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# **Disclosures:**

Supported by the Basic Science Research Program through the National Research Foundation of Korea funded by the Ministry of Education, Science and Technology (2012R1A1A4A01001873). Financial disclosure statements have been obtained, and no conflicts of interest have been reported by the authors or by any individuals in control of the content of this article.

0894-9115/14/9312-e15 American Journal of Physical Medicine & Rehabilitation Copyright © 2014 by Lippincott Williams & Wilkins

DOI: 10.1097/PHM.000000000000202

CASE REPORT

# Recovery of Injured Arcuate Fasciculus in the Dominant Hemisphere in a Patient with an Intracerebral Hemorrhage

# ABSTRACT

Jang SH, Lee HD: Recovery of injured arcuate fasciculus in the dominant hemisphere in a patient with an intracerebral hemorrhage. Am J Phys Med Rehabil 2014;93:e15-e18.

This study reports on a patient with an intracerebral hemorrhage who showed recovery of an injured arcuate fasciculus (AF) in the dominant hemisphere, using follow-up diffusion tensor tractography. A 43-year-old right-handed man presented with severe aphasia and hemiparesis resulting from a spontaneous intracerebral hemorrhage in the left parietotemporal lobes. The patient showed severe aphasia at 1 month after onset, with an aphasia quotient of 5% on the Korean-Western Aphasia Battery. He underwent comprehensive rehabilitative therapy until 22 months after onset and his aphasia showed improvement, with an aphasia quotient of 58% on the Korean-Western Aphasia Battery. On 1-month diffusion tensor tractography, only the thin ascending part of the left AF from the Wernicke area remained. In contrast, on 16-month diffusion tensor tractography, the injured left AF was thickened and elongated to around the left Broca area; however, discontinuation of the left AF was observed around the left Broca area, and this continuation was elongated to the left Broca area on 22-month diffusion tensor tractography. This study reports on a patient who showed recovery from injury of the left AF along with improvement of aphasia. Recovery of the injured AF in the dominant hemisphere appears to be one of the mechanisms for recovery from aphasia.

**Key Words:** Diffusion tensor imaging, Diffusion tensor tractography, Arcuate fasciculus, Aphasia

Stroke

he arcuate fasciculus (AF) is the neural tract connecting the Broca and Wernicke areas. The AF works as an important neural tract for language function, along with several neural tracts, including the superior longitudinal fasciculus, inferior longitudinal fasciculus, inferior fronto-occipital fasciculus, and uncinate fasciculus.<sup>1–5</sup> Injury of the AF has been reported as the cause of many language problems, such as apraxia of speech, paraphasia, and anomia, as well as conduction aphasia.<sup>6–8</sup>

The AF cannot be clearly differentiated from adjacent structures on conventional brain magnetic resonance imaging; consequently, accurate evaluation of the AF has been difficult. Diffusion tensor tractography (DTT), derived from diffusion tensor imaging (DTI), allows for three-dimensional reconstruction and estimation of the AF.<sup>2,9</sup> Therefore, DTI has been used to demonstrate injury of the AF in various brain pathologies, including stroke.<sup>8,10–15</sup> However, knowledge regarding recovery of an injured AF is limited.

The current study, using follow-up DTT, reports on a patient with an intracerebral hemorrhage who showed recovery of an injured AF in the dominant hemisphere.

## **CASE REPORT**

A 43-year-old right-handed man presented with severe aphasia and hemiparesis, which occurred at the

onset of a spontaneous intracerebral hemorrhage in the left parietotemporal lobes. He underwent decompressive craniectomy and removal of hematoma at the department of neurosurgery of a university hospital. Brain magnetic resonance imaging taken at 1 month after onset showed leukomalactic lesions in the left parietotemporal areas (Fig. 1A). The Korean-Western Aphasia Battery (K-WAB) was used for evaluation of language dysfunction.<sup>16</sup> The reliability and validity of the K-WAB have been well established.<sup>16</sup> The patient showed severe aphasia on the K-WAB (aphasia quotient, 9.0 [5%]; fluency, 1.5 [5%]; comprehension, 37.0 [12%]; repetition, 6.0 [13%]; and naming, 5.0 [16%]) at 1 month after onset. He was transferred to the department of rehabilitation and underwent comprehensive rehabilitative therapy for 1 month, 1including movement therapy, speech therapy, and medication (methylphenidate, 5 mg; pramipexole, 0.375 mg; amantadine, 250 mg; and levodopa, 375 mg). During his admission, his aphasia showed mild improvement, with an aphasia quotient of 27.0 (19%) (fluency, 8.0 [21%]; comprehension, 69.0 [21%]; repetition, 8.0 [15%]; and naming, 12.0 [22%]). After 1 month of rehabilitation at the university hospital, he was transferred to a local rehabilitation hospital and received similar rehabilitative management until 9 months after onset. After discharge from the local rehabilitation hospital, he received speech therapy (once a week) and was prescribed similar medications at the university

