Derivation of flow information from a hypocarbia challenge study using time delay correlation processing

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Target Audience: Clinicians and researchers studying circulatory dysfunction resulting in significant perfusion delays.

Purpose: Regressor Interpolation at Progressive Time Delays (RIPTiDe) extracts hemodynamic information from BOLD fMRI data using regressors obtained using near infrared spectroscopy (NIRS)[1-5] and extracted from the BOLD data itself[6]. Global endogenous random variations of blood volume and oxygenation can be tracked as they pass through the highly perfused tissue of the brain through their effect on the BOLD signal by determining the strength and peak time delay of their crosscorrelation. Hypercarbia produces transient changes in blood volume of much greater magnitude than these random fluctuations, significantly enhancing the sensitivity of the technique. Here we use this method to analyze data obtained during transient hypercarbia in patients with cerebrovascular disease and hemodynamic compromise to assess cerebral circulation pre- and post- surgical revascularization.

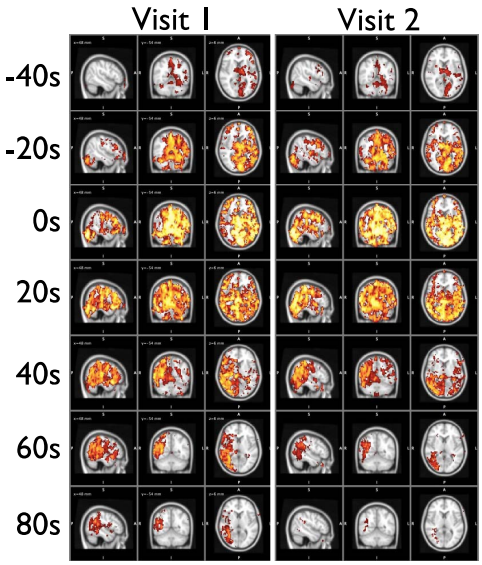

Figure 1: Correlation between the refined carbogen regressor and BOLD data at various delay times before and after surgical intervention for moyamoya disease. Correlations shown range from 0.65-1.

Methods: Functional data were recorded from 20 subjects who provided informed, written consent and were enrolled in an ongoing study of patients undergoing evaluation and treatment for intracranial stenosis. All MR data were acquired on a 3T Philips Achieva MR scanner using an 8-channel SENSE head coil. Participants were fitted with a gas delivery mask and asked to lie quietly in the scanner during the image acquisition. After acquisition of localizers and a T1 weighted high resolution anatomic scan, perfusion data were acquired (pCASL, 3x3x7 mm; TR/TE/TI=4000/13/1650 ms), followed by a BOLD acquisition during a transient hypercarbia challenge (gradient echo EPI, flip angle=90 degrees, matrix = 80 x 80 on a 220 x 220 mm FOV, 30 5 mm slices parallel to the AC-PC line extending down from the top of the brain TR=2s, 450 timepoints. Air and carbogen (5% CO2/95% O2) were alternately delivered through the mask in three minute blocks (air-carbogen-air-carbogen-air) during the scan.

Data were analyzed using an iterated RIPTiDe procedure (described in [6]) to isolate the moving hemodynamic component of the BOLD signal by examining the temporal crosscorrelations the BOLD data and the probe regressor. The hypercarbia timecourse, convolved with the hemodynamic lag function, is used as an initial input to the RIPTiDe procedure to find the voxel specific time shift and correlation with the BOLD signal throughout the brain. The BOLD signal from each voxel is then timeshifted so that the common component is in phase. A principal component analysis of the weighted, aligned timecourses is used to generate a refined estimate of the global hemodynamic signal. The procedure is repeated with the new regressor until convergence (3 iterations).

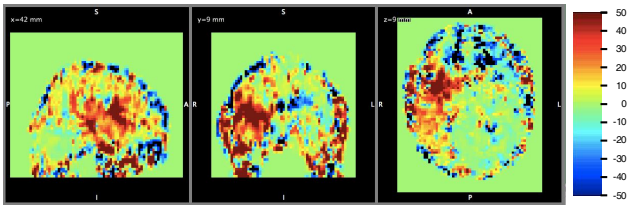

Figure 2: Decrease in time to peak correlation in the postsurgical scan compared to presurgical scan. The color scale indicates the decrease in time to peak in seconds.

Results and Discussion: The refined regressor is strongly correlated with the BOLD data over a wide range of time delays. By presenting the correlation as a movie, the arrival time of blood throughout the brain is revealed as the time of maximum correlation in each voxel. Figure 1 shows a subject with moyamoya disease before and after a surgical revascularization on the right side of the brain. Peak correlation times in the posterior right brain occur as much as 100 seconds after the peak on the contralateral side (suggesting blood arrives to one side of the brain up to 1 minute 40 seconds after arrival at the corresponding location on the other side). This delay is decreased postsurgically by as much as 50 seconds (shown in Figure 2).

Conclusions: RIPTiDe processing of hypercarbia challenge data yields rich information on perfusion timing Because the procedure uses oxygenation and volume variations that travel with the blood, relatively unchanged, rather than inverted magnetization, the detection efficiency does not depend on either the T1 of blood or the transit time through the head. This is especially useful when perfusion is delayed by as much as 100 seconds, which would not be visible to other methods such as ASL. This may be a useful clinical tool for assessing cerebrovascular pathology and treatment response.

References: 1. Tong, Y., et al., NeuroImage, 2010. **53**(2): p. 553-564. 2. Tong, Y., et al., JCBFM, 2011. **31**(12): p. 2352-2362. 3. Frederick, B., et al., NeuroImage, 2012. **60**(3): p. 1913-1923. 4. Tong, Y., et al., NeuroImage, 2011. **56**: p. 2047-2057. 5. Tong, Y., et al., Journal of Biomedical Optics, 2012. **17**(10): p. 106004-10. 6. Frederick, B. et al, 3rd Biennial Resting State Brain Connectivity Conference, Poster 0161, Magdeburg, 2012.