Effects of Mirror Therapy on Subacute Stroke Patients’ Brain Waves and Upper Extremity Functions

SEA HYUN BAE, MSc, PT1), WOO SIK JEONG, MSc, PT2), KYUNG YOON KIM, PhD, PT3)

1) Department of Physical Therapy, Gwangju Heemang Hospital
2) Department of Physical Therapy, Namgyeong Mirae Hospital
3) Department of Physical Therapy, College of Health and Welfare, Dongshin University: 252 Daeho-dong, Naju-si, Chonnam 520-714, Republic of Korea. TEL: +82 62-330-3395, FAX: +82 62-330-3394, E-mail: redbear7@daum.net

Abstract. [Purpose] The purpose of this study was to examine the effects of mirror therapy on subacute stroke patients’ brain waves and upper extremity functions. [Subjects and Methods] Twenty patients who experienced the onset of stroke within six months prior to this study were randomly and equally assigned to a control group (n=10) and a mirror therapy group (n=10). In addition to the existing rehabilitation treatment, the control group received sham therapy and the mirror therapy group received mirror therapy for 30 minutes each time, five times per week, for four weeks. Prior to and after the intervention, the changes in the subjects were measured using electroencephalography (EEG) and a manual function test (MFT). [Results] Mu rhythm suppression at C3, Cz, and C4 was significant in both groups after the intervention, with a more effective result in the mirror therapy group. Mu rhythm suppression was compared between the two groups after the intervention: it significantly differed between them at C3, Cz, and C4. According to the MFT results, manual functions improved significantly in both groups, with a better enhancement in the mirror therapy group. Each group also saw significant changes in its MFT results after the intervention. [Conclusion] Mirror therapy had an effect on mu rhythm suppression, improving brain activities and positively influencing motor function recovery. It is simple to apply, and patients can perform it independently. It is also cost-effective. Therefore, it is considered to be useful as part of a rehabilitation program for subacute stroke patients. 

Key words: Mirror therapy, Mu rhythm, Manual function test

INTRODUCTION

Eighty-five percent of stroke patients experience upper extremity motor dysfunction1). They do not precisely know what their motor ability is and tend to have a negative perception about it. Such perceptions discourage their willingness to actively participate in rehabilitation treatment2). Therefore, in order to induce them to actively participate, cognitive intervention as well as physical exercise is necessary3).

Cognitive intervention methods include the mirror therapy proposed by Altschuler et al., cognitive exercise therapy, and constraint-induced movement therapy4). Among these, mirror therapy provides the visual illusion of a functional paretic limb by using the mirror reflection of the non-paretic limb, thereby improving the function of the paretic limb5). It is simple to apply, cost-effective, and can improve a patient’s upper extremity function through his or her voluntary participation6).

Mirror therapy is a treatment method focusing on movement of the non-paretic limb7) and was first introduced by Ramachandran et al. as a method for treating phantom pain after an amputation8). Subsequently, different relevant experiments with stroke patients have been carried out, but research on mirror therapy for upper extremity function recovery has been lacking.

Thirumala et al. reported that bilateral inferior parietal areas and the supplementary motor area, which is part of the primary motor cortex, were activated by mirror therapy9). However, no relevant research on brain waves has been performed. Accordingly, the aim of this study was to examine the effects of four weeks of mirror therapy in combination with the existing rehabilitation treatment on upper extremity function recovery in stroke patients.

SUBJECTS AND METHODS

Subjects

The subjects of this study were 20 stroke patients who experienced the onset of stroke within six months prior to the study. Those who met at least one of the following criteria were excluded: those who did not understand the treatment method of this study; those whose mini-mental state examination (MMSE) scores were 15 or lower; those who had visual impairment; those who had damage to the musculoskeletal system or peripheral nerve on the paretic
side; those whose modified Ashworth scale (MAS) was at 3 or higher for their spasticity degree; and those whose Brunnstrom stage was either 1 or between 5 and 6 for motor function recovery10). All the subjects voluntarily consented to participate in this study prior to its initiation. Data collection was carried out after approval of the Institutional Review Board of Donshin University was obtained. Table 1 shows the general characteristics of the subjects.

