Transcallosal Ipsilateral Motor Pathway from the Unaffected Hemisphere in a Patient with Traumatic Brain Injury

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Purpose: We presented with a patient with traumatic brain injury who showed a transcallosal ipsilateral motor pathway from unaffected motor cortex to affected extremities, as evaluated by diffusion tensor tractography (DTT).

Methods: One patient and six age-matched normal subjects were enrolled. A 42-year-old left hemiparetic male who suffered from brain injury by motor vehicle accident 9 years ago showed a leukomalactic lesion in the right corona radiata and parieto-temporal lobe. His left extremities were completely paralyzed initially, but recovered slowly over 2 years. At the time of the evaluation, he was able to grasp and release an object, and to walk with spastic gait pattern. DTT was performed using 1.5 T with a Synergy-L Sensitivity Encoding head coil. DTT was obtained with termination criteria of FA <0.2 and an angle change >45°.

Results: The motor tracts of the unaffected (left) hemisphere of the patient and control subjects originated from the motor cortex and descended along the known corticospinal tract without any transcallosal tract. By contrast, the tract of the affected (right) hemisphere originated from the left premotor cortex, descended through the left corona radiata, and then crossed the mid-portion of the corpus callosum. The tract then descended through the known corticospinal tract pathway to the right medulla.

Conclusion: We conclude that the transcallosal ipsilateral motor pathway from the unaffected hemisphere appeared to contribute to the motor recovery in this patient.

Key Words: Brain injury, Diffusion tensor tractography, Corticospinal tract, Motor function

I. Introduction

Several mechanisms have been suggested for motor recovery following brain injury. These include the ipsilateral motor pathway (IMP) from the unaffected motor cortex to the affected extremities, peri-lesional reorganization, recovery of a damaged lateral corticospinal tract (CST), and contribution of the secondary motor area.[1-6] Among these mechanisms, the IMP is the most actively researched recovery mechanism and few studies have reported on the motor recovery through the IMP via the transcallosal pathway from the unaffected motor cortex to the affected extremities in stroke patients.[7-19] However, no study has reported on this recovery mechanism in patients with traumatic brain injury (TBI).

Recent developed diffusion tensor tractography (DTT), derived from diffusion tensor imaging (DTI), has a unique advantage in three-dimensional reconstruction and visualization of the neural tracts. Recovery of integrity of a neural tract suggested a neural recovery. On the contrary, discontinuation of integrity of a neural tract indicated neural injury.

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In the current study, we report on a hemiplegic patient with traumatic brain injury who showed a transcallosal IMP from the unaffected cortex to the affected extremities, as evaluated by DTT.

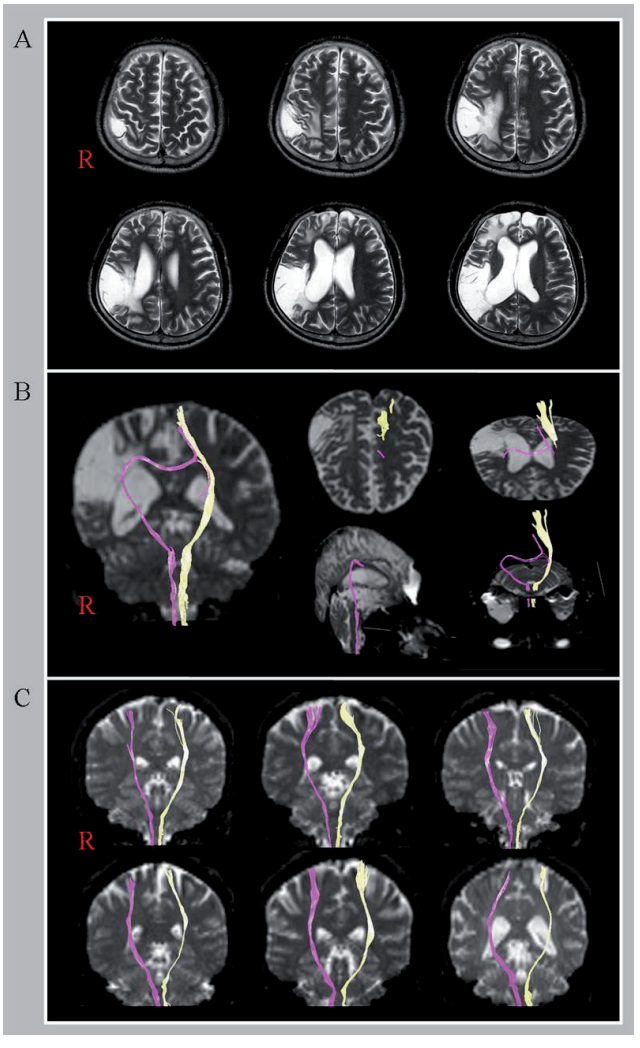

Figure1.
A: T2-weighted images reveal leukomalactic change in right parieto-temporal lobe and posterior corona radiata.
B: Diffusion tensor tractography for the corticospinal tract of the patient. The tract (purple color) of the affected (right) hemisphere originated from the left premotor cortex (2) and the subcallosal corona radiata, descended through the left corona radiata (3), and then crossed the mid-portion of the corpus callosum (4). The tract then descended through the anterior portion of the corona radiata (3) and then through the known CST pathway to the medulla in the right hemisphere.
C: Diffusion tensor tractography for the corticospinal tracts of the six control subjects. The tracts originated from the motor cortex and descended through the known corticospinal tract without any transcallosal fibers.

