Snapshot MR-OEF for Simultaneous Imaging of Tissue Oxygenation and CVR

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Introduction: Asymmetric hemispheric cerebral Oxygen Extraction Fraction (OEF) has been shown to be an independent predictor of stroke risk [1]. Furthermore, the NIH/NINDS Progress Review Group has recently named tissue oxygenation imaging as a primary research goal in its August review. We have developed a novel method of imaging OEF and Cerebral Vascular Reserve (CVR) with MRI. We present an analysis of MR-OEF images using breath-hold and cardiac-gating as inducers of physiologic stress.

Methods: We acquire a 2D k-space volume using a novel rosette trajectory in 65 ms for simultaneous imaging of OEF and vascular reserve. Subjects were tested under 2 transient stress conditions: breath-hold and cardiac-gated. *Breath-hold:* 20 susceptibility weighted measurements were taken (Δt = 3 secs) with an induced 15 second breath-hold. By acquiring 20 datasets and inducing the short breath-hold we are able to observe frequency shifts ($\delta\omega$) resulting from increased de-oxyhemoglobin in the draining veins of the head, similar to the BOLD contrast. These 4-10 Hz shifts are examined using ICA with the spatial domain defined as the length along the FID readout and with the temporal domain defined by the 20 time points separated by Δt. *Cardiac-gated:* Because of the speed of PARSE (65 ms) we are able to see the transient hemodynamic fluctuations induced from the cardiac cycle. Images were acquired in 25 ms intervals from the R-wave trigger. Relative CVR is measured in the image domain by fitting a pixel's decay through the cardiac cycle.

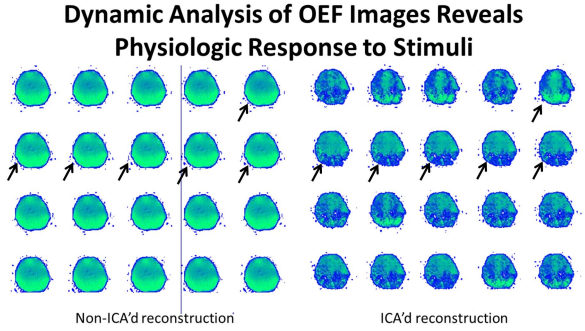

Figure 1: (left) A time series of MR-OEF images acquired over 60 seconds, with a breath-hold induced at measurement 4 (arrows). (right) Blind source separation using independent component analysis (ICA) is able to identify and display dynamic physiologic changes related to the breath-hold.

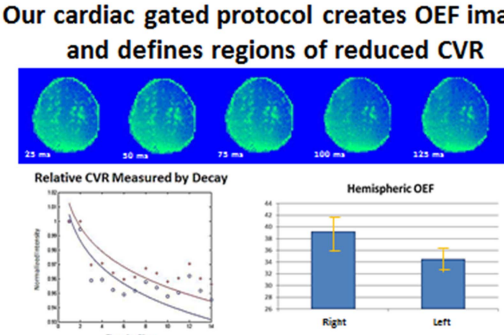

Figure 2: Five OEF images taken in the first 125 ms of the cardiac cycle in a symptomatic patient with a right ICA stenosis. Notice the early flush and subsequent flow out, suggesting sensitivity to intra-arterial pressure waveforms. Patient's right hemisphere has elevated OEF and decreased CVR consistent with symptoms..

Results: Measured mean OEF in normal brain parenchyma of 36.87 ± 6.6% and regions in symptomatic patients reaching 84.05 ± 4.54% correlate well with literature. Figure 1 shows a comparison between 20 consecutive MR-OEF images created before and after ICA analysis. Notice the enhanced physiologic information gained from the ICA'd images. Figure 2 shows, OEF images taken during the first 125 ms of the cardiac cycle in a symptomatic patient with a right ICA stenosis. Asymmetric hemispheric OEF (right hemispheric 13.06% elevation) is clearly visible. We also see a non-uniform flush in of de-oxygenated hemoglobin with a subsequent uneven outflow, unseen in healthy volunteers, suggesting regions of compromised cerebral vascular reserve.

Discussion/Conclusion: Our novel acquisition allows us to simultaneously image single slice OEF and vascular reserve in 65 ms (with total scan time less than 90 seconds). Move over, because of its unprecedented speed, we for the first time, have the temporal resolution to examine the cerebral hemodynamic fluctuations caused by the pressure waveforms induced by the cardiac cycle.

References: [1] Derdeyn, Brain 2002,[2]Twieg, MRM 2002