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Effect of high-frequency mirror therapy for upper extremities after subacute stroke

Hiroyuki Miyasaka, OTR, PhD[1], Izumi Kondo, MD, PhD[2], Hitoshi Ohnishi, OTR[1], Toshio Teranishi, RPT, PhD[3], Abbas Orand, PhD[4], Shigeru Sonoda, MD, PhD[5]

[1] Department of Rehabilitation, Fujita Health University Nanakuri Memorial Hospital, Tsu, Mie, Japan, [2] Department of Rehabilitation Medicine, National Center for Geriatrics and Gerontology, Obu, Aichi, Japan, [3] Faculty of Rehabilitation, School of Health Sciences, Fujita Health University, Toyoake, Aichi, Japan, [4] School of Mechatronic Systems Engineering, Simon Fraser University, Surrey, B.C., Canada, [5] Department of Rehabilitation Medicine II, Fujita Health University Nanakuri Memorial Hospital, Tsu, Mie, Japan

Abstract

Objectives: This study aimed to investigate the effect of high-frequency mirror therapy (MT) on the upper extremities of patients suffering paresis following subacute stroke. Altogether, 50 subacute stroke patients with upper limb paresis whose strokes had occurred within 30–60 days of the start of this study were enrolled. The patients were randomly divided equally into groups assigned to conventional therapy (CT) alone or to CT plus mirror therapy (MT). All patients underwent CT training 40 min daily for 4 weeks. The MT group patients then continued an additional 20 min of shoulder, elbow, wrist, and finger MT, whereas the CT group continued with an additional 20 min of CT. Main outcome measures were the angles achieved during active shoulder flexion and abduction and wrist dorsiflexion, as well as upper-limb Fugl–Meyer Assessment (FMA) subscores.

Results: For both the intention-to-treat and per-protocol analyses, the MT group showed significantly more improvement in active shoulder flexion range of motion than did the CT group. The FMA scores improved from before to after the start of the study in both groups, with no significant differences between the two groups.

Conclusions: Application of MT at a high frequency probably has a positive effect on improving shoulder function in these subacute stroke patients. Thus, frequent MT application is essential for alleviating stroke-induced paralysis.

Keywords: Mirror therapy, Stroke rehabilitation, Upper extremity, High frequency

Introduction

Paralysis subsequent to stroke is the most frequent sequela that interferes significantly with activities of daily living (ADL).[1] For stroke patients with moderate-to-severe paralysis during the acute phase, the probability of permanent paralysis is high, with minimal chance of recovery.[2,3] Recently, various methods have been used to rehabilitate stroke patients. Mirror therapy (MT), for example, is known to be effective for rehabilitating hemiplegic patients.[4,5]

For MT, an upright mirror is placed in front of the subject to ensure that he or she can see the reflection of both the unaffected and affected limbs simultaneously. In a systematic review of the effect of MT on paralyzed upper limbs of stroke patients, Pérez-Cruzado et al.[4] reported that its use could alleviate the paralysis. Dohle et al.[6] investigated the effect of MT on upper extremity function in chronic stroke patients, establishing that a regimen of MT training for 30 min a day, 5 days a week, for 4 weeks improved finger function. In another study, Invernizzi et al.[7] performed MT 30–60 min a day for 4 weeks of MT on subacute stroke patients in addition to conventional therapy (CT) and reported improved results of the Action Research Arm Test, Motricity Index, and Functional Independence Measure (FIM) instrument. Generally, it is reported that motor function can be improved by increasing the amount of exercise.[8,9] Sonoda et al.[10] and Mori et al.[11] reported that increasing the training frequency for stroke patients from 5 days a week to 7 days a week improved the FIM score and lower limb motor function.

Although previous studies have reported the effects of MT for >30 min a day, 5 days a week, they have not reported on the effect of daily MT. Our aim was to investigate whether MT is more effective on motor function recovery in patients with subacute stroke than CT during a regimen that, following CT training, MT is applied every day for a short time (20 min).

Methods

Subjects

The subjects were recruited from first-stroke hemiplegic patients admitted to the comprehensive inpatient rehabilitation ward of Fujita Health University Nanakuri Memorial Hospital. Inclusion criteria for each subscore (shoulder and elbow joint, wrist joint, finger) of the upper limb movement items of the Fugl–Meyer Assessment (FMA)[12] of the patient was a score other than the perfect one.