### Methods

Using a card composed of odd and even numbers, the subjects were randomly assigned to a control group and a mirror therapy group. In addition to the existing rehabilitation treatment, the control group received sham therapy and the mirror therapy group received mirror therapy for 30 minutes each time, five times per week, for four weeks. For the sham mirror therapy, the control group sat up straight without a mirror, and the intervention was applied to their paretic side only, with their non-paretic side in a comfortable position. For mirror therapy, the mirror therapy group sat up straight, the mirror was placed with the reflective surface between their bilateral upper extremities and directed toward the paretic side, and the patients conducted exercise looking at the reflective surface. They were directed to move their non-paretic upper limb and their paretic upper limb together as they followed the reflected movements. The two groups performed a total of five exercises for six minutes: flexion and extension of the glenohumeral joint in a neutral position; radial deviation and ulnar deviation; supination and pronation; simultaneous flexion and extension of the metacarpophalangeal and proximal interphalangeal joints of the four middle fingers; and flexion and extension of the thumb joint. They performed these exercises five times, for a total of 30 minutes.

Their brain waves were measured using QEEG-8 (LXE5208, Laxtha Inc., Korea). In accordance with the International 10–20 System of Electrode Placement, working electrodes were attached to C3 (left central fissure), Cz (central fissure), and C4 (right central fissure), and reference electrodes were placed on the areas behind the ears. C3 and C4 are primary sensorimotor areas, and Cz is a supplementary motor area. These three areas directly engage in the process of planning and outputting exercise orders during actual motor function performance11). The sampling frequency of the data was 256 Hz, and the data were stored on a computer using a pass filter of 0.5 to 50 Hz and a 12-bit analog-to-digital converter.

Brain waves were measured from when the subjects started the five types of exercises, and data on exercises for four minutes, excluding the first and last minutes, were used12). For brain waves at rest, data on four minutes with the patients at rest without performing any task were used. The values of mu rhythm suppression were calculated from the data on brain waves measured during the experiment. Mu rhythm suppression occurs by mere observation of task performance without actual exercise performance at frequencies between 8 and 13 Hz at C3, Cz, and C413). The values of mu rhythm suppression were calculated from the values measured while the patients were at rest with their eyes open.

Log transformation values were used because the ratio data did not have a normal distribution. The more below zero a brain area’s log transformation value is, the more the area becomes activated14).

A total of eight items were evaluated under the manual function test: (1) flexion, (2) abduction, (3) external rotation, and (4) internal rotation of the shoulder joint; (5) ability to grab or raise a ball; (6) ability to pick up a pencil, a coin, and a needle; and the numbers of 64-cm³ cubes the subject could move within (7) 5 seconds and (8) 30 seconds15).

SPSS 12.0 for Windows was employed for statistical analysis, and brain waves and upper extremity functions were compared prior to and after the experiment using a paired t-test. When both groups showed improvement after

### Table 1. Characteristics of study participants

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Control (n=10)</th>
<th>Mirror therapy (n=10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>52.6 ± 11.2</td>
<td>55.2 ± 8.5</td>
</tr>
<tr>
<td>Sex (male/female)</td>
<td>7/3</td>
<td>6/4</td>
</tr>
<tr>
<td>Time since onset (months)</td>
<td>4.8 ± 1.0</td>
<td>4.4 ± 1.1</td>
</tr>
<tr>
<td>Affected side (right/left)</td>
<td>4/6</td>
<td>3/7</td>
</tr>
<tr>
<td>Cause (hemorrhage/ischemic)</td>
<td>5/5</td>
<td>6/4</td>
</tr>
<tr>
<td>Modified Ashworth scale (n)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1+</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Brunnstrom stage of hand (n)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

(mean ± SD)
the experiment, their results were compared and analyzed using an independent t-test. The statistical significance level was set at α=0.05.

