# BOLD MR Mapping of Cerebrovascular Reactivity in Patients with Arterial Steno-occlusive Disease: Validation by Arterial Spin Labeling MRI

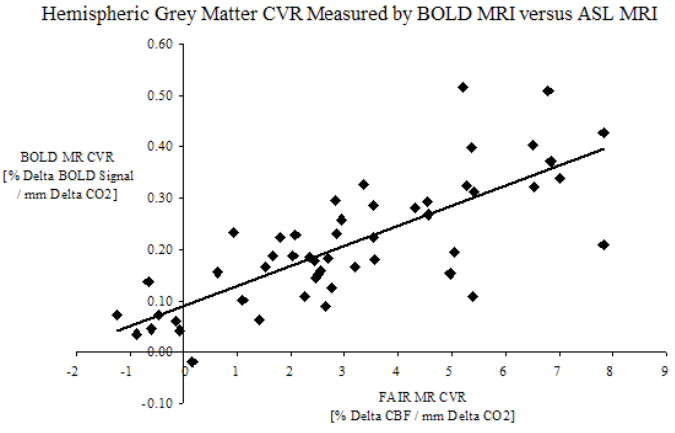
**D. M. Mandell[1,2], J. S. Han[3,4], J. Poublanc[1], A. P. Crawley[1], J. A. Stainsby[1,5], J. A. Fisher[3,4], and D. J. Mikulis[1,2]**

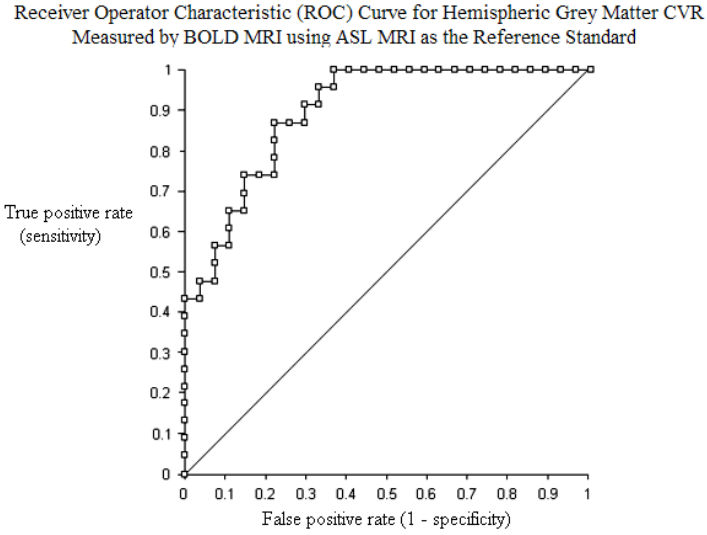
[1]Department of Medical Imaging, Toronto Western Hospital, Toronto, ON, Canada, [2]Department of Medical Imaging, University of Toronto, Toronto, ON, Canada, [3]Department of Anesthesia, Toronto General Hospital, Toronto, ON, Canada, [4]Department of Physiology, University of Toronto, Toronto, ON, Canada, [5]GE Healthcare

**Introduction:** Cerebrovascular reserve (that is, capacity for cerebral autoregulatory vasodilatation) can be assessed by measuring the change in cerebral blood flow (CBF) induced by a vasodilatory stimulus. An emerging technique uses blood oxygen level dependent magnetic resonance imaging (BOLD MRI) as an index of CBF changes, and inhaled carbon dioxide as the vasodilatory stimulus. The major concern with this technique has been that BOLD MRI signal depends on CBF, but also (and to an unknown extent) on cerebral blood volume, cerebral metabolic rate, arterial partial pressure of oxygen, and hematocrit. To determine whether BOLD MRI can be used as surrogate for regional CBF imaging to map cerebrovascular reserve, we compared the BOLD MRI signal response to hypercapnia with that of ASL MRI (a reference standard for CBF measurement), in patients with steno-occlusive disease.

**Methods:** Twenty five patients with arterial steno-occlusive disease were studied. There were 15 women and 10 men. Median age was 41 years (interquartile range 24 years). Underlying diagnoses were carotid atherosclerosis (10), Moyamoya disease/phenomenon (12), intracranial stenosis of unclear etiology (3). Each patient underwent mapping of CVR by both BOLD MRI (T2*-weighted GRE with EPI readout, TR 2000 ms, TE 30 ms, FOV 24x24 cm, matrix 64x64, thickness 5 mm, gap 2 mm, frames 254) and ASL MRI (flow-sensitive alternating inversion recovery with EPI readout, TR 2000 ms, TE 22.7 ms, TI 1000 ms, FOV 24x24 cm, matrix 64x64, thickness 5 mm, gap 2 mm, frames 254), and underwent routine clinical imaging of the neck vessels and circle of Willis. During the BOLD and ASL MRI acquisitions, an automated gas blender and sequential gas delivery mask provided near square wave changes in end-tidal pCO2 between 40 and 50 mm Hg, while maintaining pO2 at 100 mm Hg. For each subject, the BOLD MRI signal waveform underwent least squares fitting to the end-tidal pCO2 waveform on a voxel-by-voxel basis. Brain was segmented into grey and white matter, and right and left hemispheres, CVR was calculated for each segment as percentage change in BOLD MRI signal per mm Hg change in end-tidal pCO2. To generate ROC curves, mean hemispheric CVR on ASL MRI was calculated across all hemispheres with ipsilaterally normal angiography, and abnormal was defined as 2 or more standard deviations below the mean.

**Results:** There was no significant difference in end-tidal gas concentrations for the BOLD MRI versus ASL MRI acquisitions (P value > 0.48). Hemispheric CVR measured by BOLD MRI was significantly correlated with that measured by ASL MRI, for both grey matter (R=0.768,P<0.001) and white matter (R=0.654 P<0.001). Diagnostic accuracy (area under ROC curve) for BOLD MRI discrimination between normal and abnormal hemispheric CVR was 0.90 (95% CI = 0.81 to 0.98) (P < 0.001) for grey matter and 0.82 (95% CI = 0.70 to 0.94) (P<0.001) for white matter. Regions of paradoxical CVR on BOLD MRI had a moderate predictive value (14/19 hemispheres) for spatially corresponding paradoxical CVR on ASL MRI. Complete absence of paradoxical CVR on BOLD MRI had a high predictive value (31/31 hemispheres) for corresponding non-paradoxical CVR on ASL MRI.




**Discussion/Conclusion:** In patients with steno-occlusive disease, we have shown a strong correlation between hemispheric CVR measured using BOLD MRI and ASL MRI. Further, the BOLD MRI technique was accurate at discriminating between normal and impaired cerebrovascular reactivity, and had a particularly high negative predictive value for the diagnosis of paradoxical cerebrovascular reactivity. These findings suggest that BOLD MRI can be used as a surrogate for regional CBF imaging to map CVR in patients with steno-occlusive disease.