Improving Characterization of Traumatic Brain Injury by Synergistic Use of Multi-MRI Techniques

Z. Kou[1], R. Hanks[2], S. Millis[2], R. Benson[2], R. Gattu[2], and E. Haacke[1]
[1]Radiology, Wayne State University School of Medicine, Detroit, Michigan, United States, [2]Wayne State University School of Medicine, Detroit, Michigan, United States

Introduction: Traumatic brain injury (TBI) has been referred to as "a silent epidemic" with annual incidence rate of 1.5 million people in the United States alone. Clinical and neuroimaging assessment of TBI is more difficult than it seems. TBI involves a heterogeneous and complex spectrum of pathologies including hemorrhage, axonal shear injury, and ischemic/hypoxic injury, among others. For this reason, clinical trial testing of new pharmaceutical agents have failed, partly due to the lack of proper categorization of the patient population by their pathoanatomical information. Today, advanced magnetic resonance imaging (MRI) methods are uniquely suited to detect and localize many of the pathologic and pathophysiologic alterations resulting from TBI. These advanced MR technologies include susceptibility weighted imaging (SWI) for hemorrhage detection [1], MR spectroscopy (MRS) for metabolite measurement, and diffusion weighted and diffusion tensor imaging (DWI/DTI) for edema quantification and axonal shearing identification. We propose that a synergistic use of multi-imaging techniques may capture much of the heterogeneity and complexity of brain injury in individual patients therefore result in improved accuracy and detail in prognostic models and improved efficiency of clinical trials. In this study, we report our preliminary observations regarding the synergistic use of these three MRI techniques in an improved characterization of TBI.

Materials and Methods: Eight moderate to severe TBI patients (field Glasgow Coma Scale score 5-13) were recruited as part of our ongoing study sponsored by the National Institute of Disability and Rehabilitation Research (NIDRR). Patients were scanned on a 3T Siemens Verio magnet. MR sequences included SWI, DTI, and MR spectroscopy imaging (MRSI) in addition to baseline T1, T2, and FLAIR sequences. SWI images were processed in our in-house Signal Processing in NMR (SPIN) software. DTI fractional anisotropy (FA) and fiber tractography were processed by SIEMENS Neuro3D and Tractography in line software packages. MRSI were processed by using both SIEMENS MRSI in line package and LCModel. FLAIR, SWI, MRSI, and DTI images, including FA and fiber tractography, were co-registered into the same space by using SIEMENS Neuro3D package software to identity the overlap and differences that these imaging modalities reveal at the same location at voxel level.

Results: Our preliminary data demonstrate that a) a traumatized brain has heterogeneous and complex nature of injury that are unique to each individual patient, and no two patients have exact same injury; b) the same lesion location may manifest different pathologies; c) the same type of pathology may affect signals for different imaging modalities; d) each imaging modality is good at detecting certain signal abnormalities attributing to different pathologies; e) a comprehensive use of these different imaging modalities can significantly improve the detection of the complex nature of brain injury. Particularly, associated with microhemorrhagic lesions, the brain white matter may or may not have shearing lesions as demonstrated as hyperintensities on FLAIR; consequently, the DTI fiber tractography may demonstrate different fiber morphology. Meanwhile, the brain may have abnormal metabolic levels despite its normal appearing on structural imaging. Figures 1 and 2 are two sample cases to show the typical findings.

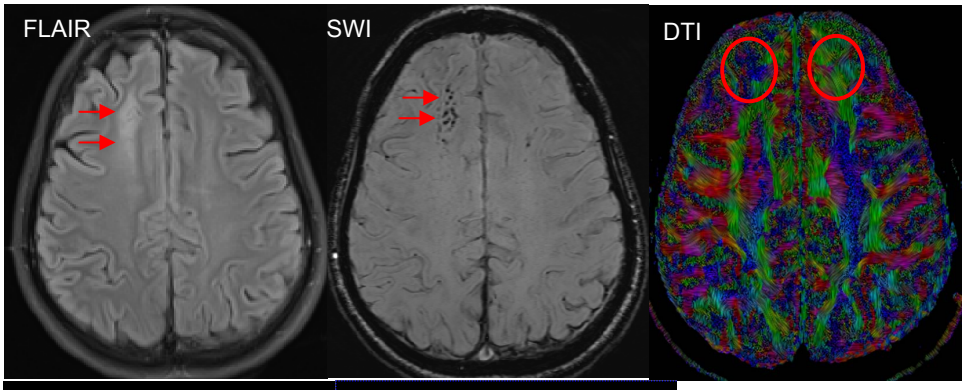

Figure 1 (Left). A traumatized brain manifests hyperintensities at right frontal white matter on FLAIR image (arrows), which is caused by edema, and hypointensities on SWI (arrows), which is caused by micro-hemorrhages. Meanwhile, color coded map of DTI directional diffusivities demonstrates the non-symmetry of left and right sides of frontal white matter (circles). This example demonstrates the complexity of brain injury pathology and its effects on the signals of different imaging modalities.

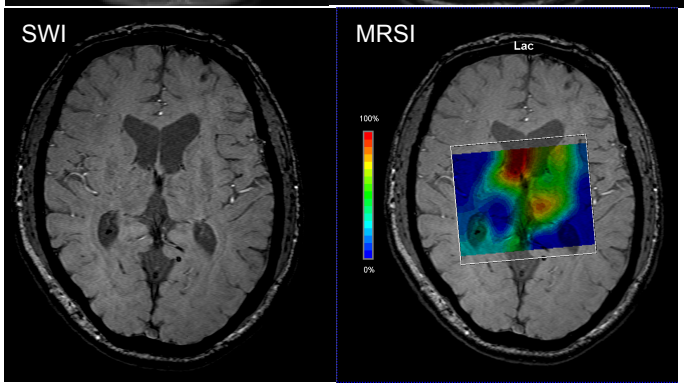

Figure 2 (Left). Normal appearing brain may not be normal. MRSI reveals abnormal lactate levels of a traumatized brain at left hypothalamus and ventricular space while SWI does not reveal any abnormality at the same level. Additionally, the patient's brain demonstrates multi-foci hemorrhages on SWI images at other slices of the brain (not shown).

Discussion and Conclusions:

There is no treatment of TBI partially due to the current clinical classification system cannot effectively identify the pathoanatomical information of the brain. A synergistic use of advanced MRI provides a solution to an improved classification system of brain injury.

References: 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.