RESULTS

Mu rhythm suppression was significant after the treatment at C3 (p<0.01), Cz (p<0.05), and C4 (p<0.05) in the control group and at C3 (p<0.001), Cz (p<0.001), and C4 (p<0.001) in the mirror therapy group relative to reference values of mu rhythm suppression measured prior to the treatment. In particular, the changes at C3 were most significant. Differences between the two groups after the treatment were significant at C3 (p<0.05), Cz (p<0.01), and C4 (p<0.01) (Table 2).

Upper extremity functions in MFT significantly improved in the control group (p<0.01) and the mirror therapy group (p<0.001) compared with reference values of MFT measured prior to the treatment. There were significant differences between the two groups in MFT after the treatment (p<0.05) (Table 3).

DISCUSSION

This study, whose subjects were subacute stroke patients, applied mirror therapy to a mirror therapy group and exercise on the paretic side without a mirror to the control group for four weeks in order to look at brain wave and upper limb function changes in hemiplegic patients. Mirror therapy provides the visual illusion of a functional paretic limb by using the mirror reflection of non-paretic limb movements observed by an exerciser, thereby improving the function of the paretic limb5). Such action observations trigger activation of brain areas and muscles engaging in actual performance of the observed activities11, 13). In this study, activation of brain areas during mirror therapy was measured using mu rhythm waves, and changes in upper extremity functions in accordance with muscle activity were examined using MFT.

The frequency of the mu rhythm ranges from 8 to 12 Hz within alpha waves at C3, Cz, and C4. In general, the mu rhythm appears in the primary sensorimotor areas and the supplementary motor areas, mu rhythm activity increases at rest, and mu rhythm suppression occurs during performance of goal achievement exercise or observation. Such mu rhythm suppression translates into activation of the relevant brain areas16).

In the present study, mu rhythm suppression occurred in both the control group and the mirror therapy group (Table 2). In other words, both groups saw their relevant brain area activity increase. In comparison between the two groups, however, mu rhythm suppression was more significant in the mirror therapy group than in the control group (Table 2). This result means that activation of the brain areas related to upper extremity functions was higher in the mirror therapy group than in the control group. Holmes measured mu rhythms of stroke patients by making them observe motions with movements and motions without movements and reported that mu rhythm suppression was stronger when the subjects observed motions with movements17). The above results suggest that observing activities suitable for the aim of such activities increases activation of the relevant brain areas.

In the present study, mu rhythm suppression occurred in both the control group and the mirror therapy group (Table 2). In other words, both groups saw their relevant brain area activity increase. In comparison between the two groups, however, mu rhythm suppression was more significant in the mirror therapy group than in the control group (Table 2). This result means that activation of the brain areas related to upper extremity functions was higher in the mirror therapy group than in the control group. Holmes measured mu rhythms of stroke patients by making them observe motions with movements and motions without movements and reported that mu rhythm suppression was stronger when the subjects observed motions with movements17). The above results suggest that observing activities suitable for the aim of such activities increases activation of the relevant brain areas.

Besides, in the present study, suppression of the mu rhythm at C3, which shows activation of the left hemisphere of the brain, was considerable (Table 2). Perry et al. noted that mu rhythm suppression was stronger at the contralateral hemisphere than at the ipsilateral hemisphere when observing the hand18). This was probably because a majority of participants observed their right upper limb. Nonetheless, mirror therapy enables bilateral exercise, which may result