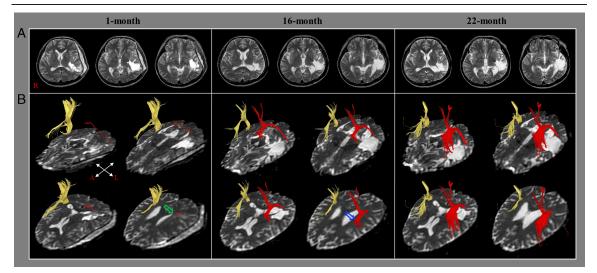


FIGURE 1 (A) Brain MR images at 1, 16, and 22 months after onset show leukomalatic lesions in the left parietotemporal areas. (B) DTT for the arcuate fasciculus (right AF, yellow; left AF, red). The right AF passes through the known pathway of the AF. On 1-month DTT, the left AF showed discontinuation (green arrow) after originating from the Wernicke area. In contrast, on 16-month DTT, the injured left AF was thickened and elongated to around the left Broca area; however, discontinuation (blue arrow) of the left AF was observed around the left Broca area without termination at the left frontal area. On 22-month DTT, the discontinuation of the left AF was elongated to the left Broca area and the left AF was thickened.

Am. J. Phys. Med. Rehabil. . Vol. 93, No. 12, December 2014

hospital until 22 months after onset. His aphasia showed improvement on 16-month K-WAB, with an aphasia quotient of 61.4 (42%) (fluency, 16.0 [71%]; comprehension, 128.0 [47%]; repetition, 30.0 [26%]; and naming, 53.0 [44%]), and the 22-month K-WAB, with an aphasia quotient of 68.4 (58%) (fluency, 17.0 [86%]; comprehension, 131.0 [53%]; repetition, 34.0 [29%]; and naming, 72.0 [71%]). The patient sometimes showed paraphasia.

The patient provided signed, informed consent, and our institutional review board approved the study protocol.

### **Diffusion Tensor Imaging**

DTIs were obtained three times (1, 16, and 22 months after onset). DTI was performed 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 and navigator echo. Sixty contiguous slices (acquisition matrix, 96 imes 96; reconstruction matrix, 192 imes192; field of view,  $240 \times 240$  mm<sup>2</sup>; repetition time (TR), 10,726 msec; echo time (TE), 76 msec; b =1000 s/mm<sup>2</sup>; number of excitations (NEX), 1; and 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 Work Space 2.6.3). Each of the DTI replications was intraregistered to the baseline "b0" images to correct for residual eddy-current image distortions and head motion effect, using a diffusion registration package (Philips Medical Systems).

For analysis of the AF, the seed region of interest was given manually in the deep white matter of the posterior parietal portion of the superior longitudinal fascicle and the target region of interest was placed on the posterior temporal lobe using the method of Nucifora et al.<sup>9</sup> Fiber tracts passing through both regions of interest were designated as the final tracts of interest. The termination criteria used for fiber tracking were fractional anisotropy less than 0.15 and angle less than 27 degrees.

On 1-month DTT, only the thin ascending part of the left AF from the Wernicke area remained, which might be ascribed to the perilesional edema or compression by hematoma or hygroma as well as injury of the left AF (DTI parameters of the left AF: fractional anisotropy, 0.35; mean diffusivity, 0.86; fiber number, 99). In contrast, on 16-month DTT, the injured left AF was thickened and elongated to around the left Broca area; however, discontinuation of the left AF was observed around the left Broca area without termination at the left frontal area (DTI parameters of the left AF: fractional anisotropy, 0.36; mean diffusivity, 0.94; fiber number, 684). On 22-month DTT, the discontinuation of the left AF was elongated to the left Broca area and the left AF was thickened (DTI parameters of the left AF: fractional anisotropy, 0.37; mean diffusivity, 0.98; fiber number, 977). At 4 months after onset, the patient underwent cranioplasty.

## DISCUSSION

The current study describes a patient with an intracerebral hemorrhage who showed recovery of the injured AF in the left hemisphere for 21 months. The patient showed improvement of severe aphasia from 5% (1 month) to 58% (22 months) as an aphasia quotient on the K-WAB. Therefore, it appears that the improvement of aphasia coincided with the recovery of the injured left AF. In the past, the AF has been regarded as a unique neural tract connecting the Broca and Wernicke areas.<sup>1</sup> More recently, involvement of various other neural tracts in language function has also been reported.<sup>1–5,15</sup> Neural tracts for language are classified according to two categories: the dorsal stream for phonation and the ventral stream for comprehension. The AF has been regarded as the major fiber tract of the dorsal stream.<sup>4</sup> Therefore, the improvements in fluency (21%->86%) and repetition (15%->29%) among aphasia quotient (AQ) appeared to be attributed to the recovery of injured left AF. However, the low repetition value (29%) of the patient on 22-month K-WAB might be ascribed to the sequelae of the left AF injury, although it showed significant recovery compared with that at 1-month DTT. Previous studies have suggested several mechanisms for recovery from aphasia, such as contribution of either the perilesional brain region in the affected hemisphere or homologous language regions in the unaffected hemisphere.<sup>17–19</sup> However, few DTI studies on the mechanisms for recovery from aphasia in stroke patients have been reported.<sup>12,13</sup> In 2009, Schlaug et al.<sup>12</sup> reported an increase in the fiber number and volume of the right AF after 75–80 intonation-based speech therapy sessions in six chronic stroke patients with Broca aphasia. Findings of their study suggested that intense and long-term therapy could lead to reorganization of the right AF. However, no study on recovery of an injured AF, like this study, has been reported.