The exclusion criteria were as follows: (1) ≤30 and ≥ 60 days since stroke onset; (2) <4 points comprehension of FIM[13]; (3) patients with rheumatism, a musculoskeletal disorder, heart disease, sitting posture problems, difficulty understanding training instructions, unilateral spatial neglect, and/or severe brain function disorder. The experimental process of this study is shown in Figure 1.

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Corresponding author: Hiroyuki Miyasaka, OTR, PhD
Department of Rehabilitation, Fujita Health University Nanakuri Memorial Hospital, 424-1 Oodori, Tsu, Mie 514-1295, Japan
E-mail: hmiyasak@fujita-hu.ac.jp

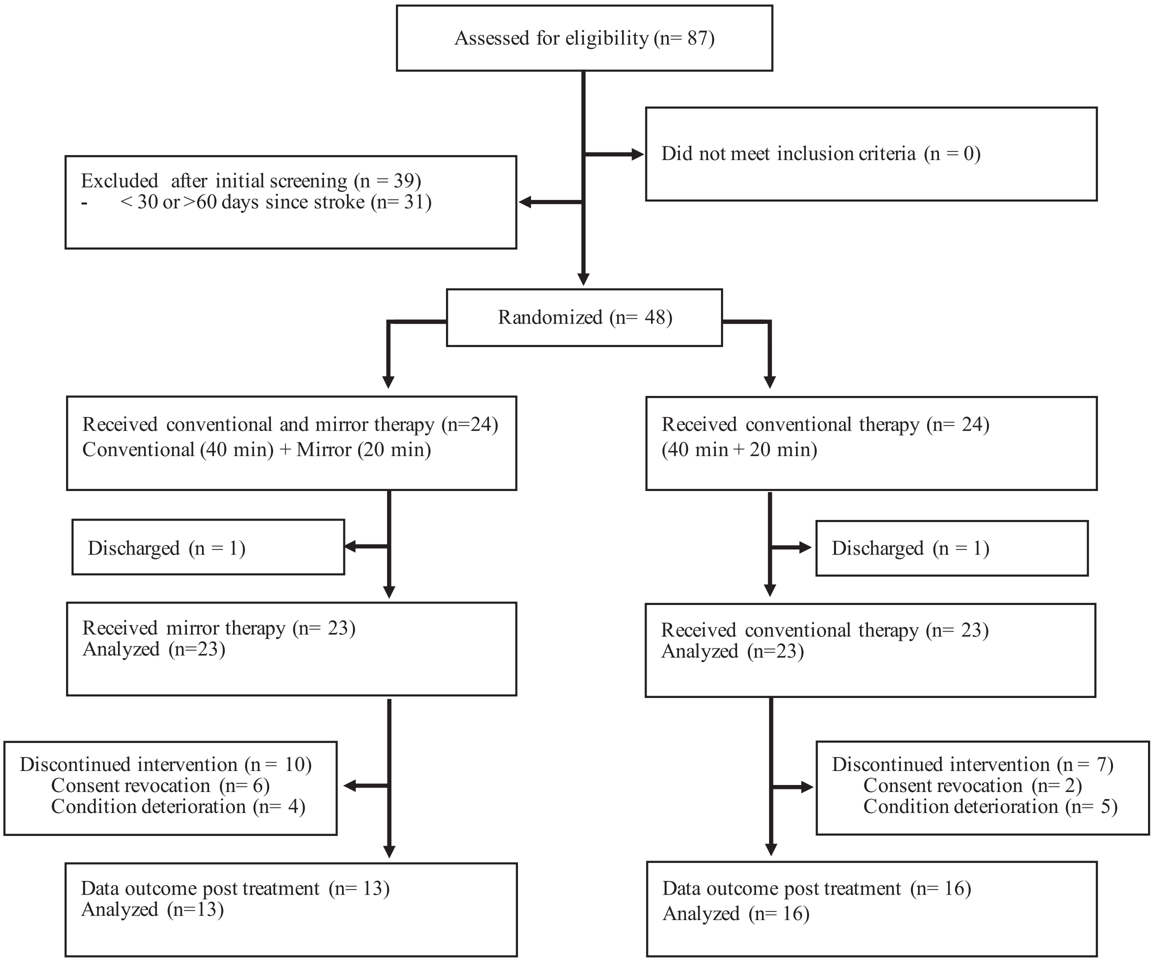

Figure 1 Experiment procedure of the study

Study design

A single-center, blind, randomized, controlled trial procedure was employed in this study. The patients were divided into two groups of MT and CT using a computerized system. Informed consent was obtained from all patients. This study and the experimental procedure were approved by the local Ethics Committee of the Fujita Health University Nanakuri Memorial Hospital, where the study took place (approval number 46). The initial evaluation was performed after the second day of admission, and the training started on the third day. Each patient was evaluated by the occupational therapist assigned to the patient.

