CASE REPORT

Purposeful activity-based electrical stimulation therapy promoted adaptability to daily life for a patient with moderate/severe upper extremity paralysis after a chronic stroke: a case report

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INTRODUCTION

Neuromuscular electrical stimulation therapy is recommended for the rehabilitation of moderately to severely paralyzed upper limbs following a stroke (The Japan Stroke Society, 2023). Neuromuscular electrical stimulation of induced peripheral nerves is suggested to affect the motor function of patients after a stroke and lead to changes in cortical excitability (Kimberley, 2004). The effectiveness of rehabilitation can be quantitatively evaluated by assessing the cognitive and motor abilities of the patients, allowing us to determine the appropriateness of the program.

We previously conducted a single-case intervention study using purposeful activity-based electrical stimulation therapy (PA-EST) for severely paralyzed upper limbs in patients after a chronic stroke. We observed changes in cerebral hemodynamics (Oxy-Hb values) using functional near-infrared spectroscopy (fNIRS) (Minami, 2021ab). PA-EST is a recovery program that utilizes muscle movements stimulated by neuromuscular electrical stimulation devices and synchronizes purposeful activities of personal interest with whole-body movements. This program enhances adaptive skills through three steps: Step 1 involves training to improve upper limb function, Step 2 is training to improve the patient's ability to predict their own purposeful activities, and Step 3 focuses on enhancing adaptability in daily life, leading to creativity (Minami, 2021b, 2022). In other words, PA-EST is a training method that enhances daily life functioning by converting partial stimulation into whole-body movements while imagining purposeful activities. This training has been shown to have effectiveness for severely paralyzed upper limbs in the chronic phase of a stroke (Minami, 2021b). However, for moderately paralyzed upper limbs in the chronic phase of strokes, there has not been sufficient demonstration of the impact on motor function, frequency of use of the affected upper limb, and on daily life activities. Evaluating the outcomes of the PA-EST program for moderately to severely paralyzed upper limbs remains a challenge.

The purpose of this case study is to demonstrate the implementation of PA-EST for moderate to severe left upper limb paralysis in the chronic phase of our patient's stroke. We aimed to improve his motor function and enhance or maintain activities of daily life. We assessed the effectiveness of the intervention based on comparison of the results pre-intervention and those three months post-intervention. Additionally, fNIRS was used to confirm changes in brain function, evaluating the patient's cognitive and motor abilities and achievement of goals.

METHODS

Participants

We targeted participants that were aged 60 or older, with at least one year having passed since the onset of a stroke. They had to score between

33 and 39 on the Fugl-Meyer assessment upper extremity (FMA-UE) and possess sufficient cognitive function to engage in everyday conversations. As a result, one participant was deemed suitable and was recruited from the facility, and the trial commenced with his consent. He was a Japanese man in his 70s who presented with right-sided hemiparesis. Two years prior, he had left basal ganglia hemorrhage and underwent emergency hematoma removal surgery on the same day. Subsequently, he lived daily life at home while undergoing outpatient and home-based rehabilitation (Figure 1). As an example, the situation related to some of the patient's personal goals was described as 'the right hand can move a little, but it is not possible to use chopsticks.'

PA-EST Intervention Program

We applied the NESS H200W® (Bioness Inc., Valencia, CA, USA) to the forearm of the paralyzed side to apply intermittent neuromuscular electrical stimulation to the forearm extensor muscles, assisting finger and wrist muscle movements (G mode). The stimulation intensity was set within a pain-free range.

The recently-reported PA-EST program was designed to synchronize purposeful activities of personal interest to the participant with whole-body movements based on muscle movements stimulated by the NESS H200W® (Minami, 2022). In our participant's case, the training involved extending the elbow with the image of reaching for a car's steering wheel in accordance with the neuromuscular electrical stimulation. The intervention period was set at three months. The frequency of using the neuromuscular electrical stimulation device was approximately 20 minutes, following a routine of pattern of one session in the morning and one in the afternoon, at least three times a week (Table 1). Occupational therapy was conducted once a week, lasting approximately 40 minutes.

Evaluation

Evaluations were conducted at the initial assessment and three months later. The assessment included the FMA-UE for motor function, the motor activity log (MAL) for the state of limb usage, the goal attainment scaling-light (GAS-L) for goal attainment, and fNIRS for monitoring changes in brain function.

FMA-UE (Bohannon, 1987; Gregson, 1999) is a comprehensive scale for assessing hand functioning in patients after a stroke, with 66 points for upper limb function. Prior to the implementation of PA-EST, the patient's motor function represented by FMA-UE score was 36/66.

