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Original Article

Relationship between white matter fiber damage and revised version of the ability for basic movement scale in patients with stroke: a diffusion tensor tract-based spatial statistic study

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Abstract. [Purpose] To clarify the relationship between white matter fiber damage and the Ability for Basic Movement Scale (ABMS) II in patients with stroke in a diffusion tensor tract-based spatial statistic study. [Subjects and Methods] Twelve patients with stroke (seven men and five women, mean age ± SD: 61.6 ± 8.5 years) were evaluated using the ABMS II. The patients were divided into the ABMS II good group and the ABMS II poor group. Tract-based spatial statistical analysis was performed using diffusion tensor images in both groups. [Results] Patients in the ABMS II good group had significantly higher fractional anisotropy values of the anterior thalamic radiation (ATR), superior longitudinal fasciculus (SLF), inferior occipitofrontal fasciculus (IOF), and uncinate fasciculus (UF) of the lesion-containing hemisphere than patients in the ABMS II poor group. [Conclusion] ATR, SLF, and IOF damage may affect ABMS II scores in patients with stroke.

Key words: White matter fiber, ABMS II, Stroke

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INTRODUCTION

Patients with acute stroke should start rehabilitation immediately after stroke onset for restoration of motor function. In addition, for better recovery of their motor function, rehabilitation should be smoothly transferred from the acute phase to the recovery phase. However, there is a tendency that the timing of transfer to a convalescent rehabilitation ward of another hospital is delayed. A study reported that the number of days of transfer from onset to a convalescent rehabilitation ward was approximately 43 days in the same hospital, but that of transfer to a convalescent rehabilitation ward of another hospital was approximately 63 days[1)]. Therefore, it is important to predict the future motor function of the patient immediately after stroke onset, gauge whether it is necessary to transfer the patient to another hospital, and plan the timing of the transfer if necessary. Tanaka et al.[2)] reported that the revised version of the ability for basic movement scale (ABMS II) is an appropriate tool to evaluate the functional ability of patients with acute stroke to perform basic movements. ABMS II evaluates performance of five basic abilities in six grades. ABMS II of patients with acute stroke was reported to correlate with activities of daily living function after 4 weeks. However, the relationship between ABMS II and the position and size of brain damage was not reported. The most famous fiber tract related to motor function is the corticospinal tract. However, many brain regions are involved in motor function; hence, damage to nerve fibers different from corticospinal fibers may also affect ABMS II. TBSS is a newly developed method that allows voxelwise statistical comparison of individual subject's diffusion tensor imaging

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(DTI) data for whole-brain analysis[3]).

In this study, we aimed to quantitatively evaluate damage to white matter fibers using tract-based spatial statistics (TBSS) and to investigate the relationship between white matter fiber damage and ABMS II scores of patients with stroke.

SUBJECTS AND METHODS

Subjects were 12 patients with stroke (7 men and 5 women, mean age ± SD: 61.6 ± 8.5 years) who accepted emergency transportation at the Kawano Neurosurgical Hospital. Of the 12 patients, 4 had cerebral infarction and 8 had cerebral hemorrhage. Sites of the lesions were as follows: corona radiata (2), putamen (7), insular (1), cingulum (1), and brainstem (1). All subjects had lesions in the left hemisphere of the brain, and all were right-handed. All subjects were evaluated using ABMS II when they were allowed to sit on a wheelchair for the first time after stroke onset. We classified subjects into two groups, namely, ABMS II good and ABMS II poor, on the basis of ABMS score of 21.5[4]) which is the borderline between discharge to home and convalescent rehabilitation ward. DTI images were acquired on a 3.0 Tesla magnetic resonance imaging (MRI) system (SIEMENS MAGNETOM Verio) using single-shot spin echo-planar imaging, with the following parameters: data matrix of 128th the fola 23 cm field of view, slice thickness of 3 mm, repetition time of 9,200 ms, echo time of 96 ms, and b-value of 1,000 s/mm^2 in 12 different directions. The total imaging time was less than 5 min. We converted the acquired DTI images to NIfTI GZ format using dcm2nii in MRIcron software[5]). Then, we preprocessed all raw DTI data with functional MRI of the brain software library (FMRIB Software Library, FSL)[6]) for TBSS analysis. All analysis protocols and detailed descriptions of the TBSS approach, which is part of the FSL, are freely available[6]). First, eddy current distortions and head motions were corrected by spatially normalizing all the diffusion-weighted images. Subsequently, non-brain tissue was removed using the brain extraction tool. Thereafter, fractional anisotropy (FA) data were aligned into the Montreal Neurological Institute common space using nonlinear registration. Finally, diffusion tensor elements were estimated, and the corresponding FA data of each voxel were calculated. After preprocessing, all subjects' FA data were later projected onto the FA skeleton to obtain their FA skeletons and deformation matrixes. Then, FA data of the ABMS II good and poor groups were compared statistically using the TBSS in the FSL software. The number of permutation tests was set at 5,000, and the level of significance was set at 5%. Statistical analysis results were displayed using FSL view, and white matter with significant difference was identified using JHU white-matter tractography atlas. This study was conducted based on the Kawano Neurosurgical hospital's ethical code and Declaration of Helsinki. Informed consent was obtained from all subjects.

