

Neurite Orientation Dispersion and Density Imaging could show the microstructural changes of Cortico-Spinal Tract in patients with Idiopathic Normal Pressure Hydrocephalus

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Target audience: Researchers and clinicians who focus on diffusion-weighted imaging and diffusion metrics

Introduction: Diffusion MRI has been proposed to describe water diffusion behavior in biological tissues. Neurite orientation dispersion and density imaging (NODDI) is a recently developed technique to evaluate the restricted diffusion. The NODDI model has 3 compartments; intra-cellular, extra-cellular and CSF. NODDI produces maps of intra-cellular volume fraction (ICVF), orientation dispersion index (ODI) and isotropic volume fraction (iso VF)¹. The purpose of this study was to evaluate diffusional changes of cortico-spinal tract (CST) in patients with idiopathic normal pressure hydrocephalus (iNPH) by NODDI.

Methods: Nineteen iNPH patients (age ranged 65-77 years, mean 74.1 years) and eight control subjects (age ranged 67-84 years, mean 75.4 years) were included in this study. In the iNPH patients, the grade of periventricular hyperintensity (PVH) with modified Fazekas grade were significantly higher than controls (the average was 1.74 vs 1.13)². DKI (diffusional kurtosis imaging) data were acquired on a clinical 3T-MRI scanner (Philips Medical systems) as follows: TR/TE 3000/80ms; 20 slices with thickness 5mm; resolution 2*2mm; imaging approximately 13min; 6 b values (0, 500, 1000, 1500, 2000, and 2500 s/mm²) with diffusion encoding in 32 directions for every b value. Gradient length (δ) and the time between two leading edges of diffusion gradient (Δ) were 27.7 and 39.2 ms. respectively. We calculated all diffusion metric maps such as fractional anisotropy (FA), apparent diffusion coefficient (ADC), axial eigenvalue (λ_1), radial diffusivity (RD), mean kurtosis (MK), axial kurtosis (AK), radial kurtosis (RK) with the software dTV.FZR_x (Image Computing and Analysis Laboratory, Department of Radiology, The University of Tokyo Hospital Japan)³. NODDI was processed using all the shells of the DKI data. DKI and NODDI were analyzed from the top part of the superior longitudinal fasciculus (SLF) to the posterior limb of the internal capsule (Figure 1)⁴. Statistical analysis was performed by IBM SPSS Statistics software (version 21.0; SPSS, Chicago, IL), Mann-Whitney *U*-test was used.

Results: DKI and NODDI analysis metrics of the CST were summarized in Table 1. ODI significantly decreased in the iNPH patients compared to controls (0.159±0.017 vs 0.079±0.017; Mann-Whitney *U*-test, *P*<0.005). In the iNPH patients, ICVF also significantly decreased (0.617±0.033 vs 0.561±0.050; *P*<0.005).

Discussion: Decreased ODI suggested that axon was oriented and compressed by ventricular enlargement. Decreased ICVF showed neurite density reduced, which could mean loss of neurite, or it was damaged or degenerated. The results of other diffusion metrics were consistent with the previous study⁴. It means our analyzing method can be acceptable. However, considering the results of the previous Study⁵, we expected ICVF in the iNPH patients increase in NODDI, which disagree with this study result. As in the method part, the grade of PVH in the iNPH patients were significantly higher than controls, that could influence ICVS decreasing. To examine this hypothesis, we should test NODDI in more cases. NODDI could show more complicated microstructural changes than other diffusion MRI.

Conclusion: In the iNPH patients, ODI and ICVF of CST significantly decreased. NODDI could show the microstructural changes on CSTs in the iNPH patients.

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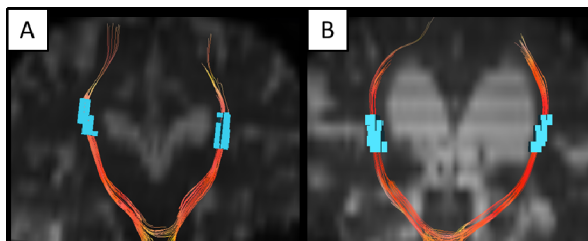


Figure 1. Representative images of the CST in the control (A) and iNPH (B) subjects. The tractographic colors were visualized by diffusion anisotropy coded from yellow (low anisotropy) to orange (higher anisotropy). The voxels of the blue were measurement range in this study.

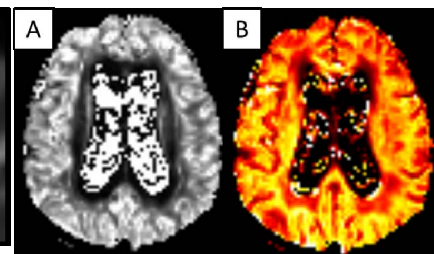


Figure 2. NODDI maps of iNPH patient; (A)-ODI and (B)-ICVF.

Table 1. DKI and NODDI analysis metrics of the CST (mean ± SD).

	iNPH	CONTROL	P value
FA	0.732±0.047	0.625±0.061	<0.005
ADC[10 ⁻³ mm ² /s]	0.761±0.055	0.683±0.036	<0.005
λ_1	1.571±0.091	1.259±0.105	<0.005
RD[10 ⁻³ mm ² /s]	0.358±0.060	0.396±0.045	0.106
MK	0.799±0.056	0.909±0.081	<0.005
AK	0.533±0.166	0.696±0.303	0.217
RK	1.279±0.592	1.106±0.618	0.389
ODI	0.079±0.017	0.159±0.017	<0.005
ICVF	0.561±0.050	0.617±0.033	<0.005