Thalamic Involvement Following Mild Brain Injury: In Vivo Occult Pathology Demonstrated by Diffusivity Kurtosis Imaging

Y. Ge1, H. Lu1, J. H. Jensen1, J. A. Helpern1, J. Reaume1, R. I. Grossman1

1Radiology / Center for Biomedical Imaging, New York University School of Medicine, New York City, New York, United States

Introduction
Water in biological tissue often shows non-Gaussian diffusion behavior due to the structural complexity of the tissue. The diffusion displacement probability distribution deviation from Gaussianity is referred to as the diffusional kurtosis and can be measured by a newly developed method, diffusional kurtosis imaging (DKI) (1). DKI does not make assumptions on the number of biophysical compartments or even the existence of compartments. In contrast to q-space imaging (2), which poses greater demands on imaging hardware and acquisition time, DKI can measure the diffusional kurtosis in humans within a moderate time (~10 minutes) on a clinical scanner. The acquired DKI data also provide the conventional diffusion tensor (1). Damage within the thalamus, which can cause various impairments of neuropsychological functions, has been recently indicated by several histopathological studies in patients with severe traumatic brain injury (TBI) (3). This study was conducted to investigate the thalamic involvement in patients with mild TBI (MTBI) using the newly developed DKI technique.

Methods
Sixteen MTBI patients who had an initial Glasgow Coma Scale (GCS) between 13 to 15 were studied on a 3T MR scanner (Trio, Siemens Medical Solutions). All patients had varied posttraumatic symptoms such as irritability, headache, memory trouble, and tingling/numbness in extremities. The median duration after onset of brain injury is 16 months (6-32 months). Fourteen age-matched healthy controls were also scanned. DKI was performed using a dual spin-echo sequence with 30 directions and 6 b values (0, 500, 1000, 1500, 2000, 2500s/mm²). TR/TE: 2000/108 msec, matrix: 128x128; voxel size: 1.72x1.72x3.00 mm³. DKI includes conventional diffusion tensor imaging (DTI) data. The mean kurtosis (MK), diffusional kurtosis averaged over all directions, as well as the mean diffusivity (MD) and the fractional anisotropy (FA) were measured on 3 contiguous levels that cover the thalamus in both patients and controls for comparison.

Results
Conventional MRI of the thalamus was unremarkable in all patients. There were also no significant differences in FA or MD between patients and normal controls in the thalamus. DKI showed significantly lower MK in the thalamus of patients with MTBI (mean/SD: 1.21/0.07) when compared with age-matched normal controls (mean/SD: 1.27/0.04, p < 0.0001) (Fig 1, 2). We also measured other basal ganglia regions including putamen and caudate nucleus as well as frontal white matter and found no statistically significant differences between patients and controls in the three measures, indicating the centrally located large-size thalamus may be more prone to the traumatic injury, even mild.

Discussion
Different from DTI, which assumes the water diffusion is perfectly Gaussian, DKI directly characterizes the non-Gaussian properties of the water diffusion and is a more specific measure of tissue structural complexity (1). Our preliminary results provide in vivo evidence of preferential thalamic involvement in patients with MTBI on DKI, which is not detected pm conventional DTI. DKI is a sensitive imaging technique for detecting subtle structural destruction of neuronal-axonal complexity within the thalamic nucleus and may be useful in better understanding of the persistent posttraumatic syndrome in MTBI patients.

References

Acknowledgement: This study is supported in part by grant 1 RO1 NS39135-10 from NIH.