

Susceptibility Mapping of Venous Blood Oxygen Saturation in Mild Traumatic Brain Injury at the Acute Stage

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Introduction: Mild traumatic brain injury (MTBI) has over one million emergency visits each year in the United States. The neurocognitive and functional symptoms significantly impact patients' quality of life and working productivity. However, clinical computed tomography (CT) and conventional magnetic resonance imaging (MRI) techniques either underestimate or fail to detect important neuropathology of mTBI. MTBI patients stay in the ED only for a few hours and then being discharged home. The acute stage is the golden window for the injury detection and outcome prediction. After injury, patients may have disturbances of cerebral blood flow in moderate to severe TBI cases. However, no data have been reported how cerebral blood flow or oxygen saturation might change in MTBI patients at the acute stage. The **objective** of this study is to use susceptibility weighted imaging and mapping (SWIM) as a means to quantify oxygen saturation in venous blood in MTBI patients at the acute stage.

Materials and Methods: Twelve mTBI patients were recruited in emergency setting in our Level-1 trauma center. Eighteen aged- and gender-matched healthy controls were also recruited for comparison. All patients met the definition of mTBI by the American Congress of Rehabilitation Medicine (ACRM) with Glasgow Coma Scale (GCS) score of 13-15 at emergency entry. All patients completed a short neurocognitive test, standard assessment of concussion (SAC), at the acute stage. SAC is a short instrument to measure patients orientation, delayed recall, attention, and executive function. Before MRI scan, all patients had undergone CT scan in emergency setting. All patients were scanned in our 3 Tesla Siemens VERIO magnet with 32-channel head coil, at the acute stage. After 6 months later, eight patients came back for the second visit. Susceptibility weighted imaging (SWI) data were acquired in conjunction with other sequences in all subjects. SWI parameters are TR/TE=30/20ms, flip angle 20 degree, in plane resolution 0.5x1x2 mm, and field of view 256x256 mm.

All SWI images were undergone QSM processing by using our previously developed method in our in-house developed SPIN software [1]. Specifically, the following steps were used: a) High pass filtering of original phase image to get SWI phase image, b) Inverse transform to generate susceptibility maps of the veins, c) Regularization and interpolation of the data in k-space of the phase image to reduce reconstruction artifacts, and d) finally, minimum intensity projection (mIP) of slices over 8 mm thickness.

After SWIM processing, eight major veins and small transmedullar veins were selected by using semi-automated region of interest (ROI) analysis to quantify blood oxygen saturation of each one (see Figure 1). A student t-test was used to compare the control and patient group data.

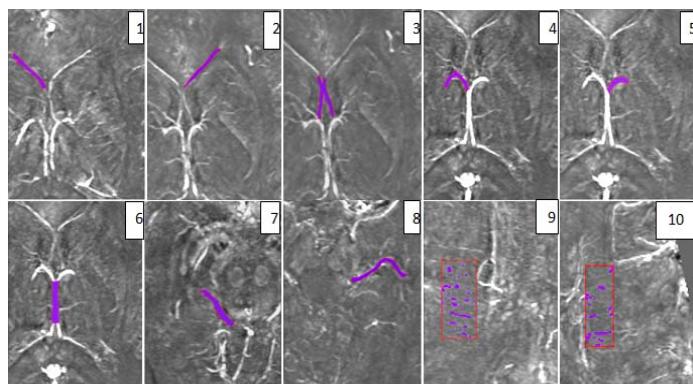


Figure 1. Selection of major veins and transmedullar veins to quantify blood oxygen saturation.

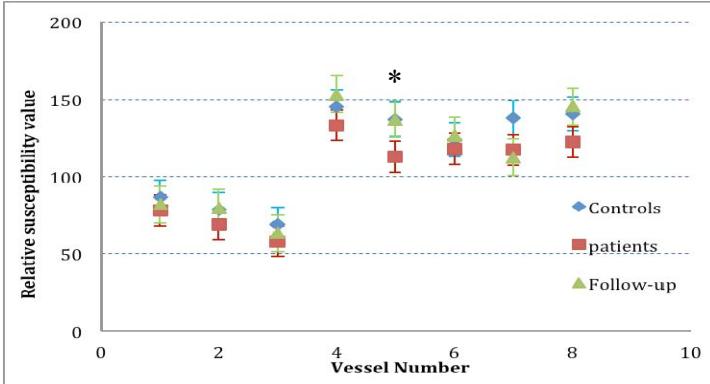


Figure 2. Mean and error bars of blood oxygen saturation measurement in major veins. * indicates statistically significant difference ($p=0.038$, two tail test).

Results: SAC test demonstrated MTBI group has significant lower SAC scores than controls ($p=0.05$), particularly lower scores in delayed recall ($p=0.03$). Group comparison of SWIM data demonstrated that MTBI patient group has significant lower susceptibility signals than controls ($p=0.038$) at left thalamus vein at the acute stage. Other veins did not demonstrate any group difference. At the follow up, the mean susceptibility signals at left thalamus vein came back to normal control level. This demonstrates that left thalamus vein had more oxygenation left at the acute stage. Or the brain tissue at left thalamus region consume less oxygenation than usual at the acute status.

Discussion and Conclusions: Our data provide further evidence of brain functional impairment in thalamus region. It demonstrated the direct evidence of reduced consumption of blood oxygenation in thalamus region at the acute stage of MTBI. Thalamus is a relay of neuronal pathways of the brain. Our data show that lower neurocognitive levels of the brain is manifested by reduced brain activities in thalamus region. This is inline with the published literature, which show reduced functional connectivity in resting state fMRI. However, it needs further investigation whether the reduced demand is due to reduced activity of brain activity or more anaerobic metabolism.

Reference: 1. Haacke EM, Tang J, Neelavalli J, and Cheng YCN. *Susceptibility Mapping as a Means to Visualize Veins and Quantify Oxygen Saturation*. *JMRI*, 32:663-676 (2010).