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Recovery of an injured dentato-rubro-thalamic tract in a patient with traumatic brain injury

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Abstract

Several studies have reported on injury of the dentato-rubro-thalamic tract (DRTT) in patients with various brain pathologies. However, no study on recovery of an injured DRTT has been reported so far. We report on a patient who showed recovery of an injured DRTT during a period of approximately 4 years following traumatic brain injury (TBI), which was demonstrated by follow-up diffusion tensor tractography (DTT). A 24-year-old male patient suffered a car accident. The patient lost consciousness for approximately 4 months. At the beginning of rehabilitation, the patient showed mild quadriparesis, severe resting and intentional tremor on four extremities and severe truncal ataxia. He was not able to sit independently. With rehabilitation, he showed continuous improvement, and was able to walk independently at 45 months after onset of injury. On 5-month DTT, DRTTs in both hemispheres were not reconstructed. In contrast, on 13-month DTT, the lower portion of the left DRTT was reconstructed, although the right DRTT was still not reconstructed. On 32-month DTT, the whole left DRTT was reconstructed, however, only the lower portion of the right DRTT was reconstructed. Finally, both DRTTs were reconstructed on 45-month DTT.
Conclusions: Recovery of an injured DRTT was demonstrated in a patient with TBI, using DTT. We believe that evaluation of the DRTT using DTT may be helpful to monitor the progress of rehabilitation in patients with movement symptoms following TBI.

Keywords: Traumatic brain injury, dentato-rubro-thalamic tract, diffusion tensor imaging, tremor, ataxia

INTRODUCTION

The dentato-rubro-thalamic tract (DRTT), a major efferent pathway from the cerebellum, is involved in movement disorder symptoms, including ataxia, tremor, and dystonia.[1-3] Due to its anatomical characteristics of a long and narrow shape, multi-synapse, low discrimination with adjacent neural structures and decussation to the opposite hemisphere in the midbrain, examination of the DRTT in the live human brain has been difficult.[1,4] However, diffusion tensor tractography (DTT), which is derived from diffusion tensor imaging (DTI), enables three dimensional reconstruction and evaluation of the DRTT in the live human brain.[5,6] As a result, several studies have reported injury of the DRTT in patients with various brain pathologies including stroke, brain tumor, and traumatic brain injury (TBI).[7-12] However, no study on recovery of an injured DRTT has been reported so far.

We report here a patient who showed recovery of an injured DRTT during a period of approximately 4 years following TBI, as demonstrated by follow-up DTT.

CASE REPORT

A 24-year-old male patient suffered a car accident; while seated in the passenger seat of a sedan, his car hit a telephone pole to avoid collision with another car, and his head then hit the front window. The patient lost consciousness for approximately 4 months from the time of the accident. Brain CT at the onset showed subarachnoid hemorrhage and hemorrhage on both frontal cortices and he underwent conservative management at the neurosurgery department of a university hospital. At five months from onset, he was transferred to the rehabilitation department of the same university hospital to undergo rehabilitation, which continued until four years after onset at the inpatient and outpatient clinic of the rehabilitation department of the same university hospital.

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At the beginning of rehabilitation, the patient showed mild quadriparesis (manual muscle test: 4/5 [upper extremity] /4/5 [lower extremity]), severe resting and intentional tremor on four extremities and severe truncal ataxia: the Scale for Assessment and Rating of Ataxia (SARA, 26 points [full mark: 40 points]) and the Functional Ambulation Category (FAC, 1 point [full mark: 5 points]). He was not able to sit independently. With rehabilitation, his movement symptoms showed continuous improvement at 13 months after onset (SARA: 22 points and FAC: 1.5 points), and at 32 months after onset (SARA: 16 points and FAC: 2 points). As a result, he developed the ability stand independently. At 45 months after onset he was able to walk independently on an even floor (SARA: 9.5 points and FAC: 3.5 points). The patient provided written informed consent, and the study protocol was approved by the local Institutional Research Board.

