Globally Correlated Brain Signals Using Resting State Arterial Spin Labeling

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Introduction: Spatially structured noise is a major component of the variability in Arterial Spin Labeling (ASL) measurements[1]. Study of the structured noise has previously highlighted the contribution from resting state fluctuations in known brain networks, but a larger, globally correlated fluctuation appears to be the greatest contributor. Here we employ cardiac and respiratory cycle monitoring during repeated ASL measurements to assess the systemic physiologic contribution to ASL fluctuations and to separate them from fluctuations with more brain specific origins.

Methods: Five healthy volunteers were imaged with eyes closed on a GE 3 Tesla scanner using an 8-channel head coil receive array. Resting-state pseudo-continuous ASL (PCASL)[2] was performed. PCASL images were acquired with a 3D stack of spirals RARE sequence, a slice thickness of 4 mm and a TR of 5 s. Each acquisition was performed with one interleave and one average, producing an in-plane spatial resolution of 7.5 mm. The timing of background suppression pulses was optimized to achieve suppression of the background tissue signal to 0.3% [3]. A labeling duration of 2 s and post-labeling delays of 1.8 s was used. After an anatomic localizer, first one hundred interleaved label and control pairs of PCASL images without vessel suppression were acquired, followed by one hundred control-only PCASL images, with vessel suppression. Pulse oximeter and respiratory bellows were used to monitor cardiac and respiratory signals during the ASL acquisition.

To assess the signal variation associated with cardiac and respiratory cycles, a cardiac and respiratory phase for each image acquisition was extracted from the monitoring waveforms. A linear increase from 0 to 2π between two adjacent peak pulse signals was assumed[4]. Individual single shot images, including separate control and label images in the first scan, were reconstructed using a phase sensitive reconstruction employing the phase map from the average ASL difference map. Global brain signal at each time point was calculated as the mean signal within a 3D brain mask. The global noise curve was calculated by subtracting the global mean of the signal-time curve and then normalizing by the mean perfusion difference value. The global noise curve was fit to a second-order Fourier series of cardiac and respiratory phase to obtain the cardiac and respiratory noise. Residual noise was calculated by subtracting the cardiac noise and respiratory noise from the global noise. Standard deviation of each noise was used to evaluate its variation. To evaluate the spatial distribution of physiological noise and residual noise, Pearson correlation coefficient maps were calculated across time series between voxel signal and global physiological noise and residual noise.

Results & Discussions: A substantial cardiac associated noise was detected with mean fitting power greater than 0.5 in ASL control signals (Fig. 1a), but negligible respiratory cycle associated noise (fitting power <0.15) was found. ASL label signals had larger fluctuations than control signals but with comparable cardiac contribution (Fig. 1a and 1b), which can be confirmed in the noise distribution plot of ASL signals (Fig. 2). This indicates that another mechanism other than cardiac noise but sensitive to perfusion labeling causes a larger signal variation. Cardiac noise was greatly reduced by suppressing vessel signals (Fig. 2), suggesting that variable velocity dependent attenuation of vessel signal in the RARE images is primarily responsible for the cardiac associated variability. This confirms that signal variation associated with labeling is minimal, as suggested by simulations of long labeling duration and post-labeling delay variability. The global cardiac and residual noise shows a quite uniform distribution on gray matter regions except very long transit time regions (Fig. 3). These results support a globally correlated brain perfusion fluctuation unrelated to cardiac or respiratory supply. Though contributions from a non-neural mechanism cannot be excluded, these data could indicate the existence of a globally correlated resting network.

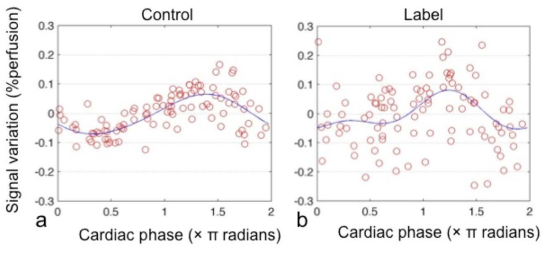

Fig.1. Global signal variation of (a) control images and(b) label images as a function of cardiac phase.

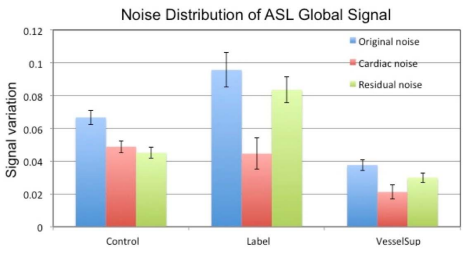

Fig. 2. Noise distribution of ASL global signals for the ASL control images, label images and control images with vessel suppression.

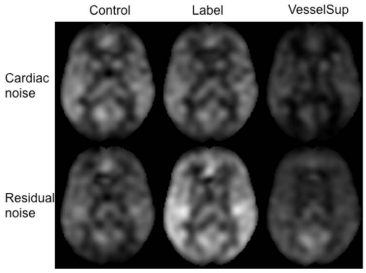

Fig. 3. Spatial distribution of cardiac noise and residual noise for the ASL control images, label images and control images with vessel suppression. The residual noise for the label images was divided by 2 and the third column was multiplied by 2 for better visibility.

References: 1. Viviani, Neuroimage 2011;54:2066-2078. 2. Dai et al, Magn Reson Med 2008;60(6):1488-97. 3. Maleki et al, MAGMA 2012;25(2):127-33. 4. Hu et al, Magn Reson Med 1995; 34:201-212.