In conclusion, this study reported on a patient who showed recovery of an injured left AF along with improvement of aphasia. To the best of our knowledge, this is the first study to demonstrate the recovery of an injured AF in the dominant hemisphere in patients with brain injury. This study has important implications in brain rehabilitation because recovery of the injured AF in the dominant hemisphere appears to be one of the mechanisms for recovery from aphasia in stroke patients. However, this study is limited because it is a case report. Conduct of further complementary studies involving larger numbers of cases is warranted. Lack of neuropsychologic data for cognition is another limitation of this study. In addition, the limitation of DTI should be considered. Although DTI is a powerful anatomic imaging tool, which can demonstrate gross fiber architecture, DTI may underestimate the fiber tracts because regions of fiber complexity and crossing can prevent full reflection of the underlying fiber architecture by DTI.<sup>20</sup>

#### REFERENCES

- 1. Geschwind N: The organization of language and the brain. *Science* 1970;170:940–4
- Catani M, Jones DK, Ffytche DH: Perisylvian language networks of the human brain. Ann Neurol 2005;57:8–16
- Saur D, Kreher BW, Schnell S, et al: Ventral and dorsal pathways for language. *Proc Natl Acad Sci U S A* 2008;105:18035–40
- Axer H, Klingner CM, Prescher A: Fiber anatomy of dorsal and ventral language streams. *Brain Lang* 2013;127:192–204
- Jang SH: Diffusion tensor imaging studies on arcuate fasciculus in stroke patients: A review. Front Hum Neurosci 2013;7:749
- Anderson JM, Gilmore R, Roper S, et al: Conduction aphasia and the arcuate fasciculus: A reexamination of the Wernicke-Geschwind model. *Brain Lang* 1999; 70:1–12
- 7. Bernal B, Ardila A: The role of the arcuate fasciculus in conduction aphasia. *Brain* 2009;132:2309–16
- Marchina S, Zhu LL, Norton A, et al: Impairment of speech production predicted by lesion load of the left arcuate fasciculus. *Stroke* 2011;42:2251–6

- Nucifora PG, Verma R, Melhem ER, et al: Leftward asymmetry in relative fiber density of the arcuate fasciculus. *Neuroreport* 2005;16:791–4
- Yamada K, Nagakane Y, Mizuno T, et al: MR tractography depicting damage to the arcuate fasciculus in a patient with conduction aphasia. *Neurology* 2007;68:789
- 11. Hosomi A, Nagakane Y, Yamada K, et al: Assessment of arcuate fasciculus with diffusion-tensor tractography may predict the prognosis of aphasia in patients with left middle cerebral artery infarcts. *Neuroradiology* 2009;51:549–55
- 12. Schlaug G, Marchina S, Norton A: Evidence for plasticity in white-matter tracts of patients with chronic Broca's aphasia undergoing intense intonation-based speech therapy. *Ann N Y Acad Sci* 2009;1169:385–94
- 13. Kwon HG, Jang SH: Excellent recovery of aphasia in a patient with complete injury of the arcuate fasciculus in the dominant hemisphere. *NeuroRehabilitation* 2011;29:401–4
- Kim SH, Jang SH: Prediction of aphasia outcome using diffusion tensor tractography for arcuate fasciculus in stroke. *AJNR Am J Neuroradiol* 2013;34: 785–90
- 15. Kummerer D, Hartwigsen G, Kellmeyer P, et al: Damage to ventral and dorsal language pathways in acute aphasia. *Brain* 2013;136:619–29
- Kim H, Na DL: Normative data on the Korean version of the Western Aphasia Battery. J Clin Exp Neuropsychol 2004;26:1011–20
- 17. Thulborn KR, Carpenter PA, Just MA: Plasticity of language-related brain function during recovery from stroke. *Stroke* 1999;30:749–54
- Saur D, Lange R, Baumgaertner A, et al: Dynamics of language reorganization after stroke. *Brain* 2006; 129:1371–84
- Raboyeau G, De Boissezon X, Marie N, et al: Right hemisphere activation in recovery from aphasia: Lesion effect or function recruitment? *Neurology* 2008; 70:290–8
- Yamada K, Sakai K, Akazawa K, et al: MR tractography: a review of its clinical applications. *Magn Reson Med Sci* 2009;8:165–74