Diffusion tensor tractography

DTI was acquired three times (5, 13, 32, and 4months after onset) using a 6-channel head coil on a 1.5T. Imaging parameters were as follows: acquisition matrix=96×96; reconstructed to matrix=192×192; field of view=240×240mm^2; TR=10,398ms; TE=72ms; parallel imaging reduction factor=2; b=1000s/mm^2; and a slice thickness of 2.5mm. Eddy current correction was applied to correct the head motion effect and image distortion in the Oxford Centre for Functional Magnetic Resonance Imaging of the Brain (FMRIB) Software Library. Fiber tracking was performed using probabilistic tractography with default tractography option in FMRIB Software Library. For reconstruction of the DRTT, the seed region of interest (ROI) was placed at the dentate nucleus behind the floor of the fourth ventricle on the coronal image.[1,5] Two target ROIs were placed on the junction of the superior cerebellar peduncle between the upper pons and cerebellum on the coronal image and the contralateral red nucleus of the upper midbrain on the axial image.[1,5] A threshold of 2 streamlines was applied for the results of fiber tracking.

On 5-month DTT, DRTTs in both hemispheres were not reconstructed. In contrast, on 13-month DTT, the lower portion of the left DRTT was reconstructed, although the right DRTT was still not reconstructed. On 32-month DTT, the whole left DRTT was reconstructed, however, only the lower portion of the right DRTT was reconstructed. Finally, both DRTTs were reconstructed on 45-month DTT (Figure 1B).

DISCUSSION

In this report, we followed the changes of an injured DRTT on DTTs with clinical change of motor function in a patient with TBI. On 5-month DTT, DRTTs in both hemispheres were not reconstructed, however, these non-reconstructed DRTTs showed gradual reconstruction on 13- and 32-month DTTs. As a result, 45-month DTT showed normal integrity of both DRTTs between cerebellum and thalamus. During this period, his clinical function in terms of ataxia (SARA) and gait (FAC) also improved: the patient, who was not able to sit independently at 5 months after onset, had developed the ability to walk independently at 45 months after onset. Therefore, we believed that improvement of his motor function was ascribed, at least in part, to recovery of the DRTT in both hemispheres.

Using DTT, several studies have reported that injury of the DRTT resulted in movement disorder including tremor and ataxia in patients with various brain pathologies including stroke, brain tumor, and TBI.[7-12] Regarding TBI, only one study has reported injury of the DRTT.[12] In 2015, Kwon and Jang examined a patient who showed tremor and ataxia following mild TBI. They suggested that injury of the DRTT was probably responsible for the patient's tremor and ataxia because other brain lesions were not detected on conventional brain MRI.[12] To the best of our knowledge, this is the first study to demonstrate recovery of an injured DRTT in a patient with brain injury, using DTT.

DTT has a unique advantage for evaluation of white matter by detection of the water diffusion preferentially in a direction parallel to the axon's longitudinal axis, but diffusion is relatively restricted in the perpendicular axis. Although, DTT is a valuable brain imaging tool, several limitations should be noted. First, result of DTT is operators dependent. Second, because various factors (motion distortion caused by subject movement, image misregistration, decreased signal to noise cause by blood products) can affect the result of DTT, these factors should be controlled. Third, crossing fiber effects can prevent full reflection of underlying fiber. In particular, corpus callosum and corona radiata, pontocerebellar fibers at pons, and superior and medial frontal gyri are known to be crossing fiber point.[13] Fourth, use of probabilistic DTT can result in false positive and negative findings due to fiber complexity in a voxel or partial volume effect.[14,15] Although we could not control the factors completely, we tried to control the

