CASE REPORT
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Visual recovery demonstrated by functional MRI and diffusion tensor tractography in bilateral occipital lobe infarction

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We report on a patient who showed visual recovery following bilateral occipital lobe infarct, as evaluated by follow up functional magnetic resonance imaging (fMRI) and diffusion tensor tractography (DTT). A 56-year-old female patient exhibited severe visual impairment since onset of the cerebral infarct in the bilateral occipital lobes. The patient complained that she could not see anything, although the central part of the visual field remained dimly at 1 week after onset. However, her visual function has shown improvement with time. As a result, at 5 weeks after onset, she notified that her visual field and visual acuity had improved. fMRI and DTT were acquired at 1 week and 4 weeks after onset, using a 1.5-T Philips Gyroscan Intera. The fiber number of left optic radiation (OR) increased from 257 (1-week) to 353 (4-week), although the fiber numbers for right OR were similar. No activation in the occipital lobe was observed on 1-week fMRI. By contrast, activation of the visual cortex, including the bilateral primary visual cortex, was observed on 4-week fMRI. We demonstrated visual recovery in this patient in terms of the changes observed on DTT and fMRI. It appears that the recovery of the left OR was attributed more to resolution of local factors, such as peri-infarct edema, than brain plasticity.

Keywords: Diffusion tensor imaging; Functional MRI; Vision; Visual pathway; Brain infarction

INTRODUCTION

Because the occipital lobe comprises the visual cortex and optic radiation (OR), injury of the occipital lobe often accompanies impairment of visual function [1-3]. Many studies have reported on recovery of visual function in patients with occipital lobe injury, therefore, the occipital lobe is known to have the characteristic of high plasticity [3-8]. However, only a few studies have demonstrated the recovery process using brain mapping techniques [9-11].

Functional magnetic resonance imaging (fMRI) offers the advantage of good spatial resolution, allowing for accurate localization of the activation site at the cortex level [12]. fMRI has been used for evaluation of visual cortex function [10,13]. By contrast, diffusion tensor tractography (DTT), derived from diffusion tensor imaging (DTI), can allow for 3-dimensional identification and estimation of the OR [14-17]. The simultaneous use of fMRI and DTT would be useful for demonstration of visual recovery in patients with occipital lobe injury. However, knowledge regarding the recovery of visual function using these techniques is limited [10,11].

In this study, we report on a patient who showed visual recovery following a bilateral occipital lobe infarct, as evaluated by follow up fMRI and DTT.

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CASE

A 56-year-old female patient underwent conservative management for a cerebral infarct in bilateral occipital lobes, which occurred 1 day after undergoing a microdiscectomy operation for treatment of a herniated lumbar disc. Findings on brain MRIs taken at 1 week and 4 weeks showed cerebral infarcts in both occipital lobes (Fig. 1A). The patient showed severe visual impairment since onset of the cerebral infarct and started rehabilitation 1 week after onset. The patient complained that she could not see anything, although the central part of the visual field remained dimly at 1 week after onset. In addition, the patient showed object agnosia, prosopagnosia, color agnosia, and alexia. As a result, she was not able to perform activities of daily living or walk independently. However, her visual impairment has shown improvement with time. As a result, at 5 weeks after onset, she notified that her visual field and visual acuity had improved, although her vision was still cloudy. In addition, her visual agonsia also showed improvement. Consequently, she could see a watch at a distance of 3 meters and walk independently on an even floor at 5 weeks after onset. Due to her poor cognitive function, ophthalmic examination for assessment of visual acuity and visual field could not be performed precisely.

