Neuroimaging of Mild Traumatic Brain injury at 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 after mTBI 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. The available biochemical markers are either non-sensitive or non-specific enough to detect complex and heterogeneous pathoanatomical information of mTBI. Consequently, emergency physicians may fail to order adequate management or follow up plan that could address prolonged neurocognitive or functional symptoms in mTBI patients.

The advanced MRI techniques, including susceptibility weighted imaging (SWI) [1], diffusion tensor imaging (DTI), and MR spectroscopy imaging (MRSI), have been reported being sensitive to subtle changes of the brain after mTBI. However, there is a lack of investigation on the role of advanced MRI in mTBI detection at acute stage, especially in emergency settings. The ***objective*** of our work is to investigate the role of advanced MR imaging techniques (DTI, SWI and MRSI) for mTBI at acute stage.

Materials and Methods: Twelve mTBI patients were recruited in emergency setting in our Level-1 trauma center. Twelve 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. 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. If an MRI scan was not performed due to logistic reason within 24 hours post injury (acutely), the patient would be scanned within 10 days post injury (subacutely). Two patients were later excluded due to previous head injury or other neurologic history. Among the remaining ten eligible patients, six patients had MRI scan at acute stage (within 24 hours after injury), four patients had MRI scan within 10 days after injury. The MRI protocol includes SWI, DTI and MR spectroscopy, in addition to baseline T1, T2, and FLAIR sequences. Both voxel-based analysis (VBA) and tract-based spatial statistical analysis (TBSS) approaches were used to analyze the DTI data.

Results: Among ten mTBI patients eligible for this study, three of them (30%) had positive CT findings with extra-axial bleeding or injury. SWI detected six of them (60%) with parenchymal injury, including those three CT-positive patients (see Figure 1 for example). Furthermore, DTI consistently detected abnormally lower fractional anisotropy (FA) areas ($p<0.05$) in major white matter tracts that appear normal in structural imaging. Specifically, TBSS analysis consistently reported abnormally lower FA values ($p<0.05$) in the splenium of corpus callosum (CC) among 4 patients (40%) (see Figure 2). Voxel-based analysis detected abnormally lower FA values ($p<0.05$) in superior corona radiata, in addition to CC. MRSI also detected abnormally higher glutamine (Gln), not glutamate, signals in fronto-parietal subcortical white matter among 2 patients (20%). Collectively, three advanced MRI could detect abnormalities in 8 out of 10 mTBI patients (80%).

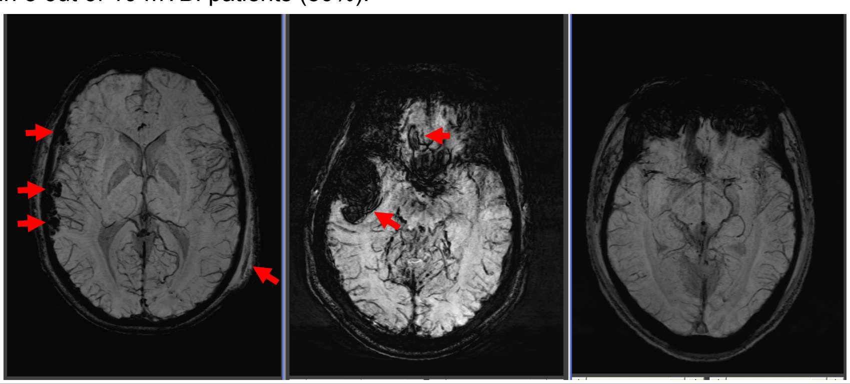

Figure 1 (upper). SWI images of three mild TBI cases. Left: A 21-year old young man fell down from a ladder with contra coup injury (see arrows for injury); Middle: A 45-year old man fell down from a stair case with contusions in inferior frontal and temporal lobes (see arrows); and Right: A 30-year old man involved in motor vehicle crash accident with normal appearing brain on structural imaging. All patients had Glasgow Coma Scale score of 15 at emergency entry but with different injury patterns.

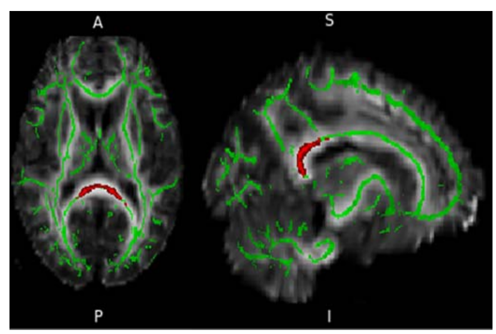

Figure 2 (upper). DTI TBSS analysis. TBSS data detect significantly lower FA values at the splenium of corpus callosum in mTBI patients that look normal in structural imaging (red voxels have lower FA values than controls, $p<0.05$).

Discussion and Conclusions: Traumatic brain injury requires a comprehensive approach to detecting its heterogeneous and complex pathophysiologies after injury. Our data showed that SWI could significantly improve the detection of hemorrhagic blood in brain parenchyma that is negative on CT, DTI could detect white matter injury on normal appearing brain on structural imaging, and MRSI could detect abnormal level of neurotransmitters. Taken together, a comprehensive use of three techniques could significantly improve the detection of mild TBI in acute setting. This is in sharp contrast with the fact that mild TBI is occult to CT and conventional MRI. This finding demonstrates a great potential of advanced MRI to assist decision making of mTBI management in acute setting.

Reference: 1. Kou Z, Benson RR, Haacke EM, *Susceptibility weighted imaging in traumatic brain injury*, in *Clinical MR Neuroimaging, 2nd Edition*, Gillard J, Waldman A, Barker P, Editor. 2008, Cambridge University: Cambridge.