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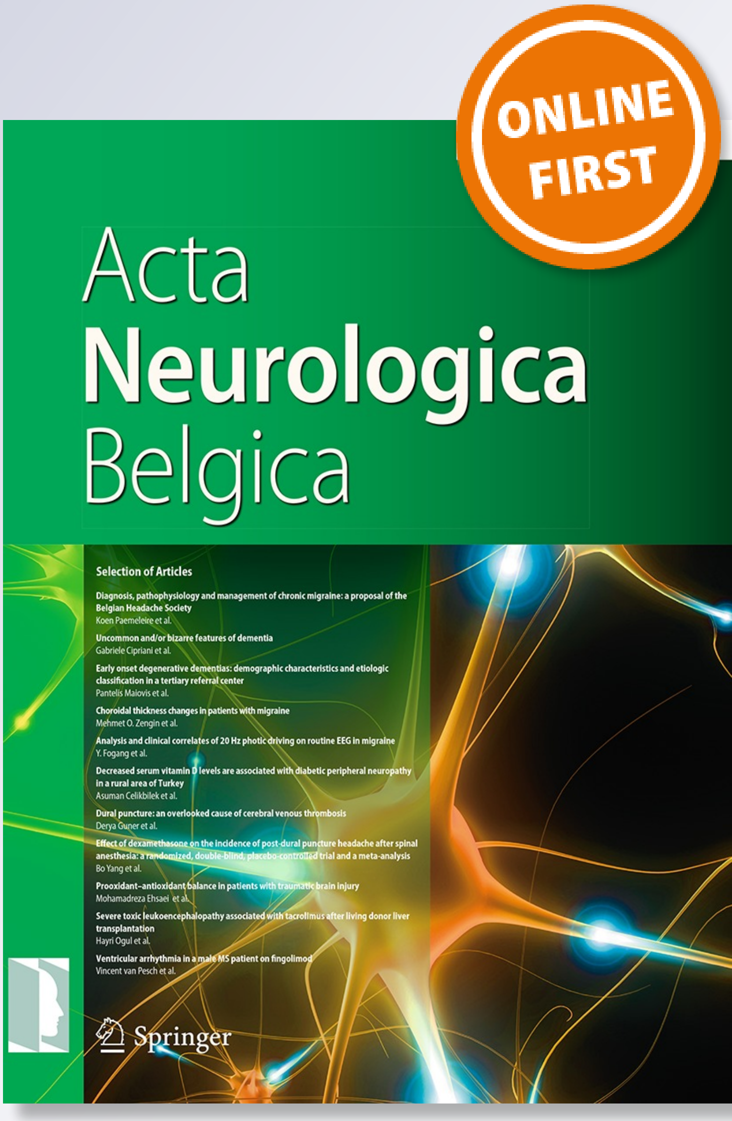
Acta Neurologica Belgica

ISSN 0300-9009

Acta Neurol Belg
DOI 10.1007/s13760-015-0465-5



Springer

Acta Neurol Belg
DOI 10.1007/s13760-015-0465-5

ORIGINAL ARTICLE

Mirror therapy enhances upper extremity motor recovery in stroke patients

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Received: 25 November 2014 / Accepted: 23 March 2015

Abstract The purpose of this study was to evaluate the effects of mirror therapy program in addition with physical therapy methods on upper limb recovery in patients with subacute ischemic stroke. 15 subjects followed a comprehensive rehabilitative treatment, 8 subjects received only control therapy (CT) and 7 subjects received mirror therapy (MT) for 30 min every day, five times a week, for 6 weeks in addition to the conventional therapy. Brunnstrom stages, Fugl–Meyer Assessment (upper extremity), the Ashworth Scale, and Bhakta Test (finger flexion scale) were used to assess changes in upper limb motor recovery and motor function after intervention. After 6 weeks of treatment, patients in both groups showed significant improvements in the variables measured. Patients who received MT showed greater improvements compared to the CT group. The MT treatment results included: improvement of motor functions, manual skills and activities of daily living. The best results were obtained when the treatment was started soon after the stroke. MT is an easy and low-cost method to improve motor recovery of the upper limb.

Keywords Stroke · Mirror therapy · Upper limb extremity · Motor recovery

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Introduction

Stroke is one of the most frequent disabling pathologies in neurological practice [1], and a significant proportion of the survivors does not achieve a good quality of life despite all therapeutic intervention [2]. Although complex motor, sensory and cognitive dysfunctions contribute in various proportions to the global disability, motor impairment is often the most striking deficit. While direct lesions/destruction of the motor structures certainly plays the most important role in causing neurological dysfunction, imbalance in cerebral informational systems and reaction mechanisms responding to damage—and similarly to training—account both for part of the dysfunction and for the recovery process. Considering that natural recovery is the result of brain's effort to rebalance itself, rehabilitation should guide neuroplasticity until best use of the existing resources is achieved.