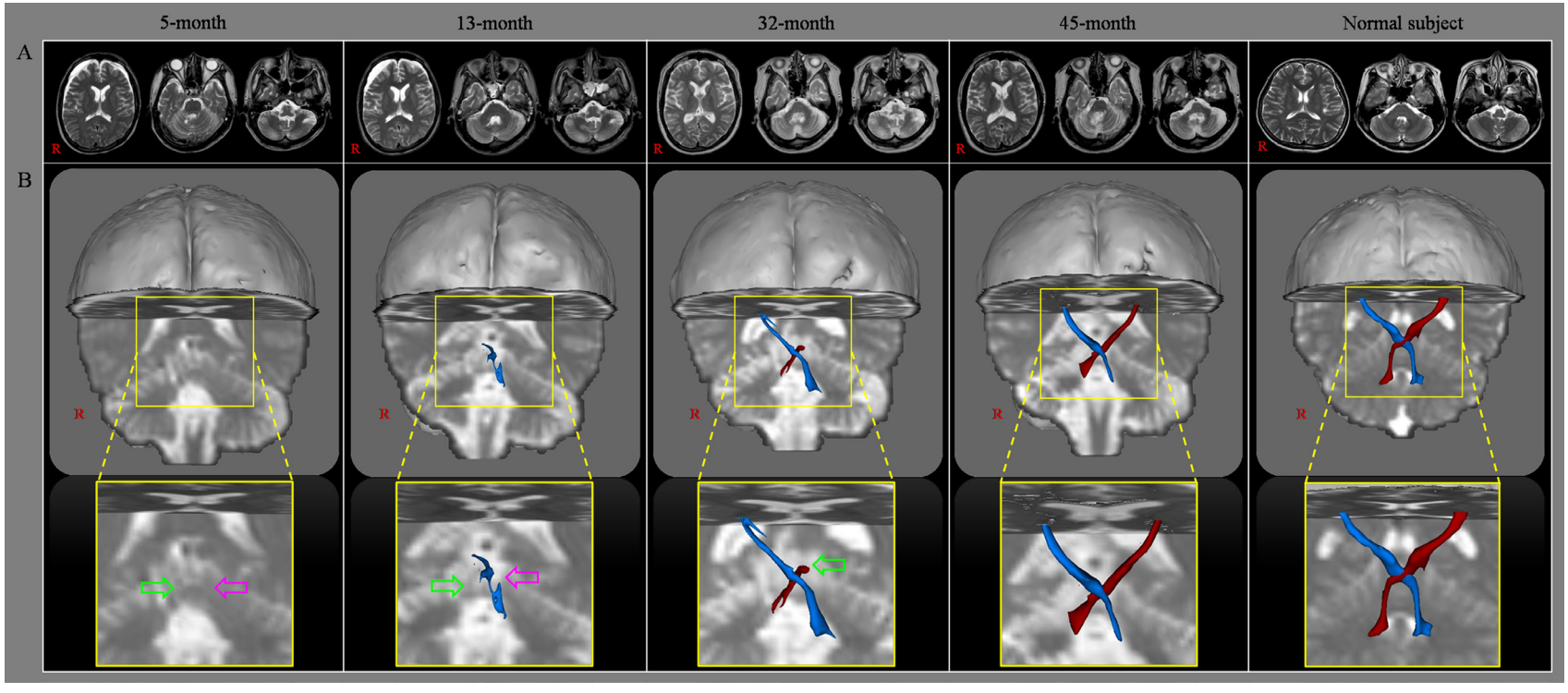

Figure 1. (A) T2-weighted brain MR images show both frontal subdural hygroma and encephalomalacia at the cerebellum. (B) Results of diffusion tensor tractography (DTT) for the dentato-rubro-thalamic tract (DRTT). On 5-month DTT, the DRTTs in both hemispheres are not reconstructed (right: green arrow, left: purple arrow). In contrast, on 13-month DTT, the lower portion of the left DRTT is reconstructed (purple arrow) although the right DRTT is not still reconstructed (green arrow). On 32-month DTT, the whole left DRTT is reconstructed, however, only the lower portion is reconstructed in the right DRTT (green arrow). Finally, both DRTTs are reconstructed on 45-month DTT. Results of DTT for the DRTT in a normal subject (25-year-old male).

factors not to affect the results of DTT. For reduction of the crossing fiber effects, we used the FMRIB Software Library based on a probabilistic technique. This probabilistic technique is known to overcome the crossing fiber effects by calculating both dominant and non-dominant orientation of diffusion in each voxel. In addition, before fiber tracking, head motion effect and image distortion due to eddy current were corrected using the FMRIB Software Library. Therefore, we think that our results might be acceptable and reliable. However, as it is based on a single case report, we suggest further studies with large numbers of patients for confirmation.