DTIs were acquired at 1 week and 4 weeks after onset, using a synergy-L Sensitivity Encoding (SENSE) head coil on

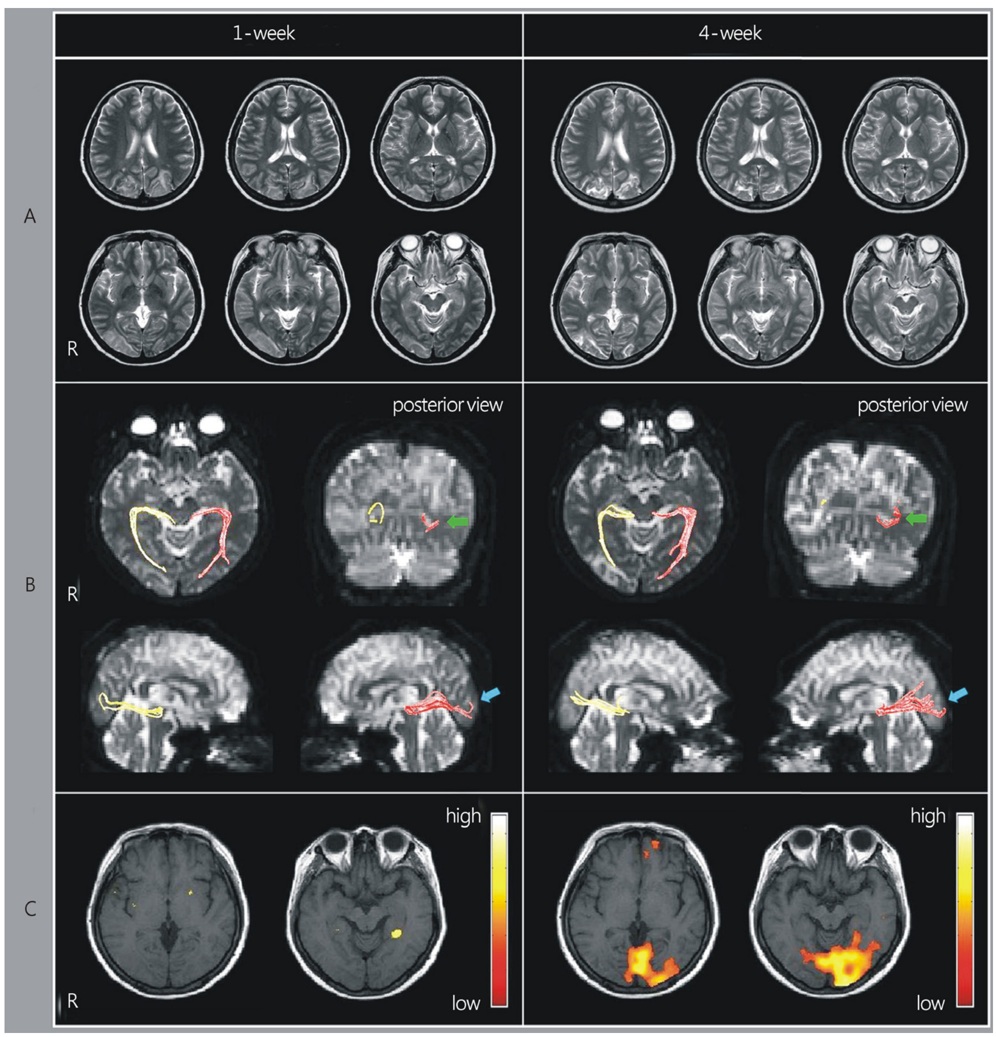

Fig. 1. (A) T2-weighted brain MR images taken at 1 week and 4 weeks showed cerebral infarcts in both occipital lobes. (B) DTT for the optic radiation. Grossly, fibers of the left optic radiation were increased on 4-week DTT, compared with that observed on 1-week DTT (blue arrows). The fibers of the left optic radiation were located around the infarct area and increased with the resolution of the peri-infarct edema (green arrows). (C) Results of fMRI. No activation was observed in the occipital lobe, except for activation in the junction between the left lingual gyrus and parahippocampal gyrus on 1-week fMRI. By contrast, activation of the visual cortex, including the bilateral primary visual cortex, bilateral lingual gyrus, and left fusiform gyrus was observed on 4-week fMRI. DTT, diffusion tensor tractography; fMRI, fuctional magnetic resonance imaging.

a 1.5-T Philips Gyroscan Intera (Hoffman-La Roche, Best, Netherlands) with single-shot echo-planar imaging and a navigator echo. For each of the 32 non-collinear diffusion sensitizing gradients, we acquired 65 contiguous slices parallel to the anterior commissure-posterior commissure line. Imaging parameters were as follows: matrix=128×128 matrix, field of view=221×221 mm^2, repetition time (TR)=10,726 ms, echo time (TE)=76 ms, SENSE factor=2, echo planar imaging (EPI) factor=67 and b=1,000 s/mm^2, number of excitations NEX=1, slice gap=0 mm, and slice thickness=2.3 mm.

