ORIGINAL ARTICLE

Program for rehabilitation of the chronic severe hemiparesis upper extremity of cerebral stroke survivors: application of purposeful activities and an electrical stimulation therapy program

Seigo MINAMI,[1,2] Ryuji KOBAYASHI,[3] Yoshihiro FUKUMOTO,[2,4] Hideaki AOKI,[5] Tomoki AOYAMA,[2] Masatoshi TAKEDA[1]

[1]Department of Occupational Therapy, School of Rehabilitation, Osaka Kawasaki Rehabilitation University, [2]Graduate School of Medicine, Kyoto University, [3]Graduate School of Human Health Sciences, Tokyo Metropolitan University, [4]Department of Physical Medicine and Rehabilitation, Kansai Medical University, [5]Graduate School of Medicine, Wakayama Medical University

Correspondence: Seigo Minami, Osaka Kawasaki Rehabilitation University, 158 Mizuma, Kaizuka City, Osaka, 597-0104, Japan. E-mail: minamise@kawasakigakuen.ac.jp

Disclosure: There are no conflicts of interest to declare.

Key words: *home-based occupational therapy, stroke, chronic severe hemiparesis in the upper extremities*

Abstract

Objective: We studied the effect of the purposeful activities and the electrical stimulation therapy program (PA-EST), based on the patient's interests and preferences as a purposeful electrical stimulation therapy in patients with chronic severe hemiparesis in the upper extremity. The aim of the therapy was to prevent the disuse of upper extremity switching to supportive upper extremity. The therapy is designed to conform to the intent, practice, subjective experience and self-efficacy of the theory of occupational therapy.

Methods: The purposeful movements of disused upper extremity of two severe chronic hemiplegia patients were studied for the effect of PA-EST, aiming for the lifestyle improvement management. In the first phase, muscle contraction force and blood flow to the muscles were promoted based on purposeful movements using supportive-type electrical stimulators. In the second phase, after voluntary contraction was confirmed, purposeful activities were conducted using volition control electrical stimulators. This regimen was performed as one cycle every seven months, with a rest period of one month between each cycle to confirm voluntary activities.

Results: After clarifying the purposeful activities within activities of daily living (ADL), electrical stimulation therapy was administrated. The amount of the use of the upper extremity on the severely paralysed side was significantly increased in these ADL.

Discussions: The study demonstrated the totally disused upper extremity of the patients with chronic severe hemiparesis can be transformed to functional restoration of purposeful activities, allowing improvements in ADL of the patient. We hypothesise the transition of the paralysed limb to a useful hand can be attained through the application of PA-EST to promote ADL of the patients with chronic severe hemiparesis.

INTRODUCTION

Hemiplegia due to cerebral stroke is associated with great interference in daily life. The treatment of hemiplegia patients usually requires an intensive approach, and the recovery from upper extremity paralysis is often difficult (Hendricks, 2002). Wolf et al. (1989) explained the reason of this difficulty that the patients have a risk of learning not to use the paralysed extremities. In severe hemiplegia due to stroke, the lack of motivation or voluntary movement is observed especially in the functional movement of hands, and the patients are discharged and sent home without enough rehabilitation (Alexander, 1994). Then the patient learns not to use their hand in daily life, after repeated failures in using the severely paralyzed upper extremity at home.

Recently, various approaches have been reported in addition to conventional exercise therapy, including constraint-induced movement therapy (Wolf, 1989; Frit, 2005), therapeutic electrical stimulation (Bolton, 2004; Francisco, 1998; Sasaki, 2012) and hybrid assistive neuromuscular dynamic stimulation therapy (Fujiwara, 2009). Yamaguchi et al. (2011) developed an integrated volitional control electrical stimulator (IVES) to apply in clinical settings. Furthermore, Thorsen et al. (2001, 2006) devised a myoelectrical controlled functional electrical stimulation (MeCFES) system and developed a device in which wrist extensor electrical signals directly control the same muscle stimulation to enhance wrist extension under voluntary control in patients with quadriplegia. The effects of objective-oriented approaches and MeCFES in the acute phase have been demonstrated (Jonsdottir, 2017). Several therapies have been developed to facilitate the rehabilitation of the paralysed upper extremity by supporting voluntary movements. Functional electrical stimulation has also been used to treat the upper extremity of moderate chronic stroke survivors with some efficacy (Alon, 2003; Japan Stroke Society, 2015). However, no study has investigated the effect of functional electrical stimulation on the upper limbs of BRS I to III because of severe hemiparesis and almost no wrist joint movements in chronic stroke survivors. Though home medical care is strongly recommended in Japan, a home-based rehabilitation program for severe chronic stroke survivors is not easily attainable.

