

Unusual compensatory neural connections following disruption of corpus callosum fibers in a patient with corpus callosum hemorrhage

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Objective: We report on a patient with hemorrhage of the corpus callosum (CC) in whom unusual compensatory neural connections were observed following disruption of CC fibers. **Methods:** A 42-year-old female patient presented with callosal alien hand syndrome (AHS) after the onset of the hemorrhage. She showed a rapid recovery and the symptoms of her AHS had almost disappeared at 7 weeks after onset. We performed diffusion tensor tractography (DTT) for the evaluation of CC fibers and performed a comparison with DTT findings acquired from a normal subject (a 47-year-old female). **Results:** Findings on DTT of the patient revealed extensive disruption of CC fibers passing through the anterior portion of the genu and most of the CC body. We observed that CC fibers in the right and left temporal lobes joined with the right and left inferior fronto-occipital fasciculus, respectively, and these neural fibers were connected to each other through the anterior commissure. These changes of neural connections were not observed in the normal subject. **Conclusion:** We think that the unusual neural connections in this patient were compensatory phenomena for disruption of CC fibers. In addition, the good recovery from symptoms of AHS in this patient appears to be correlated with these unusual compensatory neural connections. We believe that the results of this study suggest a mechanism for neural recovery following injury of the CC fibers.

KEYWORDS: corpus callosum, diffusion tensor imaging, alien hand syndrome, hemorrhage

Introduction

The corpus callosum (CC) is a bundle of neural fibers connecting both cerebral hemispheres of the brain, thus enabling the interhemispheric transfer of cognitive, somatosensory, motor, executive, auditory and visual information [1–3]. Lesions of the CC fibers can impair the interhemispheric transfer of this information, resulting in various neurologic manifestations [4–8]. Alien hand syndrome (AHS), which is characterized by purposeful and autonomous movements of the affected hand against the patient's intention, is one of the representative manifestations that occur following injury to CC fibers [9–11].

Diffusion tensor tractography (DTT), derived from diffusion tensor imaging (DTI), allows for three-dimensional visualization of CC fibers [12–15]. Therefore, DTT has been used for the assessment of disruptions of CC fibers in patients with brain injury, including diffuse axonal injury (DAI) and stroke [16–19]. However, little is known about recovery mechanisms following disruption of CC fibers.

In the current study, we report on a patient who showed unusual neural connections following disruption of CC fibers resulting from CC hemorrhage.

Case Report

A 42-year-old right-handed female underwent clipping of a ruptured left pericallosal artery aneurysm following CC hemorrhage at the neurosurgery department of a university hospital (see Figure 1A). Four weeks later, the patient was transferred to the rehabilitation department. The patient presented with callosal AHS, which

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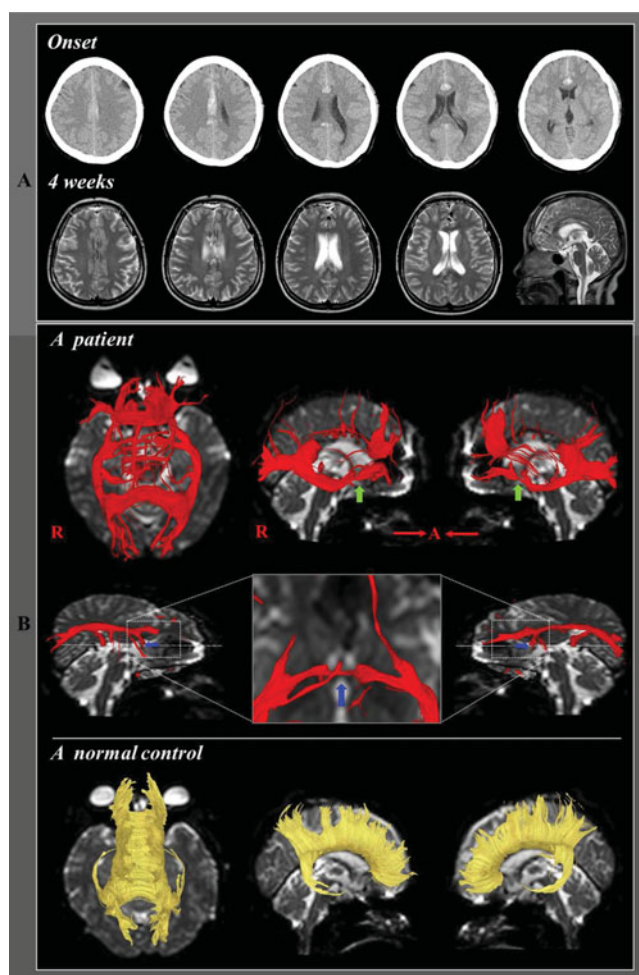


Figure 1. (A) Brain CT at onset showed hemorrhages in and around the corpus callosum. T2-weighted brain MRI at 4 weeks after onset showed hemorrhagic lesions confined to the corpus callosum, which extended to the anterior portion of the genu, the callosal midbody and the isthmus. (B) Diffusion tensor tractography of the patient showed extensive disruption of corpus callosum fibers, with the exception of those passing through the posterior portion of the genu and the splenium. The corpus callosum fibers in both temporal lobes were connected to the inferior fronto-occipital fasciculi (green arrow) and these fibers were connected to each other through the anterior commissure (blue arrow). In contrast, the corpus callosum fibers of the normal subject extended bilaterally to the frontal, parietal and occipito-temporal cortices.

is characterized primarily by intermanual conflict. Most of the time, whenever the patient attempted to perform a task using her right hand, her left hand would spontaneously inhibit the action against her will. The patient showed a rapid recovery; consequently, at 7 weeks after onset, the symptoms of her AHS had almost disappeared; the symptoms of AHS usually presented only once a day and disappeared once she paid attention to the inhibitory actions of her left hand.