RESULTS

Five subjects (3 men and 2 women, mean age ± SD: 61.8 ± 2.9 years) in the ABMS II good group had ABMS II score of 29.2 ± 1.6. Moreover, seven subjects (4 men and 3 women, mean age ± SD: 61.4 ± 10.8 years) in the poor group had ABMS II score of 12.6 ± 2.4. The number of days from onset to DTI acquisition in the good group was 2.8 ± 1.0 days and that in the poor group was 4.7 ± 4.7 days (Table1). The FA values of the anterior thalamic radiation (ATR), superior longitudinal fasciculus (SLF), inferior occipitofrontal fasciculus (IOF), uncinate fasciculus (UF) of the lesion hemisphere in the ABMS II good group were significantly higher than those of the ABMS II poor group ($p<0.05$). The FA value of the corticospinal tract was not significantly different between both groups (Fig. 1).

DISCUSSION

In DTI, the presence or absence of impaired neuronal integrity can be observed by noninvasively measuring and imaging water molecules in the body. The FA measured by DTI represents white matter integrity and is thought to reflect fiber density, axonal diameter, and myelination in white matter. Moreover, FA was reported to decrease when white matter is damaged by stroke[7]). Generally, a series of functions of monitoring, building up, and updating the postural model of our limb, i.e., body schema, are necessary for smooth and efficient movement[8]). Therefore, we believe that damage to different nerve fibers other than the cortical spinal cord fibers could also affect ABMS II score. The ATR carries nerve fibers between the dorso-medial thalamic nuclei and the prefrontal cortex[9]) and therefore participates in the neural processing of cognition[10]). In addition, the activity of the thalamo-cortical pathway modulates the information flow necessary for conscious cognitive processes[11]). The SLF carries nerve fibers between the parietal cortex and the prefrontal cortex[9]) and thereby plays a relevant role in visuospatial attention[12]), motor attention[13]), motor planning[14]), and action coding[15]). The IOF carries nerve fibers between the ventral occipital cortex[9]) and lateral orbito-frontal cortex, thereby playing a role in multimodal sensory-motor integration[16]). Therefore, damage to the ATR, SLF, and IOF may have an effect on the ABMS II score. Furthermore, the UF carries nerve fibers between the anterior temporal lobe with the orbital and polar frontal lobe, including the orbitofrontal area and inferior frontal gyrus. Recent studies have assumed that the UF functions in episodic memory, language, and social emotional treatment[17]), but it is still incompletely understood. Therefore, it is difficult to consider the relationship between UF and ABMS II score in this study. Finally, this is a pilot study; hence, we must increase the number of subjects and need more detailed analysis.

Table 1. Patient characteristics and ABMS II

	Subject	Gender	Age (years)	Lesion	ABMS II	MRI post stroke (days)	ABMS II evaluate post stroke (days)
	1	F	61	insular	30	2	2
	2	M	58	brainstem	30	2	2
Good group	3	M	64	putamen	30	2	3
	4	M	66	corona radiata	30	4	2
	5	F	60	putamen	26	4	2
Mean ± SD		M=3, F=2	61.8 ± 2.9		29.2 ± 1.6	2.8 ± 1.0	2.2 ± 0.4
	6	M	48	putamen	16	1	3
	7	M	72	putamen	15	8	4
	8	F	73	corona radiata	15	2	12
Poor group	9	F	45	cingulum	11	3	7
	10	F	58	putamen	11	2	5
	11	M	72	putamen	10	2	10
	12	M	62	putamen	10	15	4
Mean ± SD		M=4, F=3	61.4 ± 10.8		12.6 ± 2.4	4.7 ± 4.7	6.4 ± 3.2

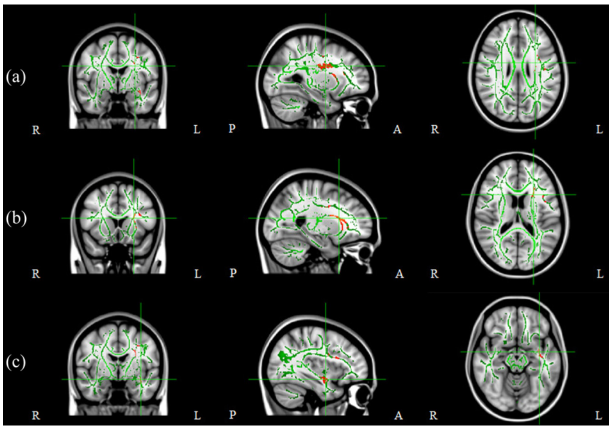

Fig. 1. Results of the tract-based spatial statistics (TBSS) analysis.
(a) superior longitudinal fasciculus, (b) anterior thalamic radiation, inferior fronto-occipital fasciculus, (c) uncinate fasciculus.

Conflict of interest

None.

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