Measurements of BOLD/CBV ratio show altered hemodynamics during stroke recovery in rats

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Background and Purpose

In recent years, fMRI has been increasingly used to understand the restoration of brain functions after ischemic insults. Spatial and temporal patterns of brain plasticity[(1)] and functional reorganization in cortical and subcortical regions have been documented in humans and animal models. [(2, 3)] Since functional brain activation with fMRI relies on coupling between neuronal activity and vascular reactivity, it is important to assess whether different MRI reporters of functional restoration (e.g., BOLD signal versus CBV) produce equivalent information, or whether flow-metabolism coupling is altered during the recovery period following an ischemic insult.

Methods

Temporary stroke was induced by 2 hour occlusion of the right middle cerebral artery (MCAO) in rats (n=3). Two weeks after the MCAO insult, fMRI was performed by electrically stimulating rat forepaws. During stimulation, animals were tracheotomized and mechanically ventilated while anesthetized by continuous infusion of α-chloralose. The fMRI activation of both BOLD and CBV (Gradient Echo Planar Imaging, TR/TE = 3700/15 ms for BOLD, TR/TE = 3700/11 ms for rCBV, FOV = 2.5x2.5 cm^2; matrix = 128x128; nine 1 mm slices) was acquired on a 9.4T Bruker system. The unilateral electrical stimulation paradigm, consisting of 3 periods of 37 sec 'stimulation on' separated by 185 sec 'stimulation off,' was alternated between the left and right forepaw and was repeated at least nine times. Following BOLD fMRI, MION was intravenously administered, and the stimulation paradigm was repeated using CBV-weighted fMRI.

Results

Restoration of fMRI activation were observed in the ipsilesional hemisphere for both BOLD and rCBV measurements. However, the ratio of ipsilesional to contralesional activation-induced signals in motor cortex was considerably larger when assessed using CBV rather BOLD signal, as shown in Figure 1. The mean percent change ratio (i.e. $\Delta SI_{fMRI\_ipsilesional} / \Delta SI_{fMRI\_contralesional}$) of the activated motor cortex areas was 45.6 % for rCBV activation but only 22.8 % for BOLD.

Conclusion

Restoration and reorganization of fMRI activation was observed in the transient ischemia model using both BOLD and CBV signal. However, the ipsilesional/contralesional ratio of BOLD amplitudes was significantly smaller than the corresponding CBV ratio, suggesting that the hemodynamic or metabolic coupling in ipsilesional somatosensory cortex may be modified following stroke. Several factors, including the baseline $CMRO_2$/CBF ratio or an altered CBF-CBV relationship, could contribute to the observed difference. These results warrant further studies to better understand underlying physiology of fMRI signal variations during stroke recovery.

References

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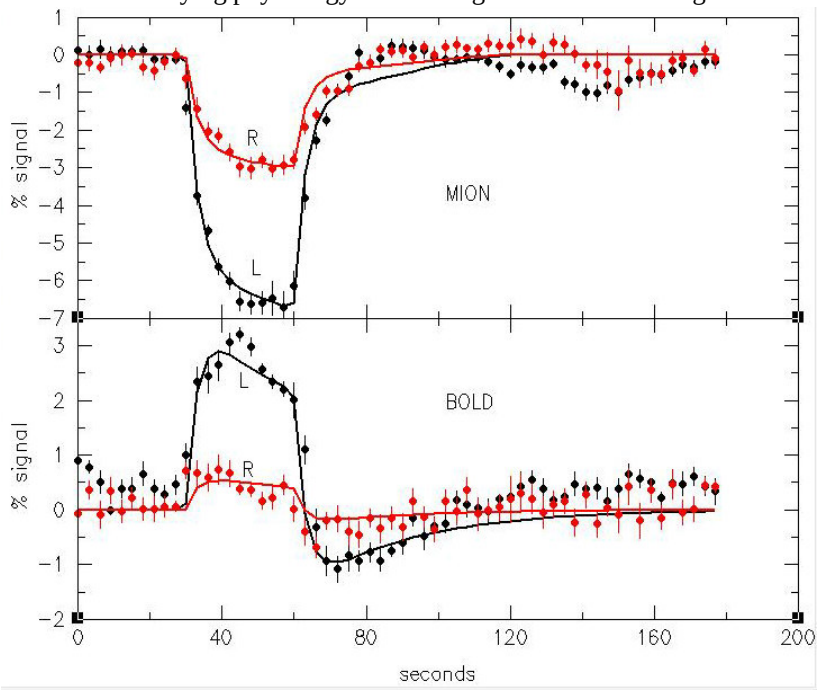

Figure 1. Representative % SI time course of ipsilesional (R) and contralesional (L) motor cortex before and after contrast agent (MION) injection