Intervention

CT consisted of occupational therapy, which was accomplished daily within 40 min, 7 times a week for 4 weeks during the study period. The MT group then participated in an additional 20 min of MT and the CT-only group with an additional 20 min of CT.

The MT patient sat at desks with a mirror in front of them. They moved both their affected and unaffected arms while observing the projection of the movement of the unaffected arm in the mirror. Patients actively moved the affected arm without assistance from the unaffected arm. Each subject performed eight movements, each lasting 2.5 min. The subjects were exercising at 40 beats/min according to a metronome to maintain a consistent speed while performing the tasks.

Training Tasks

Among the reports of MT applied to stroke patients, the MT training methods varied, with no consensus about the protocol.[7,14–16] The MT training task of the present study was to exercise each part so as to improve the patient's proximal and distal functions.

The MT group training consisted of eight tasks, including arm flexion and extension, arm abduction and adduction, elbow flexion and extension, a 10-cm reach in front, wrist extension, finger flexion and extension, finger opposition movement, and thumb radial abduction. No breaks were allowed during each task.

Assessment

Evaluation of the patient's performance consisted of analyzing the angles of the active shoulder in flexion and abduction and wrist dorsiflexion, upper-limb FMA subscores, sensory items of the Stroke Impairment Assessment Set (SIAS),[17] and the FIM. The patients were evaluated at two points in time: "before" treatment on the 2nd day after admission (Pre) and "after" treatment on the 28th day after admission (Post). These Pre and Post evaluations were also carried out for patients who dropped out.

Statistical analysis

We compared patients' demographics between groups using Student's t test for age and time since the stroke and the χ^2 test for the patient's sex, side of the stroke, hemorrhage-infarction ratio, and the sensory item of the SIAS. The intragroup differences between the Pre and Post evaluation assessment results for both MT and CT were analyzed using Wilcoxon's signed-rank test and the χ^2 test. The gain analyses of the assessment parameters were performed using the Mann–Whitney U test and the χ^2 test. All patients' assessment parameters, including those of the patients who dropped out of the study, were analyzed by intention-to-treat (ITT) methodology.[18] After excluding the patients who dropped out of the study, the per-protocol (PP) analysis method was applied. The statistical analysis was carried out using the Macintosh version of JMP® 12.0 (SAS Institute Inc., Cary, NC, USA). The significance level was set at $p<0.05$.

Results

Among the 48 patients who met the inclusion criteria, two were discharged from the hospital early. Therefore, the Pre and Post assessment parameters were finally analyzed in 46 patients. Table 1 shows that there were no significant demographic differences between the MT and CT groups regarding the ITT and PP results. Figure 1 shows that a total of 17 patients from the combined groups dropped out of the study because of revocation of consent and/or deterioration of their condition. In all, 13 patients in MT group and 16 patients in the CT group finished the study. The average dropout times were 13 days for the MT group and 9 days for the CT group.

Table 2 shows the clinical outcomes according to the Pre and Post assessment parameters. Under both the ITT and PP statistical conditions, shoulder flexion function improved after training in the MT group, whereas there was no improvement in the CT group. The median gains in the shoulder flexion function for active range of motion in the MT group were 10° and 20° for the ITT and PP analyses, respectively. In the CT group, the results from both analyses were 0°. Regarding FMA and FIM, improvements were observed in both groups, with no differences between the two groups.

Discussion

Shoulder functional improvement in post-stroke hemiplegic patients who underwent MT was obvious. In other recent studies, brain physiological mechanisms were investigated following MT. In the studies carried out in healthy subjects, it was reported that during MT excitation was observed in the motor cortex and corticospinal tract.[19,20] Especially in the study by Byblow et al., [20] longer excitation was noted in the motor area of the brain during symmetrical and repetitive movements of both hands than during alternate movement of both hands, suggesting that the reflected image of the healthy hand movement influenced motor learning. Bimanual movement shown in a mirror to hemiplegic patients provoked excitation of the affected side of the cerebral motor area, the precuneus, and the posterior cingulate cortex.[21,22] Hence, the observed reversal of motor impairment in our study could be a result of the visual feedback effect of MT and the neural reconstruction induced by repetitive motor imagery.

