Recovery of an injured anterior cingulum to the basal forebrain in a patient with brain injury: a 4-year follow-up study of cognitive function

The cingulum, a long neural tract extending from the orbitofrontal cortex to the medial temporal lobe, obtains cholinergic innervation from three cholinergic nuclei in the basal forebrain (the nucleus basalis of Meynert [Ch 4], the medial septal nucleus [Ch 1], and the vertical nucleus of the diagonal band [Ch 2]), and is the passage of the medial cholinergic pathway which supplies cholinergic innervation from the basal forebrain to the cerebral cortex (Folstein et al., 1975; Selden et al., 1998; Lucas-Meunier et al., 2003). Therefore, it is important for cognition, especially memory function (Selden et al., 1998). In this study, using DTT, changes of the anterior cingulum were observed in a patient with brain injury (meningioma and ICH).

A 66-year-old male patient underwent craniectomy and removal of meningioma and concurrent intracerebral hemorrhage (ICH) at a neurosurgery department of a university hospital (Figure 1A). He was transferred to a rehabilitation department of another university hospital in order to undergo rehabilitation at 4 months after onset. The patient received comprehensive rehabilitative therapy including cognitive therapy which was performed 30 minutes/day and 5 times per week for 1 month. His rehabilitation continued until 4 years after onset at outpatient clinic of the rehabilitation department of our hospital (30 minutes/day and twice per week). Brain MRI scans performed at 4 months and 4 years after onset showed leukomalacic lesions in the right frontal area (Figure 1A). At the beginning of the rehabilitation, the patient showed mild cognitive impairment with a score of 22 on the Mini-Mental State Examination (MMSE, full score: 30, cut-off score < 24) (Folstein et al., 1975). By contrast, at 4 years after onset, his cognitive impairment had improved to a score of 28 on MMSE. The patient and his wife provided signed, informed consent, and our institutional review board approved the study protocol.

Diffusion tensor imaging data were scanned twice (4 months and 4 years after onset) using a a 1.5 T Philips Gyroscan Intera

![Figure 1 Brain magnetic resonance images (MRI) and diffusion tensor tractography (DTT) of a 66-year-old male patient with brain injury. (A) Brain MR images at 4 months and 4 years after onset show leukomalacic lesions in the right frontal lobe (green arrows). (B) Results of diffusion tensor tractographies (DTTs) of the patient. On 4-month DTT, discontinuations (sky-blue arrow) of both anterior cingulums are observed. By contrast, on 4-year DTT, the left cingulum is elongated to the left basal forebrain (yellow arrows) without significant change of the discontinued right cingulum.](image-url)
In conclusion, using DTT, long-term recovery of an injured cingulum was demonstrated in a patient with brain injury. However, the limitation of DTT should be cautioned: a voxel in a multiple orientation cannot present full reflection of the underlying fiber architecture, resulting in possible underestimation of the neural tracts (Yamada et al., 2009). In addition, because this study was conducted retrospectively, we were not able to obtain detailed neuropsychological data, except for MMSE. Therefore, further studies without these limitations should be encouraged.

Table 1 Results of diffusion tensor tractography parameters

|          | 4-month DTT |          | 4-year DTT |
|----------|-------------|----------|------------|
|          | FA          | MD (× 10⁻³ mm²/s) | TV (voxel) | FA          | MD (× 10⁻³ mm²/s) | TV (voxel) |
| Right    | 0.36        | 0.85     | 1,286      | 0.37        | 0.86     | 1,348      |
| Left     | 0.37        | 0.90     | 1,312      | 0.39        | 0.87     | 1,732      |

DTT: Diffusion tensor tractography; FA: fractional anisotropy; MD: mean diffusivity; TV: tract volume.

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Sung Ho Jang, Hyeok Gyu Kwon*

Department of Physical Medicine and Rehabilitation, College of Medicine, Yeungnam University, Namku, Daegu, Republic of Korea

*Correspondence to: Hyeok Gyu Kwon, Ph.D., khg0715@hanmail.net.

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