Affine multi-scale 2-dimensional registration at the Oxford Centre for Functional Magnetic Resonance Imaging of Brain (FMRIB) Software Library (FSL; www.fmrib.ox.ac.uk/fsl) was used for reduction of eddy current-induced image distortions [18]. We reconstructed the OR using DTI-Studio software (CMRM, Johns Hopkins Medical Institute, USA). Fiber tracking was based on the fiber assignment continuous tracking algorithm and the multiple regions of interest (ROIs) approach. For reconstruction of the OR, we placed the seed ROI on the lateral geniculate body on the color map, and the target ROI was given on the bundle of OR at the middle portion between the lateral geniculate nucleus and the occipital pole [15,19]. Fiber tracking was started at the center of a seed voxel with a fractional anisotropy (FA) of >0.15 and ended at a voxel with a fiber assignment of >0.15 and a tract turning-angle of <70° [20]. We measured the FA, apparent diffusion coefficient (ADC), and fiber number of the OR.

Blood oxygenation level dependent (BOLD) fMRI measuremets using the EPI technique were performed 2 times, using a 1.5-T Philips Gyroscan Intera scanner (Hoffman-LaRoche, Ltd.) with a standard head coil, at 1 week and 4 weeks after onset. For the anatomical reference image, 20 axial, 5-mm thick, T1-weighted spin echo images were obtained with a matrix size of 128×128 and a field of view of 210 mm, parallel to the bicommissure line of the anterior commissure-posterior commissure. For functional imaging, BOLD-weighted EPI images (TR/TE=2 s/60 ms, field of view=210 mm, flip angle =90°, matrix size=64×64, and slice thickness=5 mm) were scanned over the same 20 axial sections, producing a total of 2,400 images. The patient was examined while in a supine position and was firmly immobilized in order to prevent motion in the fMRI scanner. Using a block paradigm (21s control, 21s stimulation: 3 cycles), flashing a light steadily (4Hz) in the eye was performed for stimulation. SPM 8 software (Wellcome Department of Cognitive Neurology, London, UK) running in the MATLAB environment (The Mathworks, Natick, Mass., USA) was used for analysis of fMRI data. All images were realigned, co-registered, and normalized. Next, they were smoothed using an 8-mm isotropic Gaussian kernel. For changes in BOLD signal, the control condition data were subtracted from the stimulated condition data. Statistical parametric maps were obtained, and voxels of cluster level were considered significant at a threshold of uncorrected p<0.001.

Table 1. Diffusion tensor imaging parameters of optic radiation in the patient

	1 week		4 weeks	
	Right	Left	Right	Left
FA	0.41	0.44	0.37	0.42
ADC	0.78	0.81	0.91	0.83
Fiber number	192	257	194	353

FA, fractional anisotropy; ADC, apparent diffusion coefficient.

The values of FA and ADC of both ORs, and the fiber number of the left OR on 1-week DTT were similar to those observed on 4-week DTT, however, the fiber number of the left OR increased from 257 (1-week) to 353 (4-week) (Table 1). Grossly, fibers of the left OR also showed an increase on 1-week DTT, compared with that of 4-week DTT (Fig. 1B).

On 1-week fMRI, except for activation in the junction between the left lingual gyrus and parahippocampal gyrus, no activation was observed in the occipital lobe (Fig. 1C). By contrast, activation of the visual cortex, including the bilateral primary visual cortex, bilateral lingual gyrus, and left fusiform gyrus, was observed on 4-week fMRI.

