



Original Article

Relationship Between Motor Paralysis and Impairments in Tactile Sensitivity in Elderly Stroke Patients

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ARTICLE INFO

Article history:

Received 4 October 2017

Received in revised form

9 January 2018

Accepted 25 February 2018

Available online 21 March 2018

Keywords:

handgrip strength,

stroke,

tactile-pressure threshold

SUMMARY

Background: Human hand functions are affected by neurological disturbances. We hypothesized that the degree of somatosensory impairments after stroke may be related to the severity of motor paralysis. In order to examine this hypothesis, we investigated the relationship between the classification of the Brunnstrom stage and tactile sensation impairments in elderly stroke patients.

Methods: Participants were 61 elderly inpatients with hemiparesis after stroke. We measured the tactile-pressure threshold and handgrip strength in both hands and assessed motor impairments of the hand using the six Brunnstrom stages. Differences due to hemiparesis after stroke were examined using paired *t*-tests. Spearman's rank correlation was performed to elucidate the relationship between Brunnstrom stage scores and the tactile-pressure threshold or handgrip strength.

Results: Significant differences were observed in the tactile-pressure threshold and handgrip strength between the impaired and unimpaired sides ($p < 0.01$). Furthermore, the Brunnstrom stage showed a negative relationship with the tactile-pressure threshold on the impaired side ($r_s = -0.43$, $p < 0.01$) and a positive relationship with handgrip strength ($r_s = 0.82$, $p < 0.01$).

Conclusion: These results suggest that the degree of sensory impairments after stroke is related to the severity of motor paralysis classified by the Brunnstrom stage.

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1. Introduction

Human hands are excellent at performing motor and sensory functions. They precisely handle and strongly grasp an object and discriminate texture, shape, and temperature on the finger surface. These maneuvers are necessary for controlling force production and interpreting sensory information (regarding touch, position, pain, and temperature).

Aging affects hand function, such as the skillful use of the fingers to grasp and manipulate objects.¹ These age-related changes in function are influenced by a marked decline in muscular strength and sensation in the elderly. Hand function is also affected by neurological disturbances (e.g., disorders of the central nervous

system and peripheral nerves). Stroke mostly occurs in the elderly and causes severe disabilities, including motor impairments such as muscle weakness and a reduced range of motion.^{2–4} Previous studies reported that approximately 75% of stroke patients exhibited upper limb motor impairments.^{5,6} Brunnstrom (1970) developed qualitative descriptions of the changes in motor synergies that occur after the onset of stroke. Recovering patients may initially move in stereotyped, synergistic patterns only. As recovery progresses, they may potentially move in any direction. The Brunnstrom stages are used to assess motor recovery in stroke.^{7,8} Safaz et al. reported that the Brunnstrom recovery stage is related to the motricity index, such as grip strength and elbow flexion.⁹

On the other hand, approximately 50% of stroke patients have hand sensory impairments, particularly in tactile and proprioceptive discrimination.¹⁰ Rehabilitation outcomes and daily living activities are negatively affected by sensory and motor impairments.^{10,11} The degree of sensory impairments may also be associated with the severity of motor impairments. Therefore, the present study investigated whether impairments in tactile

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sensitivity are relevant to the classification of the Brunnstrom stage in elderly stroke patients.

2. Materials and methods

2.1. Participants

Participants were 61 subjects with hemiparesis after stroke. The characteristics of the study population are shown in Table 1. Subjects were hospitalized and receiving therapeutic interventions at the Rehabilitation unit. They were medically stable, had an adequate comprehension of instructions and perceptual ability for testing, and had no peripheral neuropathy or history of other neurological conditions. All subjects were found to be free of unilateral neglect based on clinical observations and standard neuropsychological assessments (shape cancellation and line bisection). Prior to the initiation of this study, we conducted the Mini-Mental State Examination, which all subjects passed (borderline passing score of 24). Subjects were informed of the experimental procedures in advance, and written consent was obtained. The present study was performed in accordance with the Declaration of Helsinki and approved by the Institutional Ethical Committees of Nagasaki University, Nagasaki Medical Center, and Nagasaki Kita Hospital.

2.2. Measurements

We assessed motor impairments of the hand using the Brunnstrom stages, judged by clinical observations.^{7,8} The Brunnstrom stages describe a commonly observed sequence of motor recovery after stroke based on the degree of spasticity and appearance of voluntary movement (Table 2). Higher stages indicate better recovery.