We acquired T2-weighted MRI and DTI data from the patient at 4 weeks after the onset for comparison with those of a healthy 47-year-old female. The patient and the healthy control signed an informed consent prior to the study. The Institutional Review Board of our university hospital approved the entire study protocol. 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 and navigator echo, was used for acquisition of T2-weighted MRI and DTI. T2-weighted MRI (matrix = 250×250 , field of view = $210 \times 210 \text{ mm}^2$, echo time = 100.0 ms, repetition time = 4,202 ms, number of excitations = 1 and slice thickness = 5 mm) and DTI (matrix = 96×96 , field of view = $192 \times 192 \text{ mm}^2$, echo time = 76.0 ms, repetition time = 10,726 ms, $b = 1000 \text{ s/mm}^2$, number of excitations = 1 and slice thickness = 2.5 mm) were acquired for each of the 32 noncollinear diffusion-sensitizing gradients. Fiber tracking was performed using the fiber assignment continuous tracking algorithm implemented within the DTI task card software (Philips Extended MR Workspace 2.6.3). A region of interest was placed on the entire CC on sagittal fractional anisotropy (FA) color maps. The termination criteria used were a FA of <0.3 and an angle change $>45^\circ$.

The DTT of the normal subject showed bilateral extension of CC fibers to the frontal, parietal and occipito-temporal cortices (see Figure 1B). By contrast, the DTT of the patient showed extensive disruption of the CC fibers passing through the anterior portion of the genu and most of the CC body (i.e. from the rostral midbody to the isthmus; see Figure 1B); however, the CC fibers passing through the posterior part of the genu and the splenium were preserved and connected bilaterally to the frontal and occipito-temporal cortical areas, respectively. In addition, in the patient, the CC fibers connecting the temporal cortical areas were connected to the inferior fronto-occipital fasciculus (IFOF) in both hemispheres (see Figure 1B). In addition, these fibers were connected to each other via the anterior commissure (see Figure 1B). These changes of neural tracts were not observed in the normal subject (see Figure 1B).

Discussion

AHS is a neurological manifestation commonly resulting from damage to the CC body [2]. The neurological manifestation observed in this patient showed correlation with the DTT finding showing extensive disruption of CC fibers passing through the CC body. In addition, the DTT acquired from the patient showed that the CC fibers in both the right and left temporal lobes joined with the IFOFs; these neural fibers were connected to each other through the anterior commissure. The

IFOF is a large neural tract connecting the frontal and occipital lobes, with some connections with the parietal and temporal lobes [20]. Thus, various types of information originating from these cerebral lobes might be transferred to the opposite hemisphere through the neural connection between the IFOF and the CC fibers and the neural connection via the neural tract that passes through the anterior commissure. Because none of these unusual neural connections were observed in the normal subject, we suggest that the unusual neural connections observed in this patient appear to be compensatory phenomena for impaired interhemispheric transfer of information following disruption of CC fibers. The good recovery from the symptoms of AHS in this patient appears to be additional evidence of our assumption.

A few studies using DTI have reported disruptions of CC fibers in patients with symptoms of callosal disconnection [16–19]. In 2002, Molko et al. [19] performed DTT in a patient with left hemialexia following a posterior CC lesion after surgery for the removal of a hemorrhagic arterio-venous malformation. They observed disruption of CC fibers, which were connected to both occipito-temporal lobes. In 2005, Le et al. [18] reported on a patient with left hemialexia following DAI. Findings on DTT showed interruption of CC fibers at the posteroinferior margin of the splenium. In 2012, Chang et al. [16] reported on a patient with a CC hemorrhage who presented with symptoms of callosal disconnection, including callosal AHS, left ideomotor apraxia and left tactile anomia. They demonstrated extensive disruption of CC fibers, with the exception of CC fibers in the splenium. Jang et al. (2012) [17] recently reported on disruption of CC fibers passing through the CC body in a patient with an infarct of the CC, who showed neurologic manifestations, including frontal AHS, left agraphia, right hemiparesis, right somatosensory deficit and left neglect. Therefore, to the best of our knowledge, this is the first study to demonstrate changes of neural tracts following disruption of CC fibers.

In conclusion, we report on a patient with a CC hemorrhage who showed unusual compensatory neural connections following disruption of CC fibers. We believe that the results of this study suggest a mechanism for neural recovery following injury of CC fibers. However, this study has several limitations. First, DTT could lead to both false positive (unusual neural connections) and negative (extensive disruption of CC fibers) throughout the white matter of brain because of complex fiber configurations such as crossing or kissing fiber and partial volume effects [21–23]. Second, we obtained DTI data using relatively low angular resolution (32 directions), which can provide erroneous tracts such as false turns, false continuations and random fiber trajectories [24].

Third, we were unable to explain the exact mechanism by which the unusual neural connections could compensate for the damage to CC fibers. Fourth, DTI data were not acquired at onset of CC hemorrhage; thus, we could not perform a direct comparison. Fifth, this is a single case study. Therefore, further studies addressing these limitations are needed.

Declaration of Interest

The authors report no conflict of interest. The authors alone are responsible for the content and writing of this paper.

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