



Original Article

Relationship of white matter lesions and severity of pushing behavior after stroke

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Abstract. [Purpose] The relationship between white matter lesions (WMLs) and pushing behavior (PB) is still poorly understood. The purpose of this study was to investigate whether damage from WMLs affects the functional outcome of PB after acute stroke. [Subjects and Methods] In total, 37 patients were included. PB was assessed using the standardized Scale for Contraversive Pushing (SCP). Stroke types were classified as total anterior circulation infarct (TACI), partial anterior circulation infarct (PACI), or lacunar syndrome using the Bamford classification. WML severity was categorized into four groups using the Fazekas visual scale. Thereafter, patients were divided into 4 groups according to the stroke type and/or presence of WMLs. The SCP, Trunk Control Test (TCT), Stroke Impairment Assessment Set (SIAS), and Barthel Index were the outcome measures. [Results] The SCP and TCT in patients with PACI without WMLs were better than those in patients with TACI with or without WMLs. Regarding SCP, TCT, and SIAS, patients with TACI had poorer values compared with PACI, regardless of WML severity. Barthel Index efficiency was not significantly different between the groups. [Conclusion] Our results suggest that moderate to severe WMLs and PACI had a relationship with PB severity and truncal balance.

Key words: Pushing behaviour, White matter, Stroke

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INTRODUCTION

Posture and balance disorders occur in patients with stroke and are due to different mechanisms. The deficits may be caused by sensory loss, paresis, joint motion limitation, or modification of muscle tone. Misperception in the frame of reference may constitute another component of imbalance. Humans use internal reference models to update their sense of verticality¹⁾. Pérennou and colleagues²⁾ noted that stroke patients with pushing behavior (PB) possess an altered sense of verticality that is biased to the contralesional side; in other words, these patients have an erroneous internal reference for the vertical axis. It has been reported that this syndrome can affect the duration and outcome of rehabilitation^{3, 4)}.

A few lesion studies in patients with PB have been reported. Karnath et al. investigated a sample of 46 patients with and without contraversive pushing who had unselected cortical and/or subcortical lesions. The analysis revealed that the posterolateral thalamus was typically damaged in left hemisphere-damaged as well as in right hemisphere-damaged patients with PB. On the other hand, in addition to the subcortical area previously identified in the posterior thalamus, PB is associated with the insula and postcentral gyrus⁵⁾. PB patients with extra-thalamic lesions showed regions of abnormal perfusion

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in the structurally intact inferior frontal gyrus, middle temporal gyrus, inferior parietal lobule, and parietal white matter⁶. The aforementioned studies suggest that owing to the close anatomical connection between the posterior thalamus and both the insular cortex and parietal white matter and other structures, such lesions lead to disruption or functional alteration of thalamocortical and/or corticothalamic processing loops related to the control of upright body posture.

Despite these advances in lesion research, however, little is known about disorders that may result from white matter injury in patients with PB and whether these are related to outcome. Regarding age-related white matter changes (ARWMC) in elderly individuals, a significant association between falls and balance disturbances and primary frontal deep and periventricular ARWMC has been demonstrated⁷. To the best of our knowledge, there are no studies focusing on white matter lesions (WMLs) in patients with PB. The purpose of the present study was to investigate whether damage from WMLs affects the functional outcome in acute stroke patients with PB.

SUBJECTS AND METHODS

In the present retrospective study, we evaluated data from participants admitted for acute stroke at Saitama Medical University International Medical Center from July 2014 to July 2016. All patients in the database have a primary diagnosis of ischemic stroke, and their data may be used for research. A total of 773 patients who attended the inpatient rehabilitation program were recruited. Physicians confirmed the diagnosis of ischemic stroke by magnetic resonance imaging (MRI).

Patients underwent the conventional stroke rehabilitation program. This program is patient-specific and consists of standard physiotherapy, occupational therapy, neuropsychological therapy, speech therapy, and nursing care. Participants had to meet the following criteria: (1) age more than 20 years, (2) no history of stroke prior to the current one, (3) presence of only a supratentorial lesion of the brain; (4) stable neurological symptoms and general condition; (5) presence of PB (described later); (6) no psychiatric disorders; (7) ability to understand instructions; (8) no orthopedic problem that would interfere with activities of daily living (ADL) or functional outcome; and (9) no missing data.

This study was conducted in accordance with the Declaration of Helsinki and approved by the ethics committee of Saitama Medical University International Medical Center (15–284).