Challenge-oriented approaches of occupational therapy is a preferred neurorehabilitation intervention to improve work performance in patients with neurologic disorders, such as cerebrovascular or traumatic brain injuries (Bass-Hangen, 2008; Almhdawi, 2016). We used a combination of purposeful activities and electrical stimulation therapy (PA-EST) in patients with chronic severe hemiparesis in the upper extremities. It was based on the patients's interests and preferences as a purposeful electrical stimulation therapy with the aim of preventing the disuse of the paralysed upper extremity and promoting the transition of such extremities to supportive upper extremities (Minami, 2020). This conforms to the principle of occupational therapy-based intent and practices incorporating subjective experience and self-efficacy (Yerxa, 1967; Mobily, 1982; Kielhofner, 2008). This is an intervention method that combines lifestyle improvement management and advanced technologies (Minami, 2020), as recommended by the Japan Association of Occupational Therapists (Fukui, 2019). This therapy aims to increase the use of the severely paralysed upper extremities in daily life by clarifying purposeful activities within daily life and using electrical stimulation therapy in parallel.

The present study reports on patients with chronic severe hemiparesis in the upper extremity at a level of disuse whose transition is made from neuromuscular electrical stimulation (NMES) to IVES in response to functional restoration during purposeful activities of the patients.

METHODS

Patient selection

The selected patients were post cerebral stroke patients who lived at home for more than three years since the onset of the stroke. Patients with Stage I–III hemiplegia in fingers and Stage I–III hemiplegia in the upper extremity were selected. The patients had motor function of less than 50 points based on the Fugl–Meyer Assessment (FMA). Other inclusion criteria were frequency of intervention with occupational therapy, cognitive function at a level of being able to engage in daily conversation, and not to have issues with higher order function in daily life. The patients also had to be able to maintain a sitting position at the wheelchair level and to maintain a sitting position for longer than 30 min.

Two patients participated in this study. As an attempt to observe transition to volitional control electrical stimulation, participants (they; the patients) received supportive electrical stimulation and purposeful electrical stimulation therapy.

PA-EST

Electrical stimulators were attached to the paralysed muscles to administer electrical stimulation to the upper extremities paralysed due to central nervous system disorders. Supportive electrical stimulation and volitional control electrical stimulation can help restoring functional operations. Purposeful electrical stimulation therapy is a method that makes a use of the features of each device and a proper use of the device is in accordance with the patients' conditions. An appropriate use of the upper extremity in the paralysed side was encouraged based on the patients' interests and preferences. This was performed as part of non-purposeful activity training, such as block stacking. The program had two phases of electrical stimulation, each with purposeful activities. The program includes electrical stimulation for three months, a rest period of a month, and PA-EST for an additional 3 months (Table 1). In the first phase, muscle contraction force and blood flow to the muscles were promoted based on purposeful movements using supportive-type electrical stimulators. In the second phase, after voluntary contraction was confirmed in the first phase, purposeful activities were conducted using volition control electrical stimulators. This regimen was performed as one cycle every seven months, with a rest period of one month between each cycle to confirm voluntary activities.

