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

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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 Glascow Coma Scale (GCS) between 13 to15 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/mm^2). TR/TE: 2000/108 msec, matrix: 128x128; voxel size: 1.72x1.72x3.00 mm^3. 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.

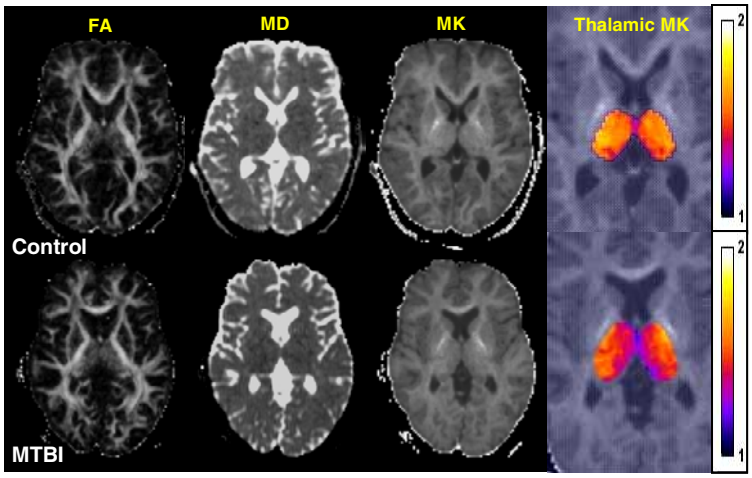

Fig 1. FA and MD (generated from DTI) and MK (generated from DKI) maps in a patient (bottom row) and an age-matched normal control (top row). Note that there is obvious decreased MK level on the parametric maps (thalamic MK) in patient compared to normal control. Such differences were not found on FA and MD maps. The contrast of gray matter and white matter on the MK map is better than on the MD map. For isotropic structures, such as gray matter, MK is superior to FA. This is because on FA maps, the values of gray matter are very low due to its isotropic nature, which makes FA not a sensitive measure for gray matter. FA map also suffers the inhomogeneous pattern of white matter, possibly due to the fiber crossing.

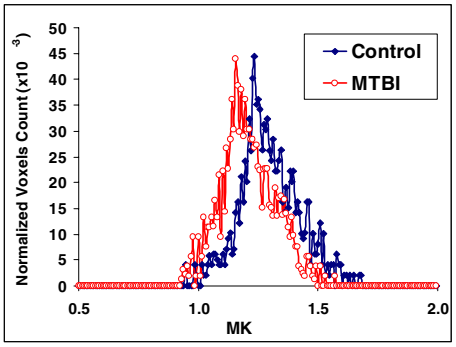

Fig 2. MK histograms from outlined bilateral thalamus (3 levels, total 6 regions) in a MTBI patient and an age-matched normal control. Note that the histogram in patient is shifted to the left toward to the smaller values of MK.

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

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