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Diffusion MRI to investigate atypical corticospinal tract microstructure and motor impairments in hemiplegic cerebral palsy

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***Abstract*— In our preliminary study, we use diffusion tensor MRI to evaluate the corticospinal tract (CST) and a quantitative force measurement assessment to characterize hand impairment severity in individuals with hemiplegic cerebral palsy (HCP). There were significant correlations between diffusivity measures of the CST and severity of paretic hand weakness and mirror movements. These preliminary findings reveal a link between atypical CST development and hand impairment severity in HCP.**

***Clinical Relevance*— DTI imaging protocols may support prognostic capabilities and inform targeted interventions to increase functional mobility in children with HCP.**

I. Introduction

Hemiplegic cerebral palsy (HCP) is caused by a unilateral brain injury occurring before or during birth. HCP severely limits the functional ability of one side of the body, causing reduced strength in the paretic hand (weakness) and involuntary movements in the paretic hand during use of the non-paretic hand (mirror movements). HCP often involves atypical corticospinal tract (CST) development due to a combination of damage to the lesioned hemisphere and lack of pruning of atypical ipsilateral projections from the non-lesioned hemisphere [1]. Diffusion tensor MRI (DTI) has been used previously to evaluate motor pathway projections and hemispheric differences in HCP [2, 3]. However, few studies have linked diffusivity metrics to hand impairments, and most have relied on only clinical assessments to measure functional deficits. In this study, atypical development of the CST was evaluated using DTI and tractography analyses as it relates to weakness and mirror movement severity in HCP.

II. Methods

Preliminary results include five participants with HCP (2M, 16±7.8 years) and six controls (2M, 12±3.5 years). DTI data were collected using a spin-echo echo-planar imaging sequence (TR=5s, TE=85ms, matrix size=150x150, FOV=225x225mm, slice thickness=1.5 mm, interslice gap=0.1 mm, number of slices=90) with diffusion weighting of b=1000 s/mm^2 in 60 different directions and 8 scans without diffusion weighting (b=0 s/mm^2). Images were processed with steps of brain extraction, denoising, motion and eddy current correction, and fit with tensors to generate maps of diffusivity metrics. Anatomical landmarks were used to guide probabilistic tractography of the CST for analyses in both the lesioned and non-lesioned hemispheres. To quantify grasp weakness and mirroring severity, participants completed a bilateral assessment of grip strength using handheld force measurement devices and custom MATLAB data acquisition software. Spearman correlation analyses were performed between diffusivity metrics and hand impairment measures with age and sex as covariates.

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III. Results

DTI is a feasible method to evaluate CST microstructure in HCP and typically developing pediatric participants (Fig. 1). For the lesioned hemisphere CST, there were significant positive correlations between grasp weakness severity and mean diffusivity (MD) (ρ=0.66, p=0.038) and between grasp weakness severity and axial diffusivity (AD) (ρ=0.68, p=0.030). There was not a significant correlation between grasp weakness severity and fractional anisotropy (FA) (ρ=-0.47, p=0.166). For the non-lesioned hemisphere CST, there was a significant positive correlation between mirroring severity and radial diffusivity (RD) (ρ=0.70, p=0.023). There was not a significant correlation between mirror movement severity and FA (ρ=-0.41, p=0.2361).

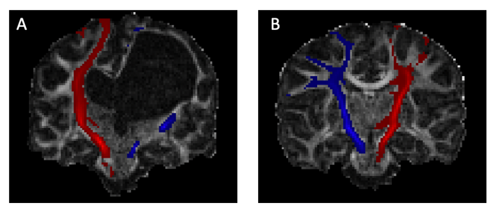

Figure 1. Tractography results of thresholded isolation of the CST overlayed on FA maps in (A) HCP and (B) control participant. The blue and red tracts are in the non-dominant and dominant hemispheres, respectively.

IV. Discussion & Conclusion

For the paretic hand weakness impairment, the increased diffusivity (MD and AD) in the lesioned hemisphere CST may be sensitive to decreased white matter tract density or myelination. For the mirror movement impairment, the increased diffusivity (RD) in the non-lesioned hemisphere CST may indicate that unpruned, disordered cellular structure is sensitive to the inability for independent hand function. While these relationships between CST diffusivity properties and hand function are preliminary, they provide the first steps to better understand underlying neural mechanisms for motor impairments in early-onset PH.

References

[1] J. A. Eyre et al., *Neurology*, 2001, doi: 10.1212/wnl.57.9.1543.
[2] L. Holmstrom et al., *Neurology*, 2011, doi: 10.1212/WNL.0b013e31822b0040
[3] H. C. Kuo et al., *Dev Med Child Neurol*, 2017, doi: 10.1111/dmcn.13192