/min in the rest of the brain.

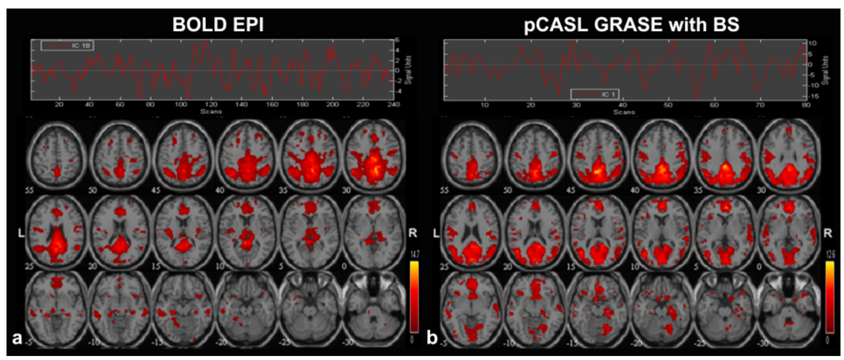

Figure 1 group t maps of DMN by BOLD EPI (a) and pCASL 3D GRASE with BS (b). The color bar shows the t-value (t>2)

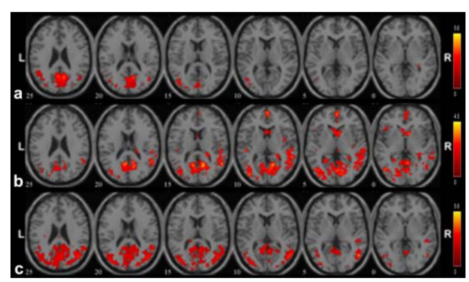

Figure 2 group t maps of DMN from pCASL 3D GRASE with compromised BS (a), label (b) and control (c) only image series of pCASL BS GRASE.

Conclusion:

This study demonstrated reliable detection of the DWN in resting-state CBF series using pCASL 3D GRASE with BS. The use of BS is critical for enhancing the sensitivity of resting-state perfusion fMRI while effectively minimizing potential BOLD contamination.

References:

[1] Chuang, K-H, et al., NeuroImage, 40:1595-1605, 2008. [2] Zou, Q., et al., NeuroImage, 48:515-524, 2009. [3] Fernández-Seara, MA, et al., Magn Reson Med, 59:1467-71, 2008.