In summary, recovery of an injured DRTT was demonstrated in a patient with TBI, using DTT. We believe that evaluation of the DRTT using DTT may be helpful to monitor the progress of rehabilitation in patients with movement symptoms following TBI.

DISCLOSURE

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REFERENCES

1. Afifi AK, Bergman RA. Functional neuroanatomy : text and atlas. 2nd ed. New York: Lange Medical Books/McGraw-Hill, 2005.
2. Lehericy S, Grand S, Pollak P *et al*. Clinical characteristics and topography of lesions in movement disorders due to thalamic lesions. *Neurology* 2001; 57:1055-66.
3. Marx JJ, Iannetti GD, Thomke F *et al*. Topodiagnostic implications of hemiataxia: an MRI-based brainstem mapping analysis. *Neuroimage* 2008; 39:1625-32.
4. Mendoza JE, Foundas AL. Clinical neuroanatomy : a neurobehavioral approach. New York ; London: Springer, 2007.
5. Kwon HG, Hong JH, Hong CP *et al*. Dentatorubrothalamic tract in human brain: diffusion tensor tractography study. *Neuroradiology* 2011; 53:787-91.
6. Mori S, Crain BJ, Chacko VP, van Zijl PC. Three-dimensional tracking of axonal projections in the brain by magnetic resonance imaging. *Ann Neurol* 1999; 45:265-9.
7. Coenen VA, Allert N, Madler B. A role of diffusion tensor imaging fiber tracking in deep brain stimulation surgery: DBS of the dentato-rubro-thalamic tract (DRT) for the treatment of therapy-refractory tremor. *Acta Neurochir (Wien)* 2011; 153:1579-85; discussion 85.
8. Coenen VA, Madler B, Schiffbauer H, Urbach H, Allert N. Individual fiber anatomy of the subthalamic region revealed with diffusion tensor imaging: a concept to identify the deep brain stimulation target for tremor suppression. *Neurosurgery* 2011; 68:1069-75; discussion 75-6.
9. Coenen VA, Allert N, Paus S *et al*. Modulation of the cerebello-thalamo-cortical network in thalamic deep brain stimulation for tremor: a diffusion tensor imaging study. *Neurosurgery* 2014; 75:657-69; discussion 69-70.
10. Marek M, Paus S, Allert N *et al*. Ataxia and tremor due to lesions involving cerebellar projection pathways: a DTI tractographic study in six patients. *J Neurol* 2015; 262:54-8.
11. Schlaier J, Anthofer J, Steib K *et al*. Deep Brain Stimulation for Essential Tremor: Targeting the Dentato-Rubro-Thalamic Tract? *Neuromodulation* 2015; 18:105-12.
12. Jang SH, Kwon HG. Injury of the dentato-rubro-thalamic tract in a patient with mild traumatic brain injury. *Brain Inj* 2015; 29:1725-8.
13. Wieqell MR, Larsson HB, Wedeen VJ. Fiber crossing in human brain depicted with dffusion tensor MR imaging. *Radiology* 2000; 217:897-903.
14. Yamada K. Diffusion tensor tractography should be used with caution. *Proc Natl Acad Sci U S A* 2009; 106:E14; author reply E5.
15. Fillard P, Descoteaux M, Goh A *et al*. Quantitative evaluation of 10 tractography algorithms on a realistic diffusion MR phantom. *Neuroimage* 2011; 56:220-34.