Gait is crucial to most current activities, and is often one of the first targets of a structured rehabilitation program. Since long-time compliance to intensive rehabilitation is difficult to achieve and also since lower limb recovers more easily, many of the stroke survivors attain lower levels of performance of the upper limb [3], with up to 70–80 % of them maintaining persistent impairment of the upper extremity movement [4]. This is why newer rehabilitation approaches—as constraint-induced movement therapy, mental practice, mirror therapy, virtual reality or repetitive task practice, concentrate on the upper limb in an effort to improve its functional prognosis.

Mirror therapy (MT) has been developed by Ramachandran and Roger-Ramachandran [5] in an attempt to control abnormal sensation in phantom limb syndrome. It has also been used in complex regional pain syndrome [6], amputation [7, 8] and stroke [7]. It acts by providing a false input to the brain, that in turn integrates it into a multimodal sensation or action: the patient has the illusion that the healthy limb he sees moving in the mirror is the affected one (that is hidden behind it), and associates correct movement with his intention/tentative.

The exact mechanisms mirror therapy triggers are not clear. Different methods to evaluate cortical reaction and variable clinical paradigms make results difficult to compare and interpret—it is clear though that mirror-assisted movement influences the inter-hemispheric dialog, and that more than just motor areas are activated. In a magnetoencephalography study, presence of the mirror changed the initial asymmetrical pattern of activation elicited during bimanual tasks in stroke patients to a more symmetrical pattern [9]. Similar results—with a shift in activation balance within the primary motor cortices toward the affected hemisphere solely in the mirror group—were found in an fMRI study [10]. Presence of the mirror did not increase excitability in the opposite M1 area in the absence of motor training in normal subjects, but it has modulated inter-hemispheric transcallosal inhibition, increasing the effect the active hemisphere has on the contralateral one [11]. In other papers, authors conclude that the non-moving/affected M1 area is activated after mirror therapy [12, 13]. The mirror illusion increases activity in the precuneus and the posterior cingulate cortex, areas associated with awareness of the self and spatial attention [14].

There are a limited number of studies on mirror therapy in stroke. A 2009 review [15] identified 5 studies, in 2012 another review found 14 studies [16] while in 2014 a number of 33 articles were found suitable [14]. Most of the available reviews show that mirror therapy is able to improve upper limb function [7, 15–18]. Whether it is able to do so alone or just in association with other therapeutic approaches is not clear, as most of the study paradigms associate MT with another type of therapy. An overview of Cochrane and other database reviews on different interventions that are thought to improve upper limb function in stroke provided moderate-quality evidence for a beneficial effect of MT on impairment, upper limb function and activities of daily living, suggesting that it may be effective. The same review concludes that in present, no high-quality evidence can be found in support of any of the approaches (either specialized interventions or part of routine practice), and also that evidence is insufficient to enable comparison of the relative effectiveness of interventions [17].

Mirror therapy has been studied in several clinical trials, but most of the patients were in the chronic phase of stroke. In this study, we try to evaluate the efficacy of MT combined with classical treatment in improving motor recovery of the upper limb in subacute stroke patients and also we try to evaluate if this simple, cost-effective therapy can be beneficial for patients recovering from the early phase after stroke.

Patients and methods

Twenty-three patients with hemiparesis following a first stroke (documented by CT scan), time from stroke (between 1 and 3 months) and without severe attention deficit, were selected for the study. After clinical and paraclinical evaluation, 5 patients were excluded. Exclusion criteria were global aphasia, cognitive impairments that might interfere with understanding instructions for testing, concomitant progressive central or peripheral nervous system disorders. Patients were informed about the objective of the study and were required written consent. 15 participants with subacute ischemic stroke, both women and men aged between 56 and 68 years, agreed and signed an informed consent form before joining the study. The study was realized in the Clinical Hospital of Rehabilitation, in the Department of Neurological Rehabilitation and was carried out in accordance with the Helsinki Declaration.

After enrolment patient information was entered into a computer. The computer randomly assigns patients in two groups: mirror therapy group (MT) and control group (CT). This was a single-blinded trial. All the patients received a 6-week conventional stroke rehabilitation program for the upper limb, consisting of five—half an hour sessions a week. The control therapy consisted in neurorehabilitation techniques, electrical stimulation and occupational therapy. Flow chart of the trial selection process can be seen in Fig. 1.