Ischemic stroke was diagnosed based on neurological signs and diffusion-weighted imaging, and the stroke types were classified as total anterior circulation infarct (TACI), partial anterior circulation infarct (PACI), or lacunar syndrome (LACS) using the Bamford classification⁸. WMLs were evaluated by fluid-attenuated inversion recovery imaging. The degree of WML severity was categorized into four groups (none, mild, moderate, and severe) using the Fazekas visual scale (Fig. 1)⁹. PVH was graded from 0 to 3 as follows: grade 0, none or rim only; grade 1, localized lesion depicted in pencil-thin lining or caps; grade 2, irregular hyperintensity, a smooth halo; and grade 3, lesion spreading into the deep white matter and periventricular region. DWMH also was graded from 0 to 3 as follows: grade 0, none; grade 1, punctate hyperintensity; grade 2, punctate hyperintensity with fusion tendency; and grade 3, large fused punctate hyperintensity. The presence of WMLs was defined as \geq grade 2 on the Fazekas visual scale. In order to exclude effects such as brain damage or cerebral edema, WMLs were determined by findings on the unaffected side. Patients were divided into groups according to the stroke type and/or presence of WMLs.

The scale for contraversive pushing (SCP)³ was used to assess the severity of PB, and the Trunk Control Test (TCT) was used to assess truncal balance¹⁰. SCP has 3 subscales, and the total SCP score is determined by summing the scores of the 3 subscales (maximum score=6 points). Patients were considered to have PB if they scored >0 points on any of the subscales¹¹. The TCT examines four axial movements: rolling from a supine position to the paretic and non-paretic side, sitting up from a lying position, and sitting in a balanced position on the edge of the bed with the feet off the ground for 30 seconds. The scoring is as follows: 0, unable to perform movement without assistance; 12, able to perform movement but in an abnormal manner; and 25, able to complete movement normally (total score range, 0 to 100). Patients were evaluated using the Stroke Impairment Assessment Set (SIAS)¹², which is a standardized measure of stroke impairment consisting of the subcategories of motor function, muscle tone, sensory function, range of motion (ROM), pain, trunk function, visuospatial function, speech, and unaffected side function. The SIAS comprises 22 items in total, and each item is rated from 0 (severely impaired) to 3 (normal) for muscle tone, sensory function, ROM, pain, trunk, higher cortical function, and unaffected side function or from 0 (severely impaired) to 5 (normal) for motor function (total score range, 0 to 76). These assessments were performed in the early stroke phase to the maximum extent possible. The Barthel Index (BI) was used to evaluate the ADL¹³. The rate of BI change with time (“efficiency”), admission, and discharge BI scores were calculated.

Variables collected to describe the sample were age, sex, time since stroke onset, length of hospital stay, and paretic side. To determine differences between the groups for the aforementioned variables, independent one-way analysis of variance (ANOVA) or χ^2 tests were used. To analyze the results, one-way ANOVA was used. Data analysis was performed using PASW for Windows version 18.0 (SPSS Inc., Tokyo, Japan). The level of significance for all analyses was set at $p < 0.05$. To determine the power of the one-way ANOVA, a post hoc power calculation was performed using G*Power3 (Heinrich Heine University, Düsseldorf, Germany)¹⁴.

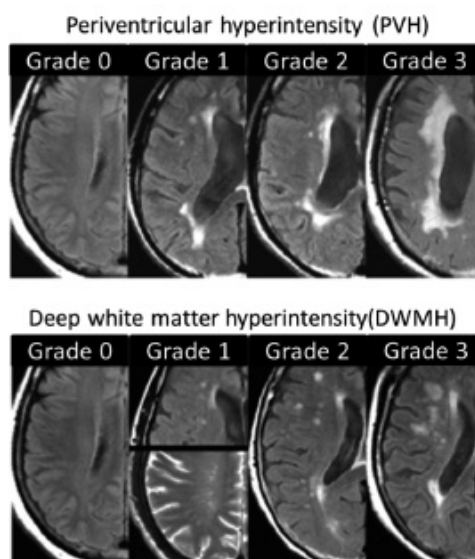


Fig. 1. Fazekas criteria for periventricular hyperintensity (PVH) and deep white matter hyperintensity (DWMH).

Table 1. Characteristics of the four groups

	TACI + group (n=5)	TACI – group (n=11)	PACI + group (n=8)	PACI – group (n=13)
Age (years)	77.0 ± 6.7	66.5 ± 14.9	77.5 ± 6.9	68.3 ± 9.6
Gender (male/female)	4 (80%) /1 (20%)	11 (100%) /0 (0%)	6 (75%) /2 (25%)	9 (69%) /4 (31%)
Time after onset (d)	12.4 ± 3.8	13.9 ± 5.3	13.4 ± 4.8	12.5 ± 6.3
Length of hospital stay (d)	38.0 ± 17.0	41.4 ± 20.4	39.3 ± 10.4	35.9 ± 8.3
Paretic side (right/left)	1 (20%) /4 (80%)	2 (18%) /9 (82%)	2 (25%) /6 (75%)	0 (0%) /13 (100%)

Values are expressed as means ± SD or n (%). TACI: Total Anterior Circulation Infarct; PACI: Partial Anterior Circulation Infarct.