MAL (Taub, 1993; Uswatte, 2005; Van der Lee, 2004) is an assessment method for quantifying the subjective functional level of use of the affected limb in daily life. It consists of 14 items assessing the frequency and quality of movement when using the affected limb in daily activities, and is scored on a 6-point scale (0 to 5). Prior to the implementation of PA-EST, the patient's quantified subjective functional level of use of the affected limb in the daily life of the usage frequency (amount of use, AOU) was 0.54 points, and quality of movement (QOM) was 0.46

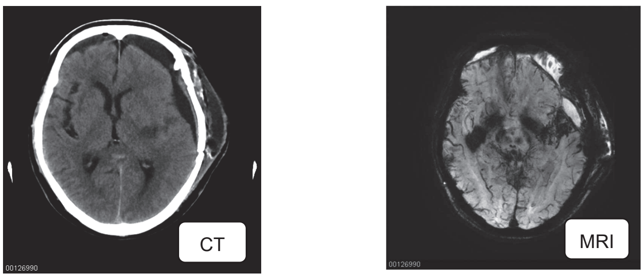

Figure 1. CT and MRI images of basal ganglia hemorrhage a few days after onset

Table 1. Program details for this trial

	Implementation over approximately 3 months
Purposeful activity-based electrical stimulation therapy	• During the 3-month intervention period, the participant engaged in self-training of PA-EST on at least 3 days per week (approximately 5-20 minutes, twice a day). • PA-EST was conducted under the supervision of an occupational therapist at least once a week.
Occupational therapy	• Clear goals for activities were established for the patient, and a program was designed that combined the capabilities of the paralyzed upper limb with the electrical stimulation device. • Confirmation and guidance on activities of daily living were provided, offering support to enable the patient to comfortably adapt to his own lifestyle rhythm.

The PA-EST program was designed to integrate motor training for purposeful activities based on muscle movements stimulated by the neuromuscular electrical stimulation device with the individual's interests and preferences. During the initial month of PA-EST intervention, the primary objective was to acclimate the participant to neuromuscular electrical stimulation (Step 1). In the second to third months of the intervention, training was conducted with the imagery of approaching a steering wheel as a purposeful activity while extending the elbow in coordination with the muscle movements during electrical stimulation of the paralyzed forearm (Step 2).

points.

GAS-L (Lynne, 2009) is a method of scoring the extent to which an individual patient's goals are achieved during the intervention process. Therapists and patients set goals and assess their effectiveness on a 5-point scale. Prior to the implementation of the PA-EST, the patient's assessment of the extent of individual goals scored 22.9. His goals included 'driving a car' and 'being able to eat using his right hand'.

fNIRS is a functional near-infrared spectroscopy method used to measure changes in brain function. It involves positioning probes parallel to the line connecting CZ (according to the International 10-20 system) to both earlobes, following Brodmann's functional localization, to measure the hand motor area (CH2 and CH6 for the finger area, CH10 and CH13 for the palm area, CH3 and CH5 for the wrist area) (Jasper, 1958; Klem, 1999; Figure 2). The measurement protocol consisted of 10 seconds of rest, 20 seconds of task execution, and another 10 seconds of rest. This was repeated for 10 sets, for both wrist dorsiflexion and finger opening movements. fNIRS data (FOIRE-3000, Shimadzu Corporation, Kyoto, Japan) were converted to absolute values after correcting for drift and were analyzed using t-tests with SPSS Statistics 26.0 (α = 0.05). Oxy-Hb values measured by fNIRS serve as indicators of whether oxygen is being supplied to the tissues in the measured region.

RESULTS

The evaluation results after PA-EST are shown in Table 2. In the reevaluation, the FMA-UE score had improved from 36 to 39 (out of 66), the MAL AOU score had increased from 0.54 to 1.15, and the MAL QOM score had increased from 0.46 to 1.23. The GAS score showed a notable effect, increasing from 22.9 to 63.6, indicating that the patient could place his arm on an armrest. In GAS-L, the patient reported the ability to move his fingers freely and use chopsticks to pick up objects, demonstrating improved finger movement and chopstick manipulation. In the fNIRS data, a significant reduction was observed in the contralateral finger area during finger opening movements (p = .007) (Table 3). Furthermore, one month after this study, the FMA-UE score had improved further to 45 (out of 66).

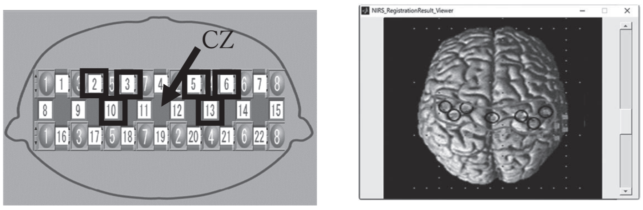

Figure 2. fNIRS attachment and location

Table 2. Evaluation results for this case study

	Pre	Post
FMA-UE	36/66	39/66
MAL AOU	0.54	1.15
MAL QOM	0.46	1.23
GAS-L	22.9	63.6

FMA-UE: Fugl-Meyer assessment upper extremity, MAL: motor activity log, AOU: amount of use, QOM: quality of movement, GAS-L: Goal attainment scaling-light