The MT group received both, control therapy and 30-min mirror therapy sessions (5 session/week, 6 weeks) consisting of mirror seen unaffected upper limb movements. Patients were seated on a chair, with the mirror positioned between the upper limbs perpendicular to the subject's midline and with the unaffected upper limb facing the reflective surface. Under the supervision of the physiotherapist, the patients observed the reflection of their unaffected limb while performing the following movements with the both arms, the affected one as good as possible: flexion and extension of the shoulder, elbow, wrist and finger, prone supination of the forearm (Fig. 2).

Motor recovery was measured using the Brunnstrom stages, the Fugl–Meyer Assessment (upper extremity), the Ashworth Scale and the Bhakta test. The Fugl–Meyer Assessment (FMA) upper extremity is a stroke-specific, performance-based impairment index. It is designed to assess motor functioning, sensation and joint functioning (passive joint motion and joint pain) in patients with post-stroke hemiplegia [19, 20]. It is applied clinically and in research to determine disease severity, describe motor

Fig. 1 Flow chart of the trial selection process

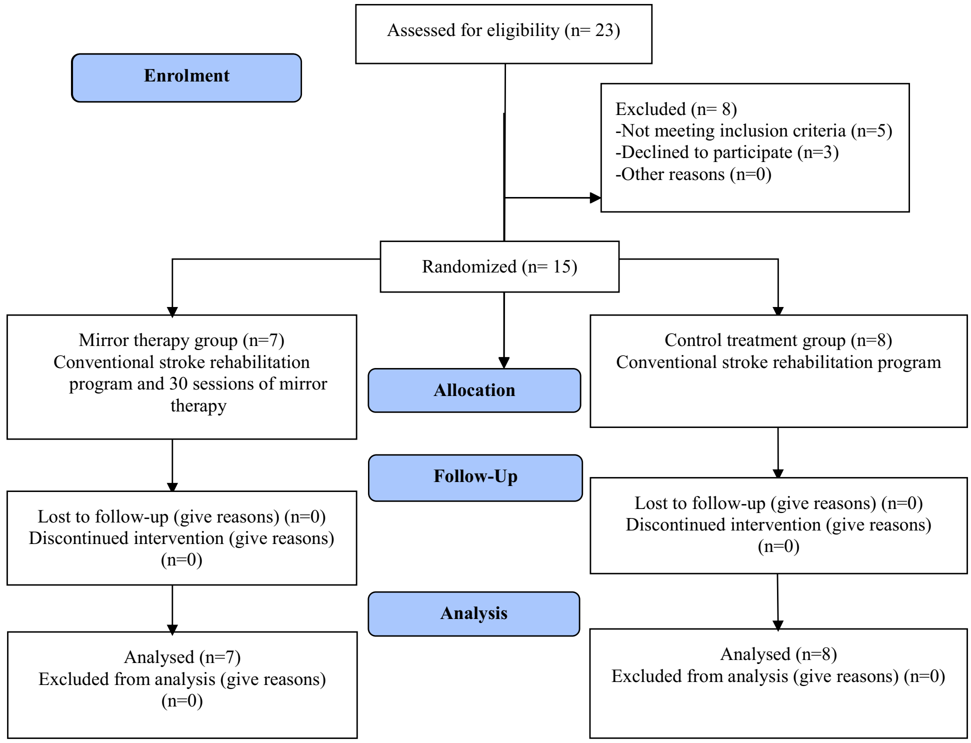

Fig. 2 Patient following mirror therapy

recovery, and plan and assess treatment. The Ashworth Scale is widely used for grading spasticity in patients with lesions of the central nervous system. Scores range from 0—indicates no resistance to 5—indicates rigidity [21].

The finger flexion scale (Bhakta) estimates the number of how many fingers of the examiner may enter without difficulty into the palm of the hand of the person assessed: 0-clenched fist, 1 finger: ¼ open, 2 fingers: ½ open, 3 fingers: ¾ open, 4 fingers: fully open [22]. Initial and final evaluations were made 1 day before and 1 day after the treatment period. None of the patients missed a session during the study and all of them finished the treatment period.

The statistical analysis of the results was performed using the software package STATISTICA 6.0 (StatSoft Inc., USA). The values are presented as mean values and standard deviation ($M \pm s$). To compare age, gender, affected side, stroke duration, we used t student test and for Brunnstrom stages, the Fugl–Meyer Assessment (upper extremity), the Ashworth Scale and the Bhakta Test we used one-way analysis of variance (ANOVA) to determine the differences between the groups. The values were considered statistically significant at the 5 % level ($p < 0.05$).