DISCUSSION

In the current study, we observed changes on DTT and fMRI in a patient with a bilateral occipital lobe infarct. We believe that this patient's recovery of visual function was demonstrated in terms of changes observed on DTT and fMRI. Regarding DTT for the OR, the fiber number of the left OR showed an increase on 4-week DTT for the OR, compared with that observed on 1-week DTT, however, FA and ADC did not change. The FA value represented the degree of directionality of microstructures and the ADC value indicated the magnitude of water diffusion [21,22]. Consequently, the increment of fiber number on 4-week DTT for the left OR appeared to indicate an increase in neural fibers of the left OR [23,24]. As for fMRI findings, no activation in the occipital lobe, except for activation in the junction between the left lingual gyrus and parahippocampal gyrus, was observed on 1-week fMRI; however, activation of the bilateral occipital lobe centered on the left primary visual cortex was observed on 4-week fMRI. These changes observed on DTT and fMRI appear to coincide with the clinical improvement of visual impairment in this patient. It is not certain whether this recovery could be attributed to the resolution of local factors, such as edema or brain plasticity [25,26]. However, we assume that because 4-week DTT showed an increase in fiber numbers of the left OR by the resolution of peri-infarct edema and rapid increment of left OR fibers during a period of 3 weeks, the recovery of the left OR could be attributed more to resolution of local factors, such as peri-infarct edema, than brain plasticity [25,26].

Many studies have reported on recovery of visual function in patients with occipital lobe lesions in various brain diseases [3-8]. By contrast, only a few studies have demonstrated the process of recovery of vision using fMRI or DTI [9-11]. In 2008, Govindan et al. [9] measured DTI parameter changes of the OR contralateral to occipital lobe ablation in 10 children with intractable epilepsy who had undergone a resection of the unilateral occipital cortex. According to their findings, the OR contralateral to the side of resection showed significant changes in FA value of the contralateral OR, which exhibited a significant positive partial correlation with duration of time between surgery and the time of DTI scanning. They concluded that these structural changes in white matter may represent an adaptive response after unilateral resection of the occipital lobe. In 2010, using fMRI and DTI, Chen et al. [10] evaluated changes of visual pathway lesions after hyperbaric oxygen treatment for 10 days in 16 patients with visual pathway lesions, including 4 patients with an occipital lobe infarct. Both numbers of activated voxels on fMRI and FA of the OR showed an increase after hyperbaric oxygen treatment. Recently, using fMRI and DTI, Polonara et al. [11] demonstrated recovery of visual impairment in a patient with left hemianopsia following a right calcarine cortex infarct in 2011. Activation of the right visual cortex was observed on acute-phase fMRI, however, activation of the right visual cortex was observed on 1-month fMRI. In addition, the decreased FA value of right OR on acute-phase DTT showed resolution on 1-month DTT. Although the above Chen's and Polonara's studies showed visual recovery by hyperbaric oxygen treatment and no intervention, respectively, our study demonstrated the visual recovery during rehabilitation.

In conclusion, using follow up fMRI and DTT, we demonstrated visual recovery in a patient with an occipital lobe infarct. We found that the simultaneous use of fMRI and DTT would be helpful in demonstrating the functional and anatomical changes of the visual system in patients with occipital lobe injury. Conduct of further complementary studies involving larger case numbers will be necessary.

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REFERENCES

1. Bogousslavsky J, Regli F, van Melle G. Unilateral occipital infarction: evaluation of the risks of developing bilateral loss of vision. J Neurol Neurosurg Psychiatry 1983;46:78-80.
2. Smith JL, Cross SA. Occipital lobe infarction after open heart surgery. J Clin Neuroophthalmol 1983;3:23-30.
3. Werth R. Cerebral blindness and plasticity of the visual system in children. a review of visual capacities in patients with occipital lesions, hemispherectomy or hydranencephaly. Restor Neurol Neurosci 2008;26:377-89.
4. Kolb B. Recovery from occipital stroke: a self-report and an inquiry into visual processes. Can J Psychol 1990;44:130-47.
5. Kong CK, Wong LY, Yuen MK. Visual field plasticity in a female with right occipital cortical dysplasia. Pediatr Neurol 2000;23:256-60.
6. Payne BR, Lomber SG. Plasticity of the visual cortex after injury: what's different about the young brain? Neuroscientist 2002;8:174-85.
7. Bova SM, Giovenzana A, Signorini S, La Piana R, Uggetti C, Bianchi PE, et al. Recovery of visual functions after early acquired occipital damage. Dev Med Child Neurol 2008;50:311-5.
8. Guzzetta A, D'Acunto G, Rose S, Tinelli F, Boyd R, Cioni G. Plasticity of the visual system after early brain damage. Dev Med Child Neurol 2010;52:891-900.
9. Govindan RM, Chugani HT, Makki MI, Behen ME, Dornbush J, Sood S. Diffusion tensor imaging of brain plasticity after occipital lobectomy. Pediatr Neurol 2008;38:27-33.
10. Chen Z, Ni P, Lin Y, Xiao H, Chen J, Qian G, et al. Visual pathway lesion and its development during hyperbaric oxygen treatment: a bold- fMRI and DTI study. J Magn Reson