While confirming the habituation to electrical stimulation, this program shifted to a program that focused

Table 1. Hybrid program of purposeful electrical stimulation therapy

	Phase 1 (supportive electrical stimulator)				Phase 2 (volitional control electrical stimulator)		
	Implementation Approximately 3 months	Rest Approximately 1 month	Implementation 3 months		Implementation Approximately 3 months	Rest Approximately 1 month	Implementation 3 months
Purposeful electrical stimulation therapy	• Electrical stimulation (supportive electrical stimulator) * Approximately 5–30 min × 2 times/day • Focused training on activities of daily living (supportive electrical stimulator) * Approximately 10–30 min × 2 times/day • The rest period encourages active use of the paralysed upper extremities in activities of daily living			Rest period 1 month	• Become familiar with electrical stimulation (volitional control electrical stimulator) * Approximately 5–30 min × 2 times/day • Focused training on activities of daily living (volitional control electrical stimulator) * Approximately 10–30 min × 2 times/day • The rest period encourages active use of the paralysed upper extremities in activities of daily living		
Occupational therapy	• Clarify the patient's purposeful activities and design a program that combines the ability of the paralysed upper extremity with an electrical stimulator • Confirm and instruct the patient on daily activities using the paralysed upper extremity and provide support that is reasonably tailored to the patient's daily life rhythm • Support habits and roles tailored to daily life rather than on a program focusing on the patient’s functional ability						

Table 2. Amount of use and intensity of orthosis-type electrical stimulation in phase 1

ID	Minute/ 1 w	Minute /1 session	Training Content 1 (min)	Training Content 2 (min)	Pulse width	Frequency of stimulation
A	80.0	10.0	FAST OPEN EXERCISE (10)		240 μs	36 Hz
B	126.5	20.0	FAST OPEN EXERCISE (10)	OPEN EXERCISE (10)	240 μs	36 Hz

Fast open exercise, exercise to repeatedly open or relax the hands (to stimulate at a high rate)
Exercise, exercise to repeatedly open and close the hands
Open exercise, exercise to repeatedly open and relax the hands

on ADL based on the observed movements of the forearm driven by electrical stimulation. The occupational therapist clarified the purposeful activities based on the interests and preferences of the patients, and the individualized programs were planned to combine the ability of the upper extremity on the paralysed side and electrical stimulation. The activities in this study were performed using NESS H200 as the supportive electric stimulator and WILMO as the volition control electric stimulator. The transition from the first to second phase was based on the observation of voluntary muscle contractions in the forearm on the paralysed side. Supportive electrical stimulation was performed for 60 min. a day at least three times a week as self-training or training in the presence of therapists. Volition control electrical stimulation was performed for approximately 10 min per dose, three times per week in the presence of a therapist whenever possible (Table 2).

Study protocol

Physical function assessment of the study was performed by the first author, and actual therapy was administered by a treating therapist. The written informed consent was obtained from all participants. The study protocol was reviewed by the ethical committee of the Osaka Kawasaki Rehabilitation University (approval number: OKRU30-A018).

RESULTS

Patient A

Patient A was a female in her early 50s with a cerebral stroke five years before the recruitment. During hospitalisation, although the patient underwent intensive rehabilitation, the paralysed upper extremity was not recognised as a usable upper extremity in daily life at the time of hospital ization. After her discharge, the patient underwent one occupational therapy visit and one physical therapy visit and spent approximately five years at home. According to the patient, the disease state remained unchanged for five years, and she spent most of her life at home, that she rarely go out of home. She looked forward to playing with her grandchildren (children of her daughter) who sometimes came to visit her.

The patient’s motor function in FMA was 13 points for the upper extremity and 10 points for the lower extremity, which was atotal of 23/100. The amount of use in the Motor Activity Log (MAL) was 0.00 and the quality of movement was 0.00. The paralysed upper extremity was spastic and painful when it was moved. The patient spent her life watching TV in a sitting position on a bed every day. Changes in motor function and lifestyle were described supportive electrical stimulator period and volitional control electrical stimulation period separately.

(1) Phase 1: Duration of supportive electrical stimulation (3 months + rest + 3 months)

The patient's goal was to hold her grandson's hand with her paralysed upper extremity. Using the supportive electrical stimulator, the training to extend the elbow in proportion to the stimulation pattern of the electrical stimulation was performed. The duration of use for six months was approximately 20 min per day. During physical function evaluation, the motor function in FMA was 27 points for the upper extremity and 22 points for the lower extremity, which was a total of 49/100 points. The amount of use in MAL increased to 0.8 and the quality of movement improved to 1.11. In the patient's daily life, she was able to walk to the bathroom with towels and clothing placed between the extremities on her paralysed side (Figure 1). However, she could not hold her grandchild's hand. Muscle contractions were observed in the forearm of the paralysed upper extremity. After one-month rest period, the patient was transitioned to a volitional control electrical stimulator.

