Serial Changes in Corpus Callosum Diffusion Tensor Imaging (DTI) Metrics in Moderate Traumatic Brain Injury (TBI) and Its Correlation with Neuro-cognitive Functions

M. Husain[1], R. Kumar[1], R. K. Gupta[2], K. M. Hasan[3], M. Haris[2], A. Agarwal[4], and P. A. Narayana[3]

[1]Neurosurgery, Chhatrapati Shahuji Maharaj Medical University, Lucknow, Uttar Pradesh, India, [2]Radiodiagnosis, Sanjay Gandhi Postgraduate Institute of Medical Sciences, Lucknow, Uttar Pradesh, India, [3]Diagnostic and Interventional Imaging, University of Texas Medical School at Houston, Houston, Texas, United States, [4]Neurology, Chhatrapati Shahuji Maharaj Medical University, Lucknow, Uttar Pradesh, India

Introduction: Traumatic brain injury (TBI) is the most common cause of brain damage and is one of the leading causes of death. Impairment in cognitive and multi-task execution sequelae have been attributed to diffuse brain/axonal injury or neural network disruption in the brain. Many patients complain of headache, dizziness, and concentration problems after mild TBI, but within a few weeks these symptoms subside and most patients return to their normal activities. However, 6 months after mild TBI, 15% to 29% of patients showed persistent problems which continued for years.[1]

Early and accurate identification of the extent of axonal injury is a major diagnostic challenge, because these injuries are rarely visible on computed tomography scans, or conventional T1 and T2-weighted magnetic resonance imaging (MRI).[2] Fluid attenuated inversion recovery (FLAIR) imaging of white matter injury offers some additional diagnostic properties, [3] but definitive diagnosis of diffuse axonal injury (DAI) is only reliably given after autopsy. Recent studies have suggested that Diffusion Tensor Imaging (DTI) may be useful in identifying early sign of axonal injury in TBI.[4] DTI studies in TBI patients have reported patterns of reduced FA in major white matter tracts in the central areas of the brain.[4] The aim of this study was to assess the distribution and severity of DAI in corpus callosum (CC) using DTI in early TBI (1-2 weeks) and after 6 months follow-up and further to correlate the DTI metrics at follow-up study with measures of neuropsychometric tests (NPT).

Materials and methods: Conventional MRI and DTI was performed in 30 age/sex matched controls and 38 patients with TBI (median age = 30 years). Patients underwent MRI at two time point: 1) within two weeks of injury (mean = 9 days), and 2) after 6 months of injury. The patients were sub-grouped as frontal (n=12), temporal (n=6), fronto-temporal (n=9) and multifocal (n=11) depending on the site of traumatic brain injury on conventional MRI. All these patients were recruited within a range of 9 to 13 Glasgow Coma Score (mean = 10.8).

Imaging protocol: MRI data was acquired on a 1.5-T GE MRI scanner using quadrature transmit–receive head coil. The MRI protocol included T2, T1, T1 magnetization transfer (MT), T2-fluid attenuated inversion recovery (FLAIR), T2 gradient recalled echo sequence, and DTI. DTI was acquired by using a single-shot echo planar dual spin-echo sequence with ramp sampling. The b-factor was set to 0 and 1,000 s/mm2; TR, 8 s; TE, 100 ms; and NEX, 8. In total, 36 axial sections were acquired with a slice thickness of 3 mm, no inter-slice gap, FOV of 240 mm. The diffusion tensor encoding used was a dodecahedral scheme with 10 uniformly distributed directions. The DTI data were processed as described in detail elsewhere.[5] The DTI-derived maps were displayed and overlaid on images with different contrasts to facilitate the region-of-interest (ROI) placement. The rectangular ROIs of size ranging from 2×2 to 5×5 pixels were placed according to Witelson method on 7 segments of CC [i.e. rostrum, genu, mid body, isthmus and splenium]at the level of massa intermedia in mid saggital image.

NP Tests: NPT were performed in healthy controls and follow-up patients. The test included number connection tests (NCT A and B), figure connection tests (FCT A and B), and performance subset of modified Wechsler Adult Intelligence Scale (WAIS-P, modified for Indian population).

