A Comparative Study of Diffuse and Focal Traumatic Brain Injury using Multi-echo Susceptibility Weighted Imaging in Rodent Model

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TARGET AUDIENCE: Scientists and clinicians interested in imaging biomarkers for traumatic brain injuries.

INTRODUCTION: Traumatic brain injury (TBI) is a serious and global public health issue. Generally, focal (specific location) and diffuse (widespread area) are the two major classifications of brain injuries. Fluid percussion injury (FPI) in rats is a commonly used animal model simulating traumatic brain injuries. Blast-induced traumatic brain injury (bTBI) is on the rise predominantly due to the use of improvised explosive devices. Susceptibility weighted imaging (SWI) allows improved detection of paramagnetic hemorrhagic blood components based on their magnetic susceptibility and provides information on microvasculature.[1] Multi-echo SWI provides phase and R_2* maps with better SNR and CNR, making it a sensitive technique for brain injuries .[2, 3] We have made a comparison of focal (FPI) and diffuse (open field blast) TBI using multi echo SWI in this study.

METHODS: Adult male Sprague Dawley rats (280 – 300g) were subjected to focal brain injury (#6 mild, ~22 psi) using the lateral fluid percussion injury model and diffuse injury (#6 Low blast, ~22 psi) using open field blast injury model.[3,4] SWI was performed using TR/flip angle/slice thickness/#slice/FOV/matrix size/# average = 45 ms /20º/0.8 mm/64/36 mm × 27 mm/512×384/2. A total of 5 echoes were acquired with a central-echo time of 14.95 ms and an echo-spacing of 4.008 ms. MR Imaging was performed using 7T ClinScan (BioSpin GmbH, Germany) equipped with 4-channel RAPID phased array coil at baseline (BL, before the injury) and day 1, 3, 14 after the injury. A Java based ImageJ (National Institute of Health, USA) plugin was developed to quantify the R_2* (5 echoes were fit to mono-exponential) maps of the entire brain. The complex data (real and imaginary) were filtered with Kaiser Bessel filter of radius 96x96 to generate phase maps.[4]

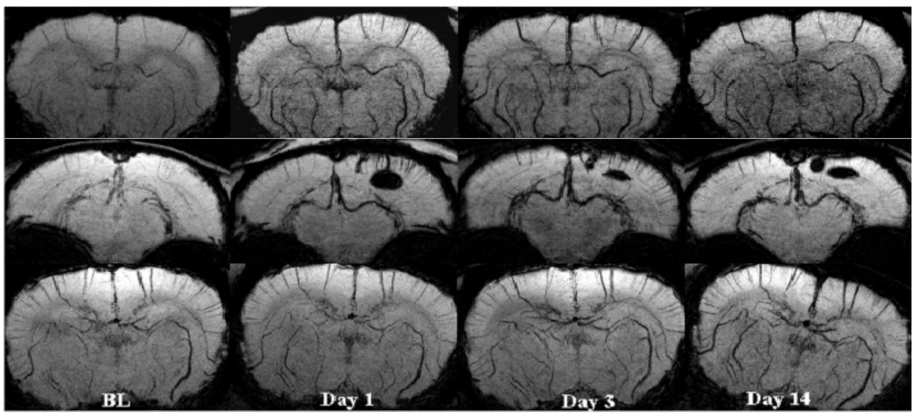

Fig. 1. Minimum intensity projection of SWI images at different time points of focal (top and middle) and diffuse (bottom) injury.

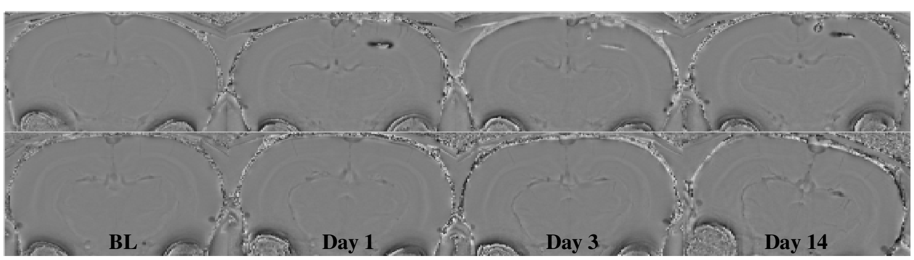

Fig. 2. Combined filter phase at different time points of focal (top) and diffuse (bottom) injury.

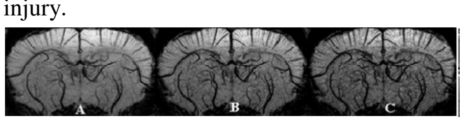

Fig. 3. Minimum intensity projection maps at first (A), second (B) and third (C) echo.

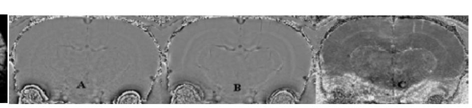

Fig. 4. Filter phase images of first (A), combined echo (B), and R2* map (C) derived from 5 echoes.

RESULTS AND DISCUSSIONS: Minimum intensity projection (mIP) over 7 slices of first echo from SWI of diffuse and focal injury at different time points are shown in Fig 1. Decrease in the signal (darkening) of SWI was observed in the major visible blood vessels in both diffuse and focal models. The darkening in vasculature at different time points are due to the increase in deoxyhemoglobin. Compared to baseline, the darkening is more at day 1 in case of focal but at day 3 for diffuse. The combined filtered phase images at different time points for diffuse and focal are shown in Fig. 2. Local haemorrhage is observed in the filtered phase images of focal injury only. The smaller venous structures are better visualized in the 3rd echo compared to first two echoes in both diffuse and focal injury (Fig.3 for diffuse injury). The combined filter phase images (Fig 4 B) have better SNR and CNR compared to individual filter phase images (Fig 4 A). The derived $R2^*$ map computed from all echoes is shown in Fig 4 C.

CONCLUSIONS: Multi-echo SWI was implemented to compute phase and R_2* for characterization of focal and diffuse injuries. The decrease in the signal from the micro blood vessels after injury is due to the increase in deoxyhemoglobin. We also observed the local haemorrhage in focal injury model due to secondary injuries, which was absent in diffuse injury model. The relative changes in cerebral blood flow can be estimated using filter phase images by utilizing the changes in oxygen saturation.[6,7]

References:

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