

Assessment of White Matter Damage in Cerebral Palsy using Quantitative Diffusion Tensor Imaging

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Introduction:

Cerebral palsy (CP) is the term used to describe a variety of neurologic syndromes with disordered movement or posture; mental retardation and seizures may also be present. This condition results from damage to the developing brain from causes such as hypoxia or infection, but in many cases no definitive cause can be ascertained. Periventricular white matter injury (PWI) is a major form of brain injury in hemiplegic patients (1). The secondary degeneration of CST has been the subject of many investigations (2). Conventional magnetic resonance imaging (MRI) cannot delineate the white matter pathway of human brain precisely and is of limited use in identifying individual white matter tracts involved in this condition (3). DTI can demonstrate the orientation and integrity of white matter tracts *in vivo*. In the present study we used DTI based color orientation maps in children with CP, for quantitative evaluation of corticospinal tracts (CST), corpus callosum, and periventricular white matter to understand the microstructural brain damage underlying the motor disability.

Methods and Materials:

Twelve children with CP (8 males, 8 years mean age) as well as 10 age/sex matched healthy controls were included in this study. Inclusion criteria for the patients group were spastic hemiparesis with or without clinical sensory involvement. All the subjects underwent a thorough, video recorded neurological examination by a pediatric surgeon to confirm the findings in patients and to exclude any deficits in controls. Whole brain conventional MRI [T2, T1 and fluid attenuated inversion recovery (FLAIR)] and DTI were performed on a 1.5-Tesla GE MRI system. All imaging was performed in the axial plane and had identical geometrical parameters: field of view (FOV) = 240 × 240 mm², slice thickness = 3 mm, interslice gap = 0 and number of slices = 36. DTI data were acquired using a single-shot echo-planar dual spin-echo sequence with ramp sampling. The DTI data were processed as described in detail elsewhere (4). The DTI-derived maps were displayed and overlaid on images with different contrasts to facilitate the region-of-interest (ROI) placement. ROIs were placed on CST (at the five levels: upper medulla, pons, midbrain, posterior limb of internal capsule, and corona radiata), genu and splenium of corpus callosum (at the level of massa intermedia), and periventricular white matter of frontal, parietal, occipital lobes, and temporal lobe. A student's independent t-test was performed to evaluate the regional differences in the DTI metrics between CP patients and healthy controls. A p value of less than 0.05 was considered to be statistically significant.

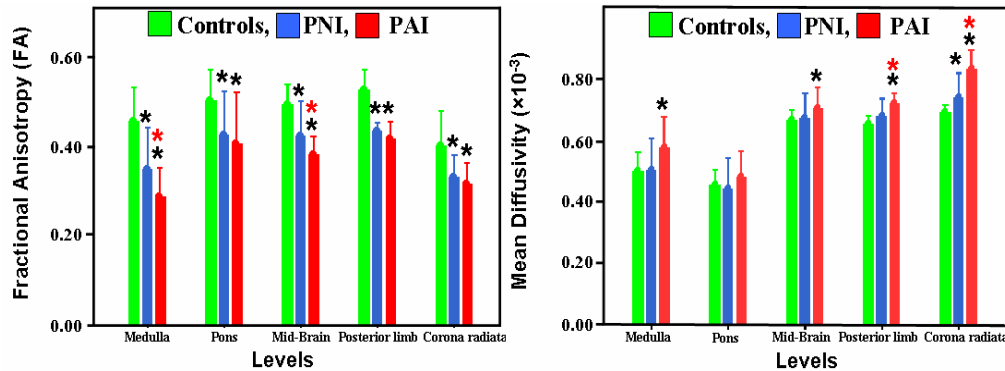


Figure 1: Results of ROI analysis of FA and MD values in CST at various levels. Note the reduction in FA and increase in MD values. * denotes p value of less than 0.05 in patient group compared to controls. * denotes the p value less than 0.05 in patient group with normal imaging compared to abnormal imaging. PNI = patients with normal imaging, PAI = patients with abnormal imaging.

Results:

Based on the conventional MRI findings, patients were grouped into normal (n=6) and abnormal (n=6) conventional imaging for the purpose of quantitative DTI analysis. Significantly decreased FA values were observed in both patient groups compared to controls in CST at all five levels (Fig. 1). Significantly decreased FA values were observed in patients with abnormal imaging compared to patients with normal imaging in CST at the level of medulla and midbrain. In patients with abnormal imaging significantly increased MD values were observed in CST at all level except for pons. No change in MD values were observed in patients with normal imaging compared to controls. Significantly increased MD values in patients with abnormal imaging were observed in CST at the level of posterior limb of internal capsule and corona radiata.

Significantly reduced FA values were observed in the corpus callosum (^agenu, and ^bsplenium), and periventricular white matter of ^cparietal lobes in both the patient with normal (^a0.44±0.07, ^b0.43±0.05, ^c0.17±0.03) as well as abnormal conventional imaging (^a0.47±0.05, ^b0.48±0.01, ^c0.19±0.05) as compared to controls (^a0.55±0.047, ^b0.61±0.07, ^c0.25±0.02). In addition in patients with abnormal imaging significantly decreased FA values were also present in occipital and temporal lobe compared to controls. MD values were significantly increased in the periventricular white matter of ^cparietal lobe in patients with normal (^c0.82×10⁻³±0.10×10⁻³) and abnormal conventional imaging (^c0.90×10⁻³±0.07×10⁻³) as compared to controls (^c0.71×10⁻³±0.03×10⁻³). In addition significantly increased MD values were observed in ^dsplenium, and periventricular white matter of ^eoccipital lobe in patients with abnormal imaging (^d0.91×10⁻³±0.08×10⁻³, ^e0.80×10⁻³±0.07×10⁻³) compared to controls (^d0.79×10⁻³±0.06×10⁻³, ^e0.73×10⁻³±0.04×10⁻³).

Discussion:

Based on the present study, it appears that patients with CP with normal imaging on conventional MRI have widespread microstructural changes in the CST, corpus callosum, and periventricular white matter of parietal lobe. These observations of significantly decreased FA in cerebral white matter of patients with normal and abnormal imaging suggest a net loss and disorganization of the structural barriers to molecular diffusion of water. The degeneration of various motor and sensory pathways appears to be important in understanding of pathophysiological mechanisms in patients with CP. Significantly decreased FA values in both patient groups in CST at all the levels compared to controls, is consistent with other studies showing degeneration of CST. Altered DTI parameters in major white matter tracts in CP patients may be helpful in better defining clinical outcome in these patients.

Reference: 1) Niemann G. Clinics in developmental medicine. London: Mac Keith Press;2000, p, 37-52; 2) Glenn OA, et al. J Magn Reson Imaging 2003;18:614-8; 3) Thomas B, et al. Brain 2005;128:2562-2577; 4) Hasan KM, et al. J Magn Reson Imaging. 2005;21:735-743.