The tactile-pressure threshold on the distal palmar pad of the index finger was evaluated using Semmes-Weinstein monofilaments (North Coast Medical, Morgan Hill, CA, USA). We employed 20 filament types ranging in weight between 0.004 and 447 g. The esthesiometer pressure (g) of each filament was converted to $\log_{10}0.1$ mg, yielding a scale composed of intervals of approximately equal intensity between filaments. Subjects were tested with their eyes closed after receiving clear instructions. The target area was marked on the volar side of the distal phalanx of the index finger. Each filament was pushed into the target area until it bent by approximately 90° for approximately 1 s. The threshold was recorded as the smallest filament diameter perceived in at least 80% of its applications (five trials).

Handgrip strength was measured using a handgrip dynamometer (TKK5401; Takei Kiki Kogyo, Japan). These tests were repeated twice, and the maximum value was obtained.

2.3. Statistical analysis

Differences due to hemiparesis after stroke were examined using paired *t*-tests. Spearman's rank correlation was performed to elucidate the relationship between Brunnstrom stage scores and the tactile-pressure threshold or handgrip strength. The level of significance was defined as $p < 0.05$.

3. Results

3.1. Differences between impaired and unimpaired sides after stroke

Fifty-two subjects were right-handed and 9 were left-handed. No significant differences were observed in the tactile-pressure threshold or handgrip strength between the dominant hand (tactile-pressure threshold; $3.4 \pm 0.1 \log_{10}0.1$ mg, handgrip strength; 19.3 ± 1.5 kg) and non-dominant hand (tactile-pressure threshold; $3.6 \pm 0.1 \log_{10}0.1$ mg, handgrip strength; 16.1 ± 1.7 kg).

The handgrip strengths of the impaired and unimpaired sides were 11.0 ± 1.5 kg and 24.4 ± 1.2 kg, respectively (Table 3). A paired *t*-test revealed a significant difference in handgrip strength between the impaired and unimpaired sides ($p < 0.01$). The tactile-pressure threshold of the impaired side ($3.9 \pm 0.1 \log_{10}0.1$ mg) was significantly higher than that of the unimpaired side ($3.1 \pm 0.1 \log_{10}0.1$ mg) ($p < 0.01$) (Table 3).

3.2. Relationship between the Brunnstrom stage and tactile-pressure threshold or handgrip strength after stroke

The Brunnstrom stage showed a negative relationship with the tactile-pressure threshold ($r_s = -0.43$, $p < 0.01$), and a positive relationship with handgrip strength ($r_s = 0.82$, $p < 0.01$) (Fig. 1).

4. Discussion

The aim of the present study was to elucidate the relationship between the classification of the Brunnstrom stage and impairments in tactile sensitivity in elderly stroke patients. The main result obtained was a negative correlation between the Brunnstrom stage and tactile-pressure threshold on the impaired side ($r_s = -0.43$), suggesting that the severities of sensory and motor impairments after stroke are related.

Subjects with hemiplegia after stroke have impaired motor activity and muscle tone, muscle weakness, and abnormal sensations.^{12,13} A significant decrease in muscular strength and tactile sensitivity were observed on the impaired side in the present study. A previous study¹ reported that the mean values of handgrip strength and the tactile-pressure threshold in age-matched (70–74 yr) healthy females were 20.6 ± 3.2 kg and 3.0 ± 0.4

Table 1
Demographic characteristics of subjects (N = 61).

Characteristics	Subjects
Age (years)	70.2 ± 7.9
Gender (Male/Female): (number)	33/28
Time post-stroke (month)	1.4 ± 2.2
Hemiparetic side (Right/Left): (number)	32/29
Type of stroke (number)	
Hemorrhage/Infarction	27/34
Site of lesion (number)	BG (17), IC (10), BS (8), MCI (6), SAH (5), TL (5), MCA (4), ICA (3), unknown (3)
Brunnstrom stage (number)	I (4), II (12), III (8), IV (7), V (12), VI (18)

BG, basal ganglia; IC, Internal capsule; BS, Brainstem; MCI, Multiple cerebral infarctions; SAH, Subarachnoid hemorrhage; TL, Thalamus; MCA, Middle cerebral artery; ICA, Internal carotid artery. Mean ± standard deviation.

Table 2
Brunnstrom stages and clinical observations.

Stage I	Immediately after the acute episode, flaccidity is present and voluntary movements of the limbs may be initiated.
Stage II	Basic limb synergies, or some of their components, may appear as associated reactions or minimal voluntary movement responses. At this stage, spasticity begins to develop.
Stage III	The patient gains the voluntary control of movement synergies; however, the full range of all synergistic components does not necessarily develop. Spasticity increases and may become severe.
Stage IV	Some movement combinations that do not follow the paths of either synergy are mastered, first with difficulty, then with more ease, and spasticity begins to decline.
Stage V	If progress continues, more difficult movement combinations are learned as basic limb synergies lose their dominance over motor acts.
Stage VI	With the disappearance of spasticity, individual joint movements become possible and coordination approaches normality.

Table 3
Responses of handgrip strength and the tactile-pressure threshold.