(2) Phase 2: Duration of volitional control electrical stimulation (3 months + rest + 3 months)

The patient's goal was to be able to walk in a relaxed manner, put cling wrap on dishes and to hold down vegetables so that they could be cut up. These goals were assessed using the Goal Attainment Scaling (GAS)-Light. The ADL goals were set as (1) walking to go shopping with relaxed upper extremities and (2) wrapping dishes. Using the volitional control electrical stimulator, the movement of pushing while the elbow joint was extended was performed under the assistance of a therapist. The stimulator was used twice a week with the therapist for approximately 5–10 min. The motor function in FMA was 34 points for the upper extremity and 24 points for the lower extremity, which was a total of 58. When performing FMA was performed, the patient stated that she felt the weight of her arms decreased. The amount of use in MAL was 0.9 and the quality of movement was 0.9. In terms of ADL, wrapping side dishes with cling wrap and holding cucumbers while cutting became possible (Figure 2). During her walks, the patient held her grandchild's shoulders with her non-paralysed extremity and was able to walk in a relaxed manner at

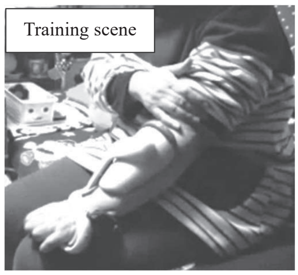
	A	B	Training scene/Living act scene
Initial evaluation			
Final evaluation			

Figure 1. The first phase of the practice result (Ms. A)
*A: raise your hand to the paralysed ear in the sitting position
*B: turn your hand to the lumbar spine while sitting
Modified from Seigo Minami, Hideaki Aoki, Ryuji Kobayashi, Yoshihiro Fukumoto, Tomoki Aoyama. Transition of a severely hemiparetic upper limb to a supporting upper limb: Development of a purposeful activity-electrical stimulation therapy rehabilitation program (A report of three cases). Japanese Academy of Health Sciences. 2020;23(1): 14-24.

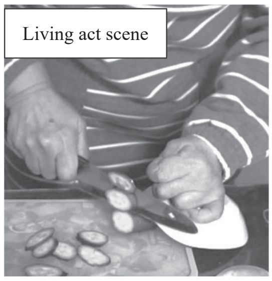
	A	B	Training scene/Living act scene
Initial evalu-ation			
Final evalu-ation			

Figure 2. The second phase of the practice result (Ms. A)
*A: Raise your hand to the paralysed ear in the sitting position
*B: Turn your hand to the lumbar spine while sitting

	A	B	Training scene/Living act scene
Initial evalu-ation	Initially, there was no resistance to projecting a face and there was no video (intention of the person) As a result, shoulder flexion was ≤90° and the hand did not go up to the shoulder		Training scene 
Final evalu-ation			Living act scene 

Figure 3. The first phase of the practice result (Mr. B)
*A: Shoulder flexion 180° in the elbow extension position
*B: Wrist joint 15° dorsiflexion with shoulder 0° and elbow flexion 90°
Modified from Seigo Minami, Hideaki Aoki, Ryuji Kobayashi, Yoshihiro Fukumoto, Tomoki Aoyama. Transition of a severely hemiparetic upper limb to a supporting upper limb: Development of a purposeful activity-electrical stimulation therapy rehabilitation program (A report of three cases). Japanese Academy of Health Sciences. 2020;23(1): 14-24.

her grandchild's pace. The frequency of their outings also increased. Based on GAS-Light, baseline score was 31.4, which increased to 68.6; the difference was 37.2 points.

Patient B

This patient was a male in his late 50s who was diagnosed as thalamic haemorrhage seven years before participating in this study. He underwent intense rehabilitation and returned to work with the support from his family and employer. After returning to work, he underwent a weekly occupational therapy visit and weekly physical therapy visit at home. His ADL was almost independent except for walking, bathing, and wearing/ removing clothing. He used of an electric wheelchair for movement.