II. Case Report

One patient with TBI and six normal subjects (male: female=2:4, mean age: 42.9 years, range: 38–47 years) were enrolled in this study. All participants provided written informed consent prior to the study, and the local ethics committee approved the study protocol.

A 42–year–old left hemiparetic male who suffered from TBI with diffuse axonal injury grade I caused by a motor vehicle accident was referred to our hospital for evaluation of motor function and rehabilitation. At the onset of the TBI, there was a traumatic hemorrhage in the right parieto–temporal lobe. T2–weighted brain images at 9 years after onset showed leukomalactic changes in the right corona radiata and parieto–temporal lobe (Figure 1A). The patient's left extremities were completely paralyzed initially, but recovered slowly over 2 years. At the time of the study (9 years after onset), he was able to grasp and release an object, and to walk with spastic gait pattern. However, he was not able to carry out fine motor activity with his left hand. Sustained mirror movements were shown by the right hand during left hand movements, but there was no mirror movement of the left hand during right hand movements.

Diffusion Tensor Tractography: The diffusion tensor images were obtained 9 years after the onset of TBI using a sensitivity–encoding head coil on a 1.5–T Philips Gyroscan Intera (Hoffman–LaRoche, Ltd, Best, the Netherlands) with single–shot echo–planar imaging with a navigator echo. Sixty contiguous slices (matrix=128 128, field of view=221 mm, repetition time/echo time=10726/76 ms, b=600 mm^2s^{-1}, thickness=2.3 mm) were acquired for each of the 32 noncollinear diffusion–sensitizing gradients. Three–dimensional reconstructions of the fiber tracts were obtained using PRIDE[20], and the termination criteria used were fractional anisotrophy〈0.2, angle〈45°. Two regions of interest were drawn in the corticospinal tract areas of the mid–pons and the upper medulla on two–dimensional fractional anisotrophy color maps.[21]

The motor tracts of the unaffected (left) hemisphere of the patient and those of control subjects originated from the motor cortex, and descended along the known CST without

any transcallosal tract (Figure 1B, 1C). By contrast, the tract of the affected (right) hemisphere originated from the left and subcortical corona radiata, descended through the left corona radiata, and then crossed the mid-portion of the corpus callosum. The tract then descended through the anterior portion of the right corona radiata, just anterior to the leukomalatic lesion of the corona radiata, and then descended through the known CST pathway to the medulla in the right hemisphere (Figure 1B).

III. Discussion

In the current study, we present a patient who showed transcallosal tract passing from the unaffected hemisphere to the affected extremities. For the following reasons, we believe that the motor function of the affected extremities in this patient recovered via IMP. First, the brain MRI of this patient showed that a severe leukomalatic lesion in the right corona radiata, which completely comprised the CST. We considered this lesion in relation to the results of previous studies on the topic of location of the CST of the CR.[22-25] Second, there was only one motor tract for the affected (right) hemisphere, which originated from the left supplementary motor area crossed the mid-portion of the corpus callosum, and then descended through the anterior portion of the right corona radiata and the known CST pathway. This suggests that some motor pathway other than the damaged CST at the right CR was responsible for the recovery of motor function. However, with the exception of the motor pathway through the corpus callosum from the unaffected hemisphere to the affected extremities, other motor tracts were not observed on DTT. Lastly, we think the mirror movements of this patient would be additional evidence for IMP because it is well-known that the pathophysiologic mechanism of mirror movements in patients with brain injury are IMP.[26] As a result, we assume that the motor function of the affected extremities was recovered through this transcallosal IMP.

The possible routes of the IMP after brain injury are still under debate; several routes have been suggested for motor recovery following brain injury, including: 1) an uncrossed anterior CST, 2) non-CST (the most plausible tracts would be the cortico-reticulospinal tract or cortiovestibulospinal tract), and 3) transcallosal fibers from the unaffected motor cortex to the affected extremities.[7,9,11-13,16-19,27-29] Regarding the transcallosal fibers, only few studies have reported in stroke patients, using DTT.[16,17] In 2009, Jang et al. reported that transcallosal fibers originating from the unaffected CST were significantly more prevalent in 40 patients with a corona radiata infarct, and the presence of these fibers showed an association with poor motor function.[16] Subsequently, Jang reported on a patient with a corona radiata infarct who showed motor recovery via the transcallosal motor pathway which was originated from the unaffected CST.[17] As a result, this is the first study to demonstrate the motor recovery via transcallosal IMP from unaffected cortex in patients with traumatic brain injury.

In conclusion, we report a patient who showed a transcallosal IMP from the unaffected hemisphere. The clinical significance and characteristics of transcallosal IMP should be elucidated through further studies. This result has important implications in terms of the mechanisms of motor recovery following brain injury. In addition, interest and comprehension about motor recovery mechanisms is important for therapist to scientific treatment planning and efficient therapy. However, this study is limited because it is a case report. Further complementary studies involving larger case numbers are warranted.

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