Susceptibility Weighted Imaging Complements Diffusion Tensor Imaging in Traumatic Brain Injury

Z. Kou[1], R. R. Benson[2], R. Gattu[1], and E. Haacke[1]

[1]Radiology, Wayne State University, Detroit, Michigan, United States, [2]Neurology, Wayne State University, Detroit, Michigan, United States

Introduction: Traumatic brain injury (TBI) is a leading cause of death and disability in the United States. Diffuse axonal injury (DAI) is a significant pathology of TBI and is the major cause of prolonged functional deficits in patients sustaining TBI. Clinical detection of DAI with conventional neuroimaging is inadequate. Several advanced magnetic resonance imaging (MRI) techniques have been reported to be sensitive to DAI, including diffusion tensor imaging (DTI) detection of axonal tract integrity [1] and susceptibility weighted imaging (SWI) identification of microhemorrhages [2]. However, there have been no published reports comparing these two MRI techniques in the detection of TBI. In this preliminary study, we report our observations regarding the combined sensitivities of these two methods in detection of abnormalities in TBI.

Materials and Methods: Five mild to severe TBI patients (field GCS 8-15) were recruited along with 62 healthy volunteers (age range = 19-81 yrs; 53.2 ± 18.9 M±SD). The patients were scanned on a 1.5T Siemens Sonata magnet. MR sequences included SWI and DTI in addition to baseline T1, T2 and FLAIR sequences. A Z-score map approach was utilized to combine both DTI and SWI for TBI detection. Both DTI fractional anisotropy (FA) map and SWI image were co-registered to a T1 image to bring them into a common space. Then each patient's FA map was normalized to a standard FA template generated by our 62 normal controls, and each FA map was then segmented into gray matter, white matter, and cerebral spinal fluid tissue classes. An FA Z-score map was generated using the mean image of 62 normals and the variance image from the same group. Each patient's FA Z-score map was thresholded and overlaid onto the patient's FA image to indicate the anatomical ocations of patient "lesions" relative to healthy subjects. Furthermore, the Z-score map was co-registered to the SWI image to identify the overlap and difference between low FA regions and SWI hemorrhages. We hypothesize that FA is decreased after traumatic injury. For the FA Z-map, we considered voxels with Z-score ≤ -2 as suspicious DTI lesions, since these were at least two standard deviations below the mean of the healthy subjects.

Results: Our preliminary results demonstrated that our DTI FA Z-map approach could localize suspicious white matter lesions that look normal in structural imaging, including SWI. Comparatively, SWI can detect more hemorrhages than the clinical standard gradient-echo T2*. Furthermore, SWI can detect microhemorrhages located in gray matter and gray/white matter junctions that DTI fails to detect. In those major white matter tracts that are rich in blood vessels, e.g. genu and splenium of corpus callosum, both SWI and DTI detected lesions in the similar areas: SWI showed hemorrhages and DTI demonstrated significantly lower FA than controls. Figures 1 and 2 below are an example of the results.

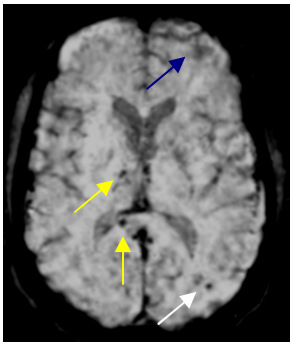

Figure 1. Comparison of SWI and DTI FA Images in a patient involved in motor vehicle crash accident with field GCS of 3. Highlighted areas in DTI FA map are pixels having FA at least 2 standard deviations lower than normal controls. Both DTI FA and SWI images showed lesions in splenium of corpus callosum and internal capsule (yellow arrows). SWI image also demonstrated microhemorrhages at gray matter (white arrows) and gray/white matter junctions (blue arrows).

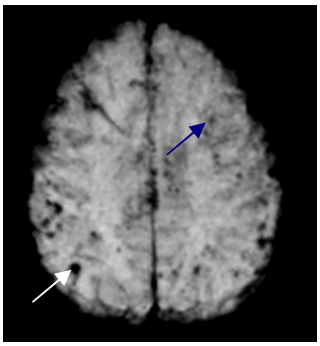

Figure 2. Comparison of SWI and DTI FA Images at the level of superior corona radiator in the same patient as Figure 1. Highlighted areas in DTI Z map are pixels having FA at least 2 standard deviations lower than normal controls. DTI Z map detected suspicious white matter lesions in superior coronal radiator (black arrows), while SWI detected microhemorrhages in gray matter (white arrows) and gray/white matter junction (blue arrows). As being sensitive to different pathological phenomena after injury, SWI and DTI complement to each other in the detection of traumatic brain injury.

Discussion and Conclusion: Both hemorrhagic and non-hemorrhagic lesions are thought radiological markers of DAI diagnosis. One problem in the detection of white matter injury is that DTI cannot localize the specific lesion locations in the white matter tracts while only giving a FA measure of some major regions, e.g. corpus callosum, internal capsule, etc. Our FA Z-map approach demonstrated a potential to resolve this problem by localizing voxels with abnormally lower FA than control population. Furthermore, a significant amount of microhemorrhages in TBI are under the detection threshold of conventional MRI. DTI and SWI are sensitive to different physiological aspects in traumatic axonal injury. Our data demonstrated their complementary nature in an improved detection of TBI. In Conclusion, a complementary use of DTI and SWI could improve the detection of traumatic brain injury.

References:

1. Benson, R.R., et al., *Global White Matter Analysis of Diffusion Tensor Images is Predictive of Injury Severity in TBI.* . Journal of Neurotrauma, 2007. 24(3): p. 446-459.
2. 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.