Motor function in FMA was 28 points for the upper extremity and 11 points for the lower extremity, which was a total of 39/100 points in the paralysed upper extremity. Skin sensation and positional sensing were severely impaired. The amount of use in MAL was 0.71 and quality of movement was 0.64. The paralysed upper extremity showed oedema and was attached to objects in a bent pattern. Changes in motor function and ADL were described separately each period, dividing into supportive electrical stimulator period and volitional control electrical stimulation period.

(1) Phase 1: Duration of supportive electrical stimulation (3 months + rest + 3 months)

The patient agreed that his ADL goal was to be able to open the cap of his favourite canned coffee and drink it. The frequency of occupational therapy visits at home was approximately 60 min once a week. A supportive electrical stimulator was used in voluntary training at least three times a week for approximately 15 min. After three months, the motor function in FMA was 52 points for the upper extremities and 12 points for the lower extremities, whidh was a total of 64 points. The amount of use in MAL was 1.36 and the quality of movement was 1.14. The patient's awareness of ADL was to regard activities such as changing clothing and consuming meals as '(naturally going through his) daily life'. In addition, in terms of the use of the paralysed upper extremity, the patient stated that he hung clothes over the paralysed side, folded these clothes up, and stored them in a drawer. He was also able to open the cap of canned coffee (Figure 3). Because muscle contraction was observed in the forearm of the paralysed upper extremity, the transition to a volitional control stimulator was attempted after a resting period of one month.

(2) Phase 2: Duration of volitional control electrical stimulation (3 months + rest + 3 months)

The patient stated that his ADL goal was to open the packaging of snacks and to tuck the tail of his

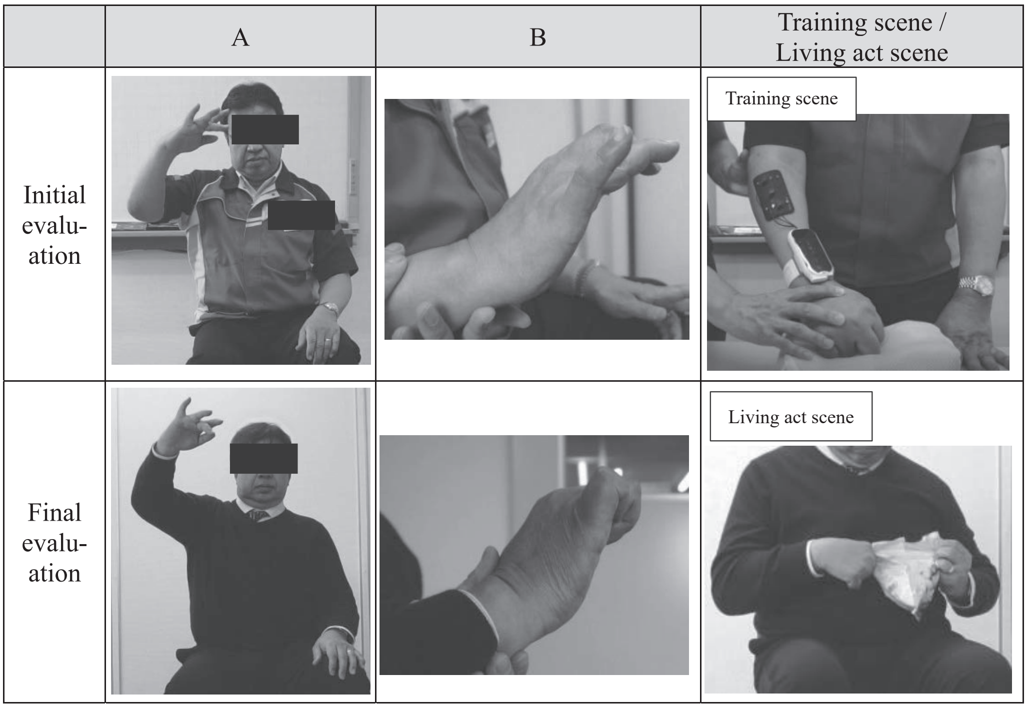


Figure 4. The second phase of the practice result (Mr. B)
*A: Shoulder flexion 180° in the elbow extension position
*B: Wrist joint 15° dorsiflexion with shoulder 0° and elbow flexion 90°