	Affected hand	Unaffected hand	P value
Handgrip strength	11.0 ± 1.5	24.4 ± 1.2	<0.001
Tactile-pressure threshold	3.9 ± 0.1	3.1 ± 0.1	<0.001

Mean ± standard error.

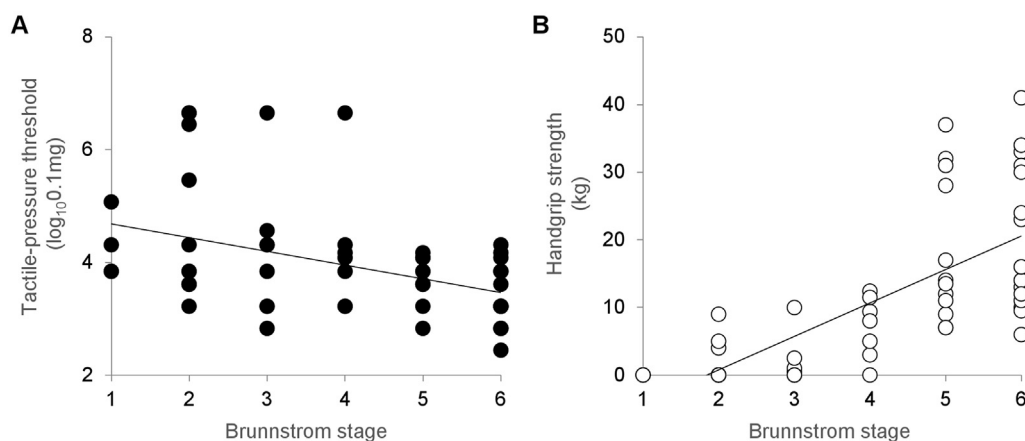


Fig. 1. (A) The relationship between the Brunnstrom stage and tactile-pressure threshold and (B) the relationship between the Brunnstrom stage and handgrip strength. These figures show the respective affected hands. The linear regression lines shown in A and B are represented by $y = -0.24x + 4.94$ ($r_s = -0.43$, $p < 0.01$) and $y = 4.94x - 9.06$ ($r_s = 0.82$, $p < 0.01$), respectively.

$\log_{10} 0.1$ mg, respectively. Using these data as a control, only a slight difference was noted from measurements on the unimpaired side (24.4 ± 1.2 kg and $3.1 \pm 0.1 \log_{10} 0.1$ mg, respectively), whereas a marked difference was observed from those on the impaired side (11.0 ± 1.5 kg and $3.9 \pm 0.1 \log_{10} 0.1$ mg, respectively). These functional impairments are considered to result in poor performance in daily life activities.^{14–16} Therefore, a long-term continuous rehabilitation approach combining physical therapy and occupational therapy is often needed by these patients.

In the present study, a negative correlation was observed between the Brunnstrom stage and tactile-pressure threshold ($r_s = -0.43$). However, the correlation coefficient of the tactile-pressure threshold to the Brunnstrom stage was smaller than that of handgrip strength ($r_s = 0.82$). A previous study reported that the recovery of sensory function was less prominent, whereas the rapid recovery of motor function was observed in the 6 months following a stroke.^{17,18} These different characteristics in functional impairments after stroke may influence differences in the correlation coefficient.

The present results need to be interpreted carefully due to some limitations. Since the study design was cross-sectional, the relationship between changes in motor and sensory impairments in

the acute and/or post-acute stage cannot be deduced. Additional longitudinal studies are needed in order to address this point. Furthermore, we only investigated the sensitivity of light touch sensations and analyzed its relationship with the classification of the Brunnstrom stage. Sensory impairments following stroke include not only the loss of tactile sensations, but also protective

and proprioceptive sensations.^{19,20} Marked deficits more commonly, occur in the discrimination and interpretation of sensory experiences, such as texture discrimination, passive movement recognition, and stereognosis.^{20,21} Therefore, the relationship between sensory impairments other than tactile sensations and the classification of the Brunnstrom stage currently remains unclear. Moreover, the types and degrees of disabilities that develop after a stroke depend on which area of the brain is damaged. The severity of motor and sensory impairments differed in each subject in the present study. However, the sample size of this study was too small to identify the area of the brain associated with the severity of functional impairments; therefore, further studies are warranted.

In conclusion, the degree of sensory impairments in elderly stroke patients is related to the severity of motor paralysis classified by the Brunnstrom stage. Training aimed at improving not only motor function, but also sensory function needs to be considered in stroke rehabilitation.

Disclosure of conflicts of interest

No potential conflicts of interest were disclosed.

Acknowledgments

This study was supported by a Grant-in-Aid for Scientific Research from the Ministry of Education, Culture, Sports, Science, and Technology, Japan (No. 26350570).

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