Imaging 2010;31:1054-60.
11. Polonara G, Salvolini S, Fabri M, Mascioli G, Cavola GL, Neri P, et al. Unilateral visual loss due to ischaemic injury in the right calcarine region: a functional magnetic resonance imaging and diffusion tension imaging follow-up study. Int Ophthalmol 2011;31:129-34.
12. Macdonell RA, Jackson GD, Curatolo JM, Abbott DF, Berkovic SF, Carey LM, et al. Motor cortex localization using functional MRI and transcranial magnetic stimulation. Neurology 1999;53:1462-7.
13. Werring DJ, Clark CA, Parker GJ, Miller DH, Thompson AJ, Barker GJ. A direct demonstration of both structure and function in the visual system: combining diffusion tensor imaging with functional magnetic resonance imaging. Neuroimage 1999;9:352-61.
14. Staempfli P, Rienmueller A, Reischauer C, Valavanis A, Boesiger P, Kollias S. Reconstruction of the human visual system based on DTI fiber tracking. J Magn Reson Imaging 2007;26:886-93.
15. Hofer S, Karaus A, Frahm J. Reconstruction and dissection of the entire human visual pathway using diffusion tensor MRI. Front Neuroanat 2010;4:15.
16. Kwon HG, Jang SH. Optic radiation injury following traumatic epidural hematoma: diffusion tensor imaging study. NeuroRehabilitation 2011;28:383-7.
17. Yeo SS, Kim SH, Kim OL, Kim MS, Jang SH. Optic radiation injury in a patient with traumatic brain injury. Brain Inj 2012;26:891-5.
18. Smith SM, Jenkinson M, Woolrich MW, Beckmann CF, Behrens TE, Johansen-Berg H, et al. Advances in functional and structural MR image analysis and implementation as FSL. Neuroimage 2004;23(Suppl 1):S208-19.
19. Glass HC, Berman JI, Norcia AM, Rogers EE, Henry RG, Hou C, et al. Quantitative fiber tracking of the optic radiation is correlated with visual-evoked potential amplitude in preterm infants. AJNR Am J Neuroradiol 2010;31:1424-9.
20. Xie S, Gong GL, Xiao JX, Ye JT, Liu HH, Gan XL, Jet al. Underdevelopment of optic radiation in children with amblyopia: a tractography study. Am J Ophthalmol 2007;143:642-6.
21. Assaf Y, Pasternak O. Diffusion tensor imaging (DTI)-based white matter mapping in brain research: a review. J Mol Neurosci 2008;34:51-61.
22. Neil JJ. Diffusion imaging concepts for clinicians. J Magn Reson Imaging 2008;27:1-7.
23. Pagani E, Agosta F, Rocca MA, Caputo D, Filippi M. Voxel-based analysis derived from fractional anisotropy images of white matter volume changes with aging. Neuroimage 2008;41:657-67.
24. Hong JH, Bai DS, Jeong JY, Choi BY, Chang CH, Kim SH, et al. Injury of the spino-thalamo-cortical pathway is necessary for central post-stroke pain. Eur Neurol 2010;64:163-8.
25. Furlan M, Marchal G, Viader F, Derlon JM, Baron JC. Spontaneous neurological recovery after stroke and the fate of the ischemic penumbra. Ann Neurol 1996;40:216-26.
26. Witte OW. Lesion-induced plasticity as a potential mechanism for recovery and rehabilitative training. Curr Opin Neurol 1998;11:655-62.