In Vivo Measurement of Blood Flow After Traumatic Brain Injury in Rats Using Susceptibility Weighted Imaging

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Introduction: Magnetic resonance imaging offers a non-invasive means to study brain trauma. In this paper, we evaluate the use of susceptibility weighted imaging (SWI) to study changes in the vasculature of the rat brain after mild traumatic brain injury. Previous methods of evaluating brain trauma have included MR spectroscopy, diffusion weighted imaging (DWI), MR angiography and perfusion weighted imaging (PWI). Each method offers its own advantages. MR spectroscopy successfully predicts the state of the tissue in terms of neuronal function, DWI shows areas of cellular disruption, MR angiography offers information about the presence of intact arterial vessels, and PWI can potentially show regions of reduced perfusion. On the other hand, SWI offers information about the intact structure of the venous system and about the oxygen saturation as well. These two added pieces of information can be used to improve the diagnosis of the state of the brain tissue.

Materials and Methods: Prior to TBI male Sprague-Dawley rats (350-400g) were anesthetized. The skull was exposed and a steel helmet was placed at bregma using dental cement. To induce brain injury, a 450 g weight was dropped from 2 m onto the helmet (1). A total of 6 rats were imaged in groups of two. The MRI scans were repeated over 4 days at 4 time points: Baseline scans, 4h, 24h, and 48h post TBI. One of the 6 rats died. All of the MRI measurements were performed on a 4.7-T Bruker AVANCE scanner. Four sequences were run: T2 and T1 weighted imaging, arterial spin labeling as a means to measure flow (2), and susceptibility weighted imaging were repeated over 4 days at 4 time points: Baseline scans, 4h, 24h, and 48h post TBI. One of the 6 rats died. All of the MRI measurements were performed on a 4.7-T Bruker AVANCE scanner. Four sequences were run: T2 and T1 weighted imaging, arterial spin labeling as a means to measure flow, and susceptibility weighted imaging.

Results: An example analysis of two vessels pre and post trauma for TBI showed in Figure 1 and 2. We chose 5 large blood vessels for analyses in each rat brain. The relative changes in flow at 4 h, 24 h, and 48 h post trauma are -0.26±0.10, -0.23±0.15, and -0.22±0.17, respectively. The blood flow decreased 20 to 30% in the 5 rats after TBI. The ASL results show that the means of the cbf values of medial dorsal cortex tended to recover but those of the hippocampus got worse.

Discussion and conclusion: Traumatic brain injury is difficult to follow with most imaging methodologies. We have shown here that it is possible to visualize changes in oxygen saturation in the veins of a rat post-trauma. By assuming a deoupling of the CMRO2 from flow, the changes in phase pre and post trauma have been shown to correlate with expected reductions in flow from the literature and from the ASL changes. SWI should prove to be an important means by which to monitor changes in the rat brain both in terms of vascular damage to the venous system and oxygen saturation changes.