Student's t-test between control and different groups of patients (1st study and 6-month follow-up study) were performed to see the statistically difference for FA and MD values measured in various regions of CC. Spearman's rank correlation coefficient was used to determine the association between NP scores, FA and MD values in follow-up patients.

Results: The FA was significantly decreased in rostrum and isthmus compared to controls in patients with fronto-temporal injury. The FA value was significantly decreased in rostrum, genu and mid body in patients with multifocal injury compared to healthy controls. On follow-up study compared to controls, frontal injury patients showed significant decreased FA along with significant increased MD values in rostrum and genu; temporal lobe injury patients showed decreased FA along with increased MD in isthmus; fronto-temporal injury patients showed significant decreased FA in rostrum, genu, mid body and isthmus with significant increased MD in rostrum and genu; and multifocal injury patients showed significantly decreased FA values in rostrum, genu, mid body and splenium with increased MD only in rostrum. We observed decreased FA values at the time of follow-up study in patients containing frontal injury in rostrum and genu compared to baseline study. At follow-up study, FA was significantly decreased in isthmus in patients with temporal injury, while in case of patients with multifocal injury it was significantly decreased in genu and splenium.

Rank Correlation between FA and NP scores (in follow-up patients): In patients with frontal injury an inverse correlation was observed, between NCT A and FA in rostrum; NCT A, FCT A and FCT B with FA in genu. In patients with temporal injury inverse correlation was observed between FA in isthmus and NCT A value. An inverse correlation between FA values in rostrum and NCT A, NCT B and FCT B value was observed in patients with fronto-temporal injury. In patients with multifocal injury positive significant correlation was observed between FA in genu and NCT A value.

Discussion: In the present study, we have observed widespread decreased FA values consistent with axonopathy in the CC within 2 weeks and these abnormalities persisted after 6 months following TBI. Only the patients with fronto-temporal and multifocal injury showed decreased FA in different regions of CC during early period of TBI that persisted even after 6 months consistent with axonopathy. In these patients, the early injury persisted and new changes were observed in the CC suggestive of Wallerian degeneration (WD). Even the groups showing no abnormality (frontal and temporal) in the initial phase also showed significant decrease in FA and increase in MD in few regions of CC. The changes in FA and MD in the CC showed significant correlation with some of the NPT. We conclude that widespread primary abnormalities in acute stage and secondary damage after 6 months in the CC can be demonstrated on DTI with normal conventional imaging. These DTI abnormalities significantly correlate with some of the NPT.

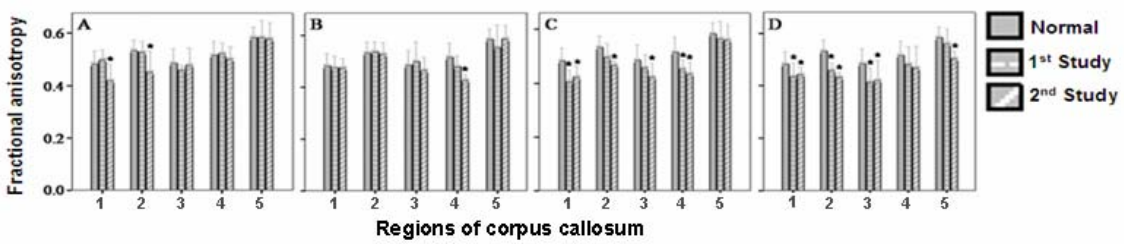

Figure: Bars show FA value in different regions of corpus callosum (1=rostrum, 2=genu, 3=midbody, 4= isthmus, 5= splenium) in normal as well as patients with frontal (A), temporal (B), fronto-temporal (C) and multifocal (D) traumatic brain injury. The star (*) represent significance difference in FA value compared to normal.

References: 1) Bohnen N, et al. Neuropsychiatry Neuropsychol Behav Neurol. 1993; **6**:193–200; 2) Adams JH, et al. MED. Sci. Law 1985;**25**:265-269; 3) Ashikakaga R, et al. Neuroradiology 1997;**39**:239-242; 4) Lee JW, et al. J. Head Trauma Rehabil. 2006;**21:**272–278; 5) Hasan KM, et al. J Magn Reson Imaging 2005;**21**:735-743.