Towards Quantitative DTI Tractography: Evaluating Congenital Hemiplegia in Corticospinal Tracts

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Abstract: Fiber tracking using diffusion tensor imaging (DTI) was used to locate and quantitatively assess the corticospinal tracts in patients with congenital hemiplegia. Tracking was performed using a region of interest (ROI) drawn at the caudal cerebral peduncle and filtered with an ROI drawn in the posterior limb of the internal capsule. Relative anisotropy (RA) and the apparent diffusion coefficient (ADC) were measured based on the tracking. The asymmetry in normal adult and pediatric controls and in congenital hemiplegic cases was evaluated.

Introduction:

Fiber tracking based on diffusion tensor imaging has emerged as a tool for identifying the location and extent of white matter pathways [1]. Manually locating and outlining the corticospinal tract in multiple slices can be difficult and subjective. In this study, axonal tracking was used to identify the corticospinal tract and to quantitatively evaluate congenital hemiplegia. It is expected that axonal structural changes associated with congenital hemiplegia will yield changes in RA and ADC of the affected coricospinal tract. Given that only one side is affected, the contralateral corticospinal tract can be used as an internal control. The asymmetry in normal adult and pediatric controls and in congenital hemiplegic cases was evaluated

Methods:

MR scans were performed on a 1.5T GE system. The adult diffusion tensor sequences consisted of a b=1000 s/mm^2, TR=11.65 s, TE=84.1 ms, FOV = 400 x 200 mm, and voxel size of 1 x 1 mm with a slice thickness of 2.1 mm with no gap. Four healthy adult controls were scanned twice, on separate occasions, to examine reproducibility. The pediatric diffusion sequences had b=1000 s/mm^2, TR = 8s, TE=97.8 ms, FOV = 360 x 180 mm, and voxel size of 2.8 x 2.8 mm with a slice thickness of 3mm with no gap. Three pediatric cases of congenital hemiplegia and four pediatric controls were included. Pediatric controls were referred for evaluation of retinoblastoma, macrocephaly, and family history of vascular anomalies and all had normal neurological exams. In both the adult and pediatric studies, 6 acquisitions were obtained and averaged.

In all cases, an ROI was drawn around the middle third of the cerebral peduncle in the caudal midbrain. Each voxel in this ROI was seeded with 25 coplanar starting points for tracking. The starting points were equally spaced in a plane intersecting the center of the voxel and perpendicular to the superior-inferior direction. Tracking was performed using the Fiber Assignment by Continuous Tracking (FACT) method as described elsewhere [2]. A second ROI was drawn in the posterior two-thirds of the ipsilateral posterior limb of the internal capsule (PLIC) at the level of the globus pallidus. Tracks originating in the cerebral peduncle ROI and passing through the PLIC ROI were identified. The superior endpoints of the tracts were examined. Any tracts ending in the anterior portion of the brain were deemed not part of the corticospinal tract and excluded. The remaining fibers were used to identify the position of the corticospinal tract. This was done bilaterally in all patients.

Tracking of the corticospinal tract was felt to be most confident and complete between the level of the two ROIs. Average RA and ADC were then calculated for both the left and right corticospinal tract from the level of the cerebral peduncle to the PLIC.

Results:

The adult and pediatric control cases showed consistency of diffusion measures based on tractography. The difference between the left and right adult corticospinal tract RA was 4.8% ±2.8% average percent change. The change in ADC between left and right was 1.9% ±1.3% average percent change. The pediatric controls exhibited an RA consistency of 4.4% ±2.1% and an ADC consistency of 2.5% ±2.0%.

Of the three pediatric patients with hemiplegia, two exhibited a large decrease in RA between the affected and unaffected sides. Only one congenital hemiplegic case showed an increase in ADC in the affected tract. One hemiplegia case did not have a change in RA or ADC larger than the variability present in the controls.

Left to Right Side Consistency in Controls

	% Change RA	% Change ADC
Adult Controls	4.8% ±2.8%	1.9% ±1.3%
Pediatric Controls	4.4% ±2.1%	2.5% ±2.0%

Diffusional Changes in Congenital Hemiplegia

	% Change RA	% Change ADC
Case 1	23.8% *	3.6%
Case 2	10.8% *	9.0% *
Case 3	0.18%	2.7%

Changes represent the decrease in RA and increase of ADC in affected tract as compared to contralateral tract.

* corresponds to more than 2 standard deviations above normal pediatric controls.

Discussion/Conclusion:

Tractography can be used to reproducibly locate the corticospinal tracts and quantitatively analyze structural changes of these tracts. The observed decrease in RA of the corticospinal tract in the affected cerebral hemisphere in two patients with congenital hemiplegia indicates the presence of axonal damage involving one side of the brain. The axonal tracking method uses ROIs drawn at different locations known to contain the corticospinal tracts as well as other white matter tracts. By filtering the tracks with multiple ROIs and using prior anatomical knowledge, the corticospinal tracts can be consistently measured as part of a diagnostic tool.

References:

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