Table 3. fNIRS results for this case study

			Pre		Post				
			Mean (z-value)	SD	Mean (z-value)	SD	t value	p-value	
Wrist dorsiflexion exercise	CH2	Contralateral side	184.98	141.83	36.64	532.66	0.766	0.463	
	CH6	Ipsilateral	125.19	127.25	162.33	360.33	-0.262	0.799	
	CH10	Contralateral side	193.99	166.03	59.48	151.15	1.645	0.134	
	CH13	Ipsilateral	104.79	65.41	140.31	337.96	-0.296	0.774	
	CH3	Contralateral side	167.36	188.98	72.52	149.18	1.107	0.297	
	CH5	Ipsilateral	198.19	180.02	109.53	163.82	1.073	0.311	
Finger extension exercise	CH2	Contralateral side	282.50	233.27	26.48	82.02	3.436	0.007	*
	CH6	Ipsilateral	173.73	195.79	154.46	136.87	0.242	0.814	
	CH10	Contralateral side	142.91	102.83	84.89	115.40	1.186	0.266	
	CH13	Ipsilateral	119.53	59.78	73.32	142.16	0.905	0.389	
	CH3	Contralateral side	136.15	97.15	152.71	89.90	-0.459	0.657	
	CH5	Ipsilateral	199.20	131.33	131.36	107.42	1.494	0.169	

*$p < 0.05$

DISCUSSION

PA-EST is implemented with the goal of improving motor function and enhancing or maintaining daily life for people with moderately to severely paralyzed upper limbs in the chronic phase of a stroke. In this study, combining a program that converts purposeful activities based on the individual's interests with the neuromuscular electrical stimulation of the paralyzed forearm into whole-body movements, we observed improvements in upper limb motor function, frequency of use of the paralyzed limb, and goal attainment from before to after the intervention.

In this case, it can be inferred that there was improved adaptability of the paralyzed limb in daily life. Additionally, changes in brain function were confirmed through fNIRS, showing a significant reduction in Oxy-Hb values in the contralateral finger area during finger opening movements ($p = 0.007$) (Table 1). This suggests an increase in the motor cortical area on the same side, in line with previous research on the effect of PA-EST for severely paralyzed upper limbs in the chronic phase of a stroke (Minami, 2022). Although our patient did not show significant Oxy-Hb values on the paralyzed side compared with the contralateral side, there was a reduction in brain blood flow dynamics. This implies that the adaptability of the paralyzed limb in daily life was enhanced through the reduction of excessive brain blood flow dynamics in moderately to severely paralyzed upper limbs in the chronic phase of a stroke.

Conversely, FMA-UE (Page, 2012), indicates a minimal clinically important difference (MCID) ranging from 4.25 to 7.25 points. In our patient's case, an improvement of 3 points was observed, then one month later, the FMA-UE score had improved to 9. The degree of change needed to achieve the MCID for the FMA-UE may not necessarily be the same as the change in this case, however, as there was variation in the methods, duration and onset period. Similarly, the MCID for the MAL, used to assess the frequency of limb use and movement quality (Lang, 2008), falls between 1.0 and 1.2 points. In our patient, the MAL AOU score increased to 1.15, and the MAL QOM score improved to 1.23. Again, direct comparisons with the MCID for the MAL were challenging because of the differences in implementation methods, duration and onset. Clinically, combining weekly occupational therapy with PA-EST as self-training was suggested to have enhanced ease of use of the paralyzed limb.

The assessment of goal attainment using GAS-L showed increased subjective evaluations of the paralyzed limb, with the patient feeling more capable of performing tasks. Although functional recovery in the upper limb of individuals with chronic stroke is recognized, it can be challenging to increase everyday usage (Rand, 2012). Furthermore, a lack of movement opportunities for the paralyzed limb in daily life can lead to disuse and a significant reduction in quality of life (Lai, 2002). In our patient, increased goal attainment suggested improved adaptability in daily life.

This was a single case study and does not establish a clear relationship between brain function, motor function, and goal attainment. Continuous evaluation and data accumulation from additional cases are required. Furthermore, an evaluation of brain function related to supplementary motor areas and sensory areas was not conducted. It is therefore necessary to capture the factors contributing to the activation of various regions in the cerebral cortex. Future research should focus on investigating changes in brain function resulting from PA-EST during the transition to the supplementary upper limb for individuals after a chronic stroke. Additionally, it is necessary to evaluate the infarct location, the time since stroke, overall function, patient motivation, and environmental factors.

The patient with moderate/severe upper extremity paralysis after a chronic stroke in this study was demonstrated to have favorable changes in motor function, frequency of use of the affected limb, and brain function through the PA-EST program. The program may enhance goal achievement and improve the ability to predict the patient's ability to achieve their purposeful activities, potentially contributing to the enhancement of adaptability in daily life.

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ETHICAL CONSIDERATIONS

The principles of the Helsinki Declaration and ethical guidelines for medical research involving human subjects set forth by the Ministry of Health, Labour, and Welfare were strictly followed, ensuring adequate protection of stroke survivors. We explained the purpose of this research to the patient and obtained their written consent before proceeding with the intervention.

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