shirts into his pants. These goals were assessed using GAS-Light. The ADL goals were set as (1) tucking the tail of shirts into pants in the paralysed side, (2) maintaining balance when closing the door and (3) getting hot water from a water dispenser and bringing it to the sofa. Using a volitional control electrical stimulator, the movement of pushing while the elbow joint was extended was performed under the assistance of a therapist. The stimulator was used twice a week with the therapist for approximately five min. The motor function in FMA was 50 points for the upper extremity and 16 points for the lower extremity, whidh was a total of 66/100 points. The amount of use in MAL was 1.90 and the quality of movement was 1.70 (Figure 4). The patient was able to open a bag of the snacks with both hands as a ADL. In addition, the paralysed side was used to pick up the tail of pants when raising and lowering the pants and was used for belts and zippers. The patient also started planning for an overseas trip that he had gave on several years previously. Based on GAS-Light, the baseline score was 36.6, which increased to 61.0; the difference was 24.4 points.

DISCUSSIONS

In this study, we developed a program for chronic severe hemiparesis in the upper extremities at disuse level, in which an electrical stimulator was transitioned from NMES to IVES based on the stage of functional restoration of the patient during a purposeful activity and a program that improves the quality of life. By combining the use of interventional means and electrical stimulators, not only improvements in motor function but also efficacy in the transition of chronic severe hemiparesis in the upper extremities to a supportive state in daily life practice were indicated. The impact of support in purposeful electrical stimulation therapy is discussed to aid in planning future interventions for severely paralysed upper extremities.

Patient selection

The patients in this study were limited to those in their 50s who suffered a stroke more than 5 years previously. They had a paralysed upper extremity that it was not utilised in ADL and was thus regarded as non-used. Both of them had similar disease onset and age and were considered appropriate for identifying changes. The credibility of the data collection method's efficacy was assured by assigning two different individuals as a practitioner and evaluator.

Program development of purposeful electrical stimulation for chronic severe hemiparesis in the upper extremity

We developed a program based on the structural changes in the brain due to chronic severe hemiparesis in the upper extremity. Severely paralysed upper extremity is identified as a hand that have not been used for several years or more in daily life and that are recognised as disuse limbs, which are affected by walking (Bovonsunthonchai, 2012). Motor recovery in individuals after stroke involves electrical stimulation to activate the suppressed electrical signals (Thorsen, 2001; Jonsdottir, 2017). Studies have suggested that the combination of voluntary rehabilitation of severely paralysed upper extremities and electrical stimulation therapy has more efficacy than exercise therapy alone (Hara, 2008; Alon, 2007). Wearing an orthosis during the implementation of orthosis-type electrical stimulation increases the awareness of the importance of the severely paralysed upper extremities in the rehabilitation process; therefore, the patients were informed about this. In addition, purposeful activity was clarified, content that matched ADL was included in the plan, electrical stimulation and image conducted in daily life were discussed and empirical findings related to the use of the paralysed upper extremities were analysed. All of these are speculated as having led to increased awareness of the severely paralysed upper extremity.

In this study, by using volitional control electrical stimulators, voluntary movement was observed upon dorsiflexion of the forearm of the patients; therefore, the device was transitioned from an supportive electrical stimulator to volitional control electrical stimulator. At this instance, purposeful activity was clarified and electrical stimulation therapy was conducted based on the content that was in accordance with daily life. And the relationship between a therapist and a patient were enhanced by using electrical stimulators for purposeful movements. Good responses were observed with these stimulators due to the assistance of a therapist; therefore, the therapist was able to ascertain the patient's response. Because voluntary contraction seemed to be achieved, the opportunity for more challenges in life might be also increased. These findings suggested that the paralysed upper extremities could have been used more frequently in daily life.

