Physiological motion correction of ASL fMRI measurement of rhesus monkey

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[Introduction] The ASL-based perfusion measurement is vulnerable to the physiological motion. There are two major approaches in the physiological motion correction of ASL-fMRI [1,2], namely: 1) correction in k-space or image-space using independently recorded physiological data (i.e. respiratory belt), and 2) correction based on calibration scans like navigator echoes. In this study, we introduce a simple phase correction approach to eliminate the physiological motion artifacts for ASL fMRI measurement with echo-planar imaging in the non-human primate at 3T. This method does not require acquisition of additional data or pulse sequence modification . Our results show the significant improvements and robustness on the reduction of the physiological artifacts in the ASL-based fMRI measurement.

[Material and Methods] Three healthy rhesus monkeys (~7 kg) were anesthetized under ~1 % isoflurane delivered to a non-rebreathing circuit. The animal was placed in the sphinx position in the scanner in a home-made animal holder. Physiological parameters, (end-tidal CO_2, heart rate, respiration rate, rectal temperature, O_2 saturation) were maintained within normal physiological ranges. Hypercapnic challenge used a premixed gas of 5% CO_2 with 30% O_2 and balanced N_2, relative to a baseline of 30% O_2 and balanced N_2. There are 3 minutes for control and then 3-minute CO_2 stimuli. BOLD and CBF response time courses are collected simultaneously.

MRI was performed on a Siemens 3T Trio scanner using an extremity CP knee coil. The amplitude-modulated continuous ASL pulse sequence was applied for the CBF measurement [3] with TR = 4000 ms, TE = 31 ms, post-labeling delay = 800 ms, labeling duration = 2000 ms, FOV = 96x96 cm, matrix = 64x64, eight 2.0-mm slices with 15% slice gap, and 60 pairs of images.

The reference phase maps were generated for each slice from one pair of optimal sequential control and labeled images, and were applied for all other control and label images in the time serials respectively.

$$S(control) = A(control) * \exp(-\varphi(control\_ref))$$
$$S(label) = A(label) * \exp(-\varphi(label\_ref))$$

where S is the k-space data intensity in complex, A is the amplitude of the raw k-space data, φ is the phase of the reference image. Perfusion images were computed from the simple pair-wise subtraction of the control and labeling images. BOLD (obtained from non-labeled images) and CBF percent-change maps were generated [4].

[Results and Discussion] **Figure 1** shows the time courses showing the up-down signals of pair-wise ASL measurements during hypercapnia challenge with (red) and without (blue dash) physiological motion correction. The corrupted up-down signals (pointed by arrows) were improved in several images. **Figure 2** shows the histogram of CBF percent-change with (red) and without (blue dash) physiologic correction. Physiological correction increased the number of "active" pixels by 30 mainly for CBF increase less than 40%, which implies that the correction is more effective to detect subtle or small CBF changes. **Figure 3** shows cross-correlation maps of CBF-percent changes at a fixed threshold with and without physiologic correction. With correction, more active pixels were observed. In short, a simple phase correction approach demonstrates significant improvement in detecting mild increase in CBF with CO_2 inhalation. Since the reference scan can correct the N/2 ghost artifacts as well, this approach would be applicable in the segmented EPI motion correction.

[Conclusion] The proposed post-processing approach effectively eliminates the physiological motion artifacts in the ASL CBF measurements. This method does not require acquisition of additional data or pulse sequence modification, and easily be applied to other animal or human ASL fMRI measurements.

[References] [1] Restom et al, NeuroImage, 31:1104, 2006. [2] Pfeuffer et al, MRM, 47:344, 2002. [3] Wang et al, Radiology 235:218, 2005. [4]Strupp J, Neuroimage, 3:S607, 1996.

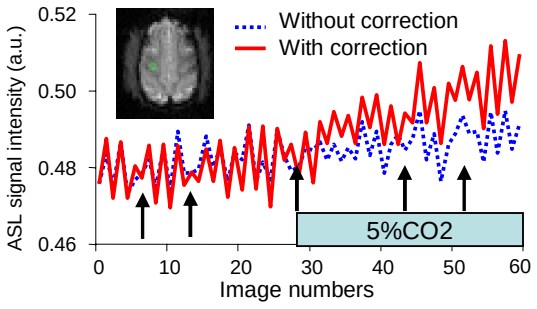

Figure 1. Time-series of alternative labeled and non-labeled images with and without physiological correction from an ROI as shown.

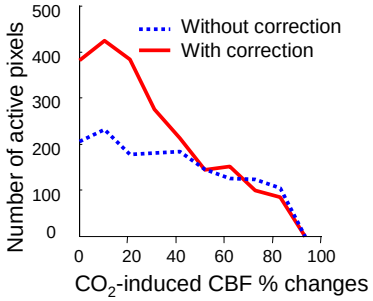

Figure 2. CBF %-change histograms with and without physiological correction.

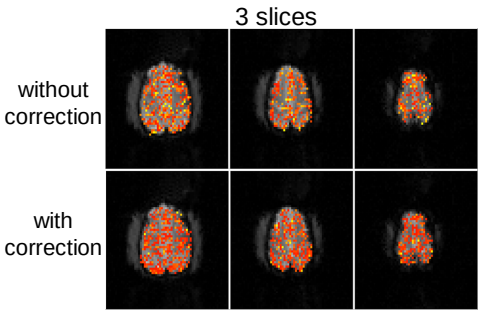

Figure 3. Cross-correlation maps of CBF percent-change with and without correction.