However, the only significant improvement compared with that of the CT group was the MT group's shoulder flexion function during active range of motion. In this study, 20 min of MT was added to the ordinary rehabilitation training in the MT group, although the durations of the training of both MT and CT groups were kept the same. All patients performed tasks related to proximal and distal functions of the arm. We think that MT effectively improves proximal function in interventions such as the one described herein in which the training durations were the same and MT was applied to all upper limb joints.

Montgomery et al.[23] reported that the trunk and proximal upper extremity muscles are innervated by the ipsilateral cerebral cortex. Thus, proximal function is thought to achieve greater improvement than distal function because of the bilateral innervation in stroke patients. In this study, alleviation of the paralysis by activating the ipsilateral cortex while giving visual feedback and the influence of the ipsilateral descent path due to activation of the contralesional cortex might contribute to improving control of the paralyzed limb.[24] Therefore, we thought that proximal function was more improved than distal function.

In reported series of both acute and subacute stroke patients, the frequency of MT application has been five times per week.[6,7,25,26] Hence, we hypothesized that increasing MT to a daily basis would improve upper-limb functionality, and we carried out this study. However, the total time of daily MT of our study was 9.3 h per week and less than 5 days per week, which is shorter than that in previous studies, which was 15–16 h total.[6,7,25,26]

Table 1 Patient demographics

Characteristic	Within dropout patients (intention to treat)			Without dropout patients (per protocol)		
	MT group	CT group	p-value	MT group	CT group	p-value
Number	23	23	—	13	16	—
Age (years)	63.0 (11.8)	64.1 (13.4)	n.s.	64.2 (12.9)	63.4 (9.2)	n.s.
Sex (male/female)	14/9	12/11	n.s.	8/5	9/7	n.s.
Paretic side (right/left)	10/13	11/12	n.s.	6/7	7/9	n.s.
Onset of stroke (day)	41.0 (6.1)	42.2 (9.2)	n.s.	40.6 (8.3)	38.8 (5.3)	n.s.
Lesion type (ischemic/hemorrhagic)	16/7	11/12	n.s.	8/5	9/7	n.s.
FIM						
Motor item	50.8 (18.2)	44.7 (17.8)	n.s.	51.2 (16.9)	47.2 (16.5)	n.s.
Cognitive item	27.4 (6.2)	26.3 (7.4)	n.s.	27.0 (6.2)	25.3 (8.0)	n.s.
SIAS upper extremity sensory						
Light touch [0/1/2/3]	1/11/2/9	1/7/8/7	n.s.	1/6/1/5	1/5/5/5	n.s.
Position [0/1/2/3]	3/5/7/8	3/5/7/8	n.s.	2/1/6/4	2/5/4/5	n.s.

Values are means (SD)
MT: mirror therapy; CT: conventional therapy; FIM: functional independence measure; SIAS stroke impairment assessment set; n.s.: not significant.