Purposeful electrical stimulation therapy could clarify the purposeful activities in severely paralysed upper extremities and moving upper extremities via electrical stimulation in relation to daily life. The development of this program would present a unique technique for therapists because it is an individualised approach to ADL that evaluates patients' motivation, ability. and environment. With this program, the patients were provided support for the transition from non-used hands to supportive upper extremities by selecting and gradually using electrical stimulators. Purposeful electrical stimulation therefore would be an effective program for cases presenting with chronic severe hemiparesis in the upper extremities.

Possibilities for purposeful electrical stimulation therapy

Based on the findings with the patients reported in this study, we should be aware with the difference in infarct site, haemorrhage site and existence of benefit based on the degree of effects of purposeful electrical stimulation therapy for chronic severe hemiparesis in the upper extremities. In addition, it is necessary to evaluate the degree of brain activation when there is transition from non-used hands to supportive upper extremity. Purposeful electrical stimulation therapy, which combines the conventional concept of occupational therapy and advanced technology, is effective not only for functional improvement but also for enhancing quality of life and improving motivation.

Future purposeful electrical stimulation therapy should be investigated about brain activation caused by interventions focusing on ADL of patients with chronic severe hemiparesis in the upper extremities. It is inferred that purposeful electrical stimulation therapy can promote the transition from non-used hands to supportive upper extremities by voluntarily encouraging the experience of using the upper extremities with severe hemiplegia based on individual wants and needs (i.e., roles and habits) and simultaneously discussing this with the patient.

Study limitations and challenges

This study attempted to use electrical stimulators in a step-wise manner in patients with severe hemiparesis in the upper extremities. For chronic hemiparesis in the upper extremities, support for the transition from non-used hands to supportive upper extremities was provided due to clarification of the purposeful activity through improved management of ADL, use of a hybrid of supportive orthosis-type electrical stimulators and volitional control electrical stimulators. However, as this study included only two patients, there are limitations on its generalisation. It is necessary to verify the effectiveness for patients with different lesions and different degree of paralysis. In addition, although improvements in the motor function of the upper trunk and scapula were observed, improvements in the motor function of the finger were not achieved, which indicated that the programs and the devices for further development.

As for the future directions, it will be necessary to verify whether utility, as demonstrated by improvements caused by purposeful electrical stimulation therapy, is statistically significant and clinically relevant. In addition, the transition from supportive electrical stimulators to volitional control electrical stimulators should be standardised. Unfortunately, the amount of use and intensity of volitional control electrical stimulators could not be checked because a memory function was not built in. However, we believe that its use was appropriate because of the efficacy observed from the practice results.

CONCLUSIONS

In summary, our patients with chronic severe hemiparesis in the upper extremities who had stroke more than 5 years before the therapy achieved improvements in motor performance and use of extremity in their paralysed side with the administration of electrical stimulation based on purposeful activities. The transition of long-term unused upper extremity due to chronic severe hemiparesis to a supportive state was further facilitated by using a hybrid electrical stimulator. Therefore, further research exploring stem changes with the central nervous approach as well as studies on the efficacy of purposeful electrical stimulation therapy are expected.

ACKNOWLEDGEMENTS

The authors would like to express their deep gratitude to the occupational therapists who participated in the evaluation of study participants: Hidetoshi Nakagawa, Kota Takamura, Takaaki Hayashida, Mikiko Fujiwara and Shizuka Ueno.

FUNDING

The study was funded by the Japan Society for the Promotion of Science (institution number: 34447).

REFERENCES

Alexander MP Stroke rehabilitation outcome A potential use of predictive variables to establish levels of care. Stroke 25(1), 128-34, 1994

Almhdawi KA, Mathiowetz VG, et al. Efficacy of occupational therapy task-oriented approach in Upper extremity post-stroke rehabilitation. Occup Ther 23(4), 444-56, 2016

Alon G, Levitt AF, et al. Functional electrical stimulation enhancement of upper extremity functional recovery during stroke rehabilitation: a pilot study. Neurorehabil Neural Repair 21(3), 207-15, 2007

Alon G, Sunnerhagen KS, et al. A home-based, self-administered stimulation program to improve selected hand functions of chronic stroke. NeuroRehabilitation 18(3), 215-25, 2003