Table 2. Change in brain wave between the control and mirror therapy group

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Control</th>
<th>Control</th>
<th>Mirror therapy</th>
<th>Mirror therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>C3μ</td>
<td>–0.06 ± 0.03</td>
<td>–0.11 ± 0.04**</td>
<td>–0.06 ± 0.03</td>
<td>–0.16 ± 0.04***</td>
</tr>
<tr>
<td>Czμ</td>
<td>–0.11 ± 0.04</td>
<td>–0.15 ± 0.04*</td>
<td>–0.10 ± 0.04</td>
<td>–0.21 ± 0.05***</td>
</tr>
<tr>
<td>C4μ</td>
<td>–0.08 ± 0.03</td>
<td>–0.11 ± 0.04*</td>
<td>–0.09 ± 0.03</td>
<td>–0.18 ± 0.06***</td>
</tr>
</tbody>
</table>

(Mean±SD) The changes in mu rhythm are shown as means±standard deviation. A paired t-test was conducted in order to examine differences between before and after the treatment in the control group and mirror therapy group (*p<0.05; **p<0.01; ***p<0.001), and an independent t-test was carried out in order to look at differences between the two groups after the treatment (#p<0.05; ##p<0.01).

Table 3. Change in upper limb function between the control and mirror therapy group

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Control</th>
<th>Control</th>
<th>Mirror therapy</th>
<th>Mirror therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>MFTμ</td>
<td>13.10 ± 2.28</td>
<td>14.20 ± 2.34**</td>
<td>12.40 ± 2.37</td>
<td>17.10 ± 3.03***</td>
</tr>
</tbody>
</table>

(Mean±SD) The changes in MFT are shown as means±standard deviation. A paired t-test was conducted in order to examine differences between before and after the treatment in the control group and mirror therapy group (**p<0.01; ***p<0.001), and an independent t-test was carried out in order to look at differences between the two groups after the treatment (#p<0.05).
in activation of the bilateral hemispheres.

MFT was conducted to examine the effects of mirror therapy on upper limb functions. MFT scores significantly improved in both groups, and upper limb function recovery occurred in both groups (Table 3). However, comparative analysis of the two groups showed that upper limb functions improved by more in the mirror therapy group than in the control group, suggesting more functional recovery in the former (Table 3). This study result is consistent with those of other researchers who found that mirror therapy applied to stroke patients led to improvement in Brunnstrom motor recovery (BMR) and functional independence measurement (FIM).

Mirror therapy activates mirror neurons of the brain. Mirror neurons visually transform motions into images and conduct the process of exercise performance. Yavuzer et al. observed that symmetric movements of both hands activated the bilateral hemispheres and increased activation of the paretic hemisphere through interaction between the hemispheres. Summers et al. reported that concurrent movements of the paretic and non-paretic upper limbs were more effective in increasing activation of the motor cortex and recovering motor functions than movements of the paretic upper limb.

Stroke patients undergo excessive excitation of the motor cortex (M1) of the non-paretic side, which triggers cortex suppression of conduction through the corpus callosum, lowering the mobility of the paretic side. On the other hand, Cauraugh et al. asserted that bilateral exercise adjusted the balance between the paretic side and non-paretic side and prevented excessive suppression of conduction.

In the present study as well, the mirror therapy group, which performed bilateral movements while observing the non-paretic side through a mirror, saw their relevant brain areas activated more than the control group, and the mirror therapy group’s motor functions recovered more than the control group’s. This is considered to be because observing movements of the non-paretic upper limb resulted in visual stimulation and positive visual feedback, thereby helping motor function recovery. Altschuler et al. noted that positive visual feedback replaced decreased proprioceptive information, which facilitated mobilization of the premotor cortex.

In the present study, mirror therapy led to mu rhythm suppression and resulting activation of the brain hemisphere, which was found to influence motor function recovery. Mirror therapy is simple to apply and can be performed by patients with minimal intervention by therapists. It is also cost-effective. Accordingly, mirror therapy will be useful as a rehabilitation treatment method for subacute stroke patients.

REFERENCES

17) Holmes P: Evidence from cognitive neuroscience supports action observation as part of an integrated approach to stroke rehabilitation. Man Ther, 2011, 16: 40–41. [Medline] [CrossRef]