Table 2. Comparison of outcome measures

	TACI + group (n=5)	TACI – group (n=11)	PACI + group (n=8)	PACI – group (n=13)	ANOVA		Power (1-β)
					main effect	multiple comparisons	
SCP	5.0 ± 1.2	4.9 ± 0.7	3.9 ± 0.9	3.3 ± 1.0	*	T+, T->P-	0.85
TCT	9.6 ± 13.2	16.4 ± 13.4	19.5 ± 19.2	36.0 ± 13.0	*	T+, T-<P-	0.71
SIAS	20.6 ± 4.0	21.5 ± 7.5	35.5 ± 12.7	40.9 ± 9.6	*	T+, T-<P+, P-	0.94
BI efficiency	0.4 ± 0.3	0.4 ± 0.4	0.6 ± 0.5	0.9 ± 0.6			0.40

Values are expressed as means (SD). TACI: Total Anterior Circulation Infarct; PACI: Partial Anterior Circulation Infarct; SCP: Scale for Contraversive Pushing; TCT: Trunk Control Test; SIAS: Stroke Impairment Assessment Set; BI: Barthel Index; ANOVA: analysis of variance; *p<0.01.

RESULTS

In total, 37 patients with PB were included in the study (mean age, 70.9 ± 11.4 years; 28 males and 9 females). Based on the Bamford classification, 16 patients were classified as having TACI and 21 were classified as having PACI. There were no patients with LACS.

According to the Fazekas scale, patients were divided into a WMLs +group (n=13) or –group (n=24). Thereafter, patients were divided into 4 groups according to the stroke type and/or presence of WMLs. The characteristics of the 4 groups are shown in Table 1. No significant differences were observed between the 4 groups.

The results of clinical assessments are shown in Table 2. For the SCP and TCT, the main effect was significant (p<0.01). In the test of multiple comparisons, both scores were more severe in the TACI+ group and TACI– group than in the PACI–

group. For the SIAS, the main effect was significant ($p < 0.01$). Moreover, the test of multiple comparisons for the SIAS showed a significant difference when comparing the TACI+ and TACI–group to the PACI+ and PACI–group. For BI efficiency, the main effect was not significant.

Power ($1 - \beta$) was calculated from the number of samples in the study, effect size, and significance level. The power of the one-way ANOVA was 0.40 to 0.94 (Table 2).

DISCUSSION

The present study has two important clinical findings. First, moderate to severe WMLs and PACI had a relationship with PB severity and truncal balance. Second, SCP, TCT, and SIAS were more severe in patients with TACI than in those with PACI regardless of the WML severity.

Blahak et al. reported that falls and balance disturbances are associated primarily with frontal deep and periventricular ARWMC⁷). These lesions involve the cortico-subcortical circuit for motor control¹⁵) and result in disturbances of the widespread subcortical motor network, which is most likely the cause of balance disturbances and falls in ARWMC¹⁶). Lesions in the frontal deep white matter and lateral to the frontal horns of the ventricles may affect the fronto-occipital fasciculus and the more laterally located superior longitudinal fasciculus, which are involved in sensorimotor integration and postural control¹⁷). The present results suggest that WMLs contribute to the perception of disturbed postural control in PB with PACI. On the other hand, TACI was not related to the presence of WMLs. Sturm et al. reported that among circulation infarct (CI) subtypes, patients with TACI were the most disabled, and patients with PACI had intermediate disability at 3 and 12 months after stroke¹⁸). This result indicates that WMLs may cause PB in patients with PACI to become severe.

There was no significant difference in BI between the subtypes of CI and presence of WMLs. In the present study, the impairment severity of our patients was moderate to severe based on the SIAS score. Moreover, it is known that patients with PB experience a considerably slow recovery process. Pedersen et al. reported that stationary ADL function is obtained in 80% of patients without PB within 6 weeks and in 80% of patients with PB within 13 weeks. Therefore, this result may depend on the impairment severity and PB presence. It would be useful for future studies to extend the assessment period to clarify the influence of WMLs on patients with PB.

This study has some limitations. First, only the short-term changes in functional outcome were evaluated. Second, the study had a relatively small sample size. Thus, there is a possibility of a Type 2 error because of the low power, especially in BI. Further studies should include the examination of the long-term changes in functional outcome and ADL with a larger number of patients using multiple regression analysis.

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