Bass-Haugen J, Mathiowetz V Optimizing motor behavior using the occupational therapy task-oriented approach. In: Radomski MV, Latham CT, editors. Occupational therapy for physical dysfunction. 6th ed. Baltimore: Lippincott Williams & Wilkins, 598-617, 2008

Bolton DA, Cauraugh JH, et al. Electromyogram-triggered neuromuscular stimulation and stroke motor recovery of arm/hand functions: a meta-analysis. J Neurol Sci 223(2), 121-7, 2004

Bovonsunthonchai S, Hiengkaew V, et al. Effect of speed on the upper and contralateral lower limb coordination during gait in individuals with stroke. Kaohsiung J Med Sci 28(12), 664-72, 2012

Francisco G, Chae J, et al. Electromyogram-triggered neuromuscular stimulation for improving the arm function of acute stroke survivors: a randomized pilot study. Arch Phys Med Rehabil 79(5):570-5, 1998

Fritz SL, Light KE, et al. Active finger extension predicts outcomes after constraint-induced movement therapy for individuals with hemiparesis after stroke. Stroke 36(6), 1172-7, 2005

Fujiwara T, Kasashima Y, et al. Motor improvement and corticospinal modulation induced by hybrid assistive neuromuscular dynamic stimulation (HANDS) therapy in patients with chronic stroke. Neurorehabil Neural Repair 23(2), 125-32, 2009

Fukui M, Yoshida Y, et al. Effect of the management tool for daily life performance on patients with cardiovascular disease: A randomized controlled trial. Prog Rehabil Med 4, 1-8, 2019

Hara Y, Ogawa S, et al. A home-based rehabilitation program for the hemiplegic upper extremity by power-assisted functional electrical stimulation. Disabil Rehabil 30(4), 296-304, 2008

Hendricks HT, Van Limbeek J, et al. Motor recovery after stroke: a systematic review of the literature. Arch Phys Med Rehabil 83(11), 1629-37, 2002

Jonsdottir J, Thorsen R, et al. Arm rehabilitation in post stroke subjects: A randomized controlled trial on the efficacy of myoelectrically driven FES applied in a task-oriented approach. PLoS One 12(12), 1-16, 2017

Kielhofner G Therapeutic strategies for enabling change. In Model of human occupation: theory and application. Baltimore: Lippincott Williams & Wilkins,185-203, 2008

Minami S, Aoki H, et al. Transition of a severely hemiparetic upper limb to a supporting upper limb: Development of a purposeful activity-electrical stimulation therapy rehabilitation program (A report of three cases). Japanese Academy of Health Sciences 23(1), 14-24, 2020

Mobily KE Motivational aspects of exercise for the elderly: barriers and solutions. Phys Occup Ther Geriatr 1(4), 43-54, 1982

Sasaki K, Matsunaga T, et al. Effect of electrical stimulation therapy on upper extremity functional recovery and cerebral cortical changes in patients with chronic hemiplegia. Biomed Res 33(2), 89-96, 2012

The Japan Stroke Society. Japanese Guidelines for the Management of Stroke 2015. Tokyo: Kyowa Kikaku Ltd; 2015

Thorsen R, Spadone R, et al. A pilot study of myoelectrically controlled FES of upper extremity. IEEE Trans Neural Sys Rehabil Eng 9(2), 161-8, 2001

Thorsen RA, Occhi E, et al. Functional electrical stimulation reinforced tenodesis effect controlled by myoelectric activity from wrist extensors. J Rehabil Res Dev 43(2), 247-55, 2006

Wolf SL, Lecraw DE, et al. Forced use of hemiplegic upper extremities to reverse the effect of learned nonuse among chronic stroke and head-injured patients. Exp Neurol 104(2), 125-32, 1989

Yamaguchi T, Tanabe S, et al. Effects of integrated volitional control electrical stimulation (IVES) on upper extremity function in chronic stroke. Keio J Med 60(3), 90-5, 2011

Yerxa E Authentic occupational therapy. Am J Occup Ther 21, 1-9, 1967