Table 2 Clinical outcomes

Parameter	With dropout patients (intention to treat)						Without dropout patients (per protocol)					
	MT (n=23)			CT (n=23)			MT (n=13)			CT (n=16)		
	Pre	Post	Gain	Pre	Post	Gain	Pre	Post	Gain	Pre	Post	Gain
Active ROM												
Shoulder flexion	35 [0–82.5]	45** [0–125]	10 [0–35]	20 [0–85]	20 [0–120]	0† [0–0]	50 [0–85]	85** [40–125]	20 [5–40]	7.5 [0–85]	7.5 [0–122.5]	0† [0–1.3]
Shoulder abduction	45 [0–77.5]	50* [30–110]	0 [0–27.5]	30 [0–80]	40* [0–102.5]	0 [0–10]	40 [0–85]	60* [35–110]	15 [0–30]	17.5 [0–80]	35 [0–112.5]	0 [0–17.5]
Wrist extension	0.0 [0–37.5]	15* [0–45]	0 [0–10]	0 [0–42.5]	25* [0–47.5]	0 [0–7.5]	30.0 [0–40]	35 [10–40]	0 [0–10]	0 [0–41.3]	0 [0–47.5]	0 [0–6.3]
FMA												
Shoulder/elbow	7 [2–22.5]	10** [6–26.5]	1 [0–4.5]	14 [0–22]	15** [1–25.5]	2 [0–4]	7 [6–22]	18** [9–27]	4 [1–8]	2.5 [0–23]	5* [0–24.8]	2 [0–4]
Wrist	0 [0–6]	4* [0–8]	0 [0–1.5]	2 [0–5.5]	3* [0–7]	0 [0–2]	5 [0–6]	5 [0–7]	0 [0–2]	0 [0–5.3]	0 [0–7]	0 [0–0.5]
Finger	1 [0–8.5]	2** [0–11.5]	0 [0–1.5]	2 [0–0]	6** [0–13]	1 [0–3]	6 [1–10]	7** [1–14]	1 [0–3]	0 [0–8.5]	1* [0–13]	0 [0–1.5]
Total	11 [2–35.5]	22** [7–43.5]	2 [0–6]	16 [0–37.5]	22** [1–5.5]	4 [0–8.5]	18 [6–35]	29** [10–46]	4 [2–3]	2.5 [0–35.8]	6* [0–44.3]	1.5 [0–6.5]
FIM												
Motor	54 [42.5–62]	74** [61–78.5]	17 [9–19.5]	46 [30.5–56.5]	66** [46.5–76]	15 [11–20]	55 [44–62]	74** [61–79]	17 [13–19]	48.5 [34–55.3]	70** [48.8–80]	15.5 [11.8–19.5]
SIAS												
Light touch (0/1/2/3)	1/11/2/9	0/6/9/8	n.s.	1/7/8/7	1/6/4/12	n.s.	1/6/1/5	0/3/6/4	n.s.	1/5/5/5	1/5/3/7	n.s.
Position (0/1/2/3)	3/5/7/8	1/6/5/11	n.s.	3/5/7/8	1/5/7/10	n.s.	2/1/6/4	1/2/3/7	n.s.	2/5/4/5	0/5/5/5	n.s.

Values are expressed as the median (lower and upper quartiles)
MT: Mirror therapy group; CT: conventional therapy group; ROM: range of motion; FMA: Fugl-Meyer assessment; FIM: fuctional independence measure; SIAS: stroke impairment assessent set; n.s.: not significant
* Significant improvement at 4 weeks after training compared with before training (** $p<0.01$, * $p<0.05$)
† Significant difference in gain between MT and CT (†† $p<0.01$, † $p<0.05$)

Lee et al.[25] reported a total of 16.7 hours of MT for acute-stage stroke patients and noted a 9.5-point improvement in the shoulder and elbow FMA items. Investigating the effect of MT in chronic stroke patients, Arya et al.[14] reported that MT was performed for a total of 30 h, with the FMA shoulder and elbow items improving by 4.5 points and the wrist and finger items by 6.2 points. In addition, Wu et al.[15] reported that MT was performed for a total of 20 h, and the FMA shoulder and elbow items improved by 3.1 points and the wrist and finger items by 2.3 points. The training times of all the studies were longer than in this study, and their improvement rates according to the FMA items were better than in our study.

Thus, for better results of MT application, it seems that increasing the MT period is essential. In future studies, it will be necessary to investigate further the optimal period for MT application.

Study Limitations

There were limitations to this research study. First is the number of patients who dropped out of the MT group. As a result, the level of paralysis of the patients in the MT and CT groups varied, and more data from patients with severe paralysis in the CT group was used for the PP analysis (Table 2). This could have affected the results of our study, which showed no statistically significant difference in the baseline parameters between the two groups. The reason for using both the ITT and PP analyses in this randomized, controlled study was based on a CONSORT 2010 Statement recommendation.[27] In the future, we hope to perform a study with a larger number of matched functional-level patients.

Second, the training methods of the control group were different from those of the MT group. Yavuzer et al.[16] reported that the control group undertook the same training methods as the MT group without a mirror. Colomer et al.[28] reported that the control group underwent passive mobilization. Thus, the training methods of the control group differed in each study, with no consensus. In the future, it is necessary to analyze the details of the training methods of the control group.

The third limitation of this study is the duration of the intervention. We investigated the effect of the rehabilitation interventions that took place seven times a week. We obviously could not compare intervention periods of 3–5 days a week with those conducted 7 days a week. Therefore, future studies are necessary to examine the effects of using the same training times with MT.

Conclusion

MT was applied in this study for 20 min per day, 7 times a week, for 4 weeks. Our results indicated significant improvement in shoulder function in the MT group. There were no significant improvements in the functions of other joints. We think that in the MT trial, the total training time more clearly reduced the extent of the paralysis than its frequency. In future studies, further investigation of increasing period of MT are necessary.

Conflict of Interest

The authors have no conflict of interest directly relevant to the content of this article.

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