Evaluation of removing residual motion artifacts and global signal fluctuations in functional Arterial Spin Labeling data

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Introduction: Arterial spin labeled (ASL) MRI is a noninvasive method to measure cerebral blood flow (CBF) using the magnetically labeled arterial blood water as an endogenous tracer. ASL-CBF is derived from signal changes between label and control images and are therefore highly sensitive to motion, not only the head motion at each time point but also the relative motion between the control-label images within each pair. Therefore, denoising is critical to improve the quality and stability of CBF maps [1]. Previous studies have been focused on suppressing noise in ASL data using different ASL signal models, spatial smoothing, temporal filtering, outlier cleaning, or some image-based denoising methods; however, less attention has been given to the residual motion artifacts (RMA) and the global signal fluctuations (GSF). The purpose of this work was to discuss the effects of removing RMA and GSF from our ASL data set used for functional analysis of the brain at rest.

Materials and Methods: Images of 20 healthy subjects (age = 24±3 years, 13 male) were acquired in a 3T system, using a 32-channel head coil for signal reception. For resting state functional evaluation, axial images of pseudocontinuous ASL (pCASL) were acquired (2D EPI, TR/TE = 4000/14 ms, flip angle = 90°, FOV = 240 x 240 mm², matrix = 80 x 80, 20 5-mm slices, labeling time = 1525 ms, post-labeling delay = 1650 ms, 75 dynamic pairs). For anatomical reference, images were acquired using a 3D T1-weighted GRE sequence (TR/TE = 7/3 ms, flip angle = 8°, matrix = 240 x 240, FOV = 240 x 240 mm², 160 1-mm slices). Images were processed using own routines developed in MATLAB (MathWorks, Natick, MA), SPM12 and analyzed in CONN Toolbox. The procedure for removing of RMA and GSF were divided in three steps: (1) all label and control images in the original acquisition order were input to the standard motion correction procedure and the 3 translational and 3 rotational motion time courses were estimated for the entire ASL image series; (2) the zig-zagged label-control patterns were removed from those motion time courses through simple regressions; (2) the cleaned motion parameters were then used for real motion correction. Finally, a temporal filtering was performed using a high-pass Butterworth filter (cut-off frequency = 0.02 Hz).

Results: All brain networks identified, without and with the RMA and GSF corrections (Figure 1a), demonstrated visual similarity on spatial pattern and similar correlation coefficients with Harvard-Oxford functional atlas. However, regarding functional connectivity, there was a change in the number of significant correlations between brain regions ($p < 0.05$ FDR-corrected), with a slight decrease in the number of anti-correlations (Figure 1, b and c) and an increase in the positive ones.

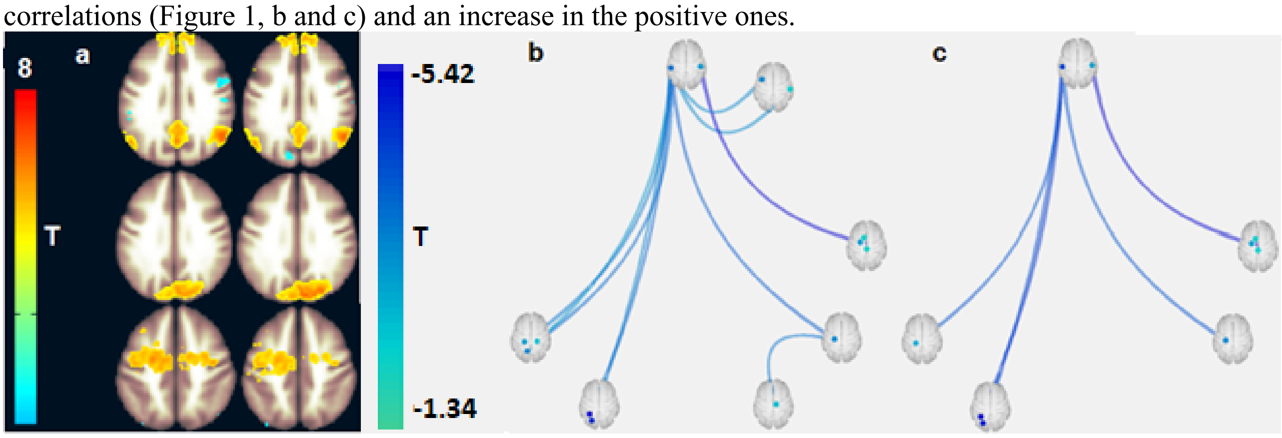

Figure 1: a) Default mode, visual and sensorimotor resting-state networks. b,c) Significant anti-correlations obtained without and with correction for RMA and GSF, respectively.

Conclusion: Our results indicate that the application of RMA and GSF correction in ASL data appears to not affect the identification of brain resting-state networks; however, functional connectivity analysis may be influenced by the addition of extra significant correlations.

References: [1] Ze Wang. Improving Cerebral Blood Flow Quantification for Arterial Spin Labeled Perfusion MRI by Removing Residual Motion Artifacts and Global Signal Fluctuations. 2012. Magnetic Resonance Imaging 30;10: 1409-15.