Results

We compared the baseline characteristics among 7 patients of the MT group and 8 patients of the control group, who received treatments for 6 weeks. There were no statistically significant differences in the sex, age, sites of stroke, and affected sides between the two groups (Table 1). The baseline assessments had no statistically significant difference between the groups. All parameters in the MT combined with conventional stroke rehabilitation program group showed significant improvements when compared with control group.

The Brunnstrom stage initial was 3.16 ± 0.71 and after therapy 4.52 ± 0.54 with $p < 0.005$ for patients in MT group. Also in CT was 3.28 ± 0.75 before and 4.33 ± 0.89 after treatment with $p < 0.05$. The Fugl–Meyer Assessment upper extremity score was 34.1 ± 8.4 before and 46.5 ± 7.5 after 6 weeks of rehabilitation, with $p < 0.01$ in MT group. In the control group, there were small statistically significant improvements in the Fugl–Meyer Assessment, $p < 0.05$ (Table 1). When we compare initial and final values using the Ashworth Scale, we see improvements in elbow ($p < 0.02$), wrist ($p < 0.04$) for the MT group and for the CT group, improvements were only in wrist level ($p < 0.05$). Finger flexion scale was statistically significant in MT group with values before 3.44 ± 0.52 and after 3.88 ± 0.33 therapy, $p < 0.04$. For the CT, we did not find any statistically significant improvement (Table 1).

Table 1 Patients characteristic before and after therapy

	MT ($N = 7$)	CT ($N = 8$)	p
Mean age(years)	58.2 ± 7.2	56.8 ± 8.3	0.72
Gender (female/male)	4/3	4/4	0.41
Affected side (right/left)	5/2	5/3	0.73
Stroke duration (days)	54.3 ± 7.9	52.2 ± 12.7	0.38
Brunnstrom Stage			
Initial	3.16 ± 0.71	3.28 ± 0.75	0.72
Final	4.52 ± 0.54	4.33 ± 0.89	0.68
p	**0.005**	**0.05**	
Fugl–Meyer Assessment			
Upper extremity initial	34.1 ± 8.4	38.6 ± 6.2	0.22
Upper extremity final	46.5 ± 7.5	47.3 ± 6.3	0.84
p	**0.01**	**0.04**	
Ashworth Scale			
Shoulder initial	1.72 ± 0.36	1.83 ± 1.44	0.34
Shoulder final	1.53 ± 0.35	1.61 ± 0.41	0.14
p	0.21	0.32	
Elbow initial	1.83 ± 0.55	1.55 ± 0.46	0.26
Elbow final	1.27 ± 0.36	1.33 ± 0.43	0.77
p	**0.02**	0.30	
Wrist initial	1.55 ± 0.48	1.61 ± 0.33	0.19
Wrist final	1.11 ± 0.22	1.38 ± 0.22	**0.01**
p	**0.04**	**0.05**	
Bhakta Test			
Initial	3.44 ± 0.52	3.22 ± 0.19	0.34
Final	3.88 ± 0.33	3.55 ± 0.52	**0.05**
p	**0.04**	0.16	

The p value is a function of the observed sample results (a statistic) that is used for testing a statistical hypothesis. The smaller the p value, the larger the significance because it tell us that the hypothesis under consideration may not adequately explain the observation. We use the term p to describe the probability of observing such a large difference purely by chance in two groups of exactly-the-same people. So 0.5 means a 50 % chance and 0.05 means a 5 % chance

$p > 0.05$ means not statistically significant (the values are not in bold)

$p < 0.05$ means statistically significant (the values are in bold)

After 6 weeks of treatment, patients of MT showed improvements in the Fugl–Meyer Assessment ($p < 0.01$), in the Ashworth Scale only for elbow ($p < 0.02$), wrist ($p < 0.04$) and the Bhakta test ($p < 0.04$) compared to the CT group. If painful symptoms generally improved, according to patients, the statistical processing has not achieved significant results. Both MT and CT were well tolerated and no relevant adverse event was recorded during the study.

Our patients also followed an exercise program for the hand. The practice consisted of no paretic side wrist and finger flexion and extension movements and also prehensions while patients looked into the mirror, watching the image of their non-involved hand, thus seeing the reflection of the hand movement projected over the involved hand. The most important results that we found are in the wrist articulation. As a result, the initial and the final measurements showed that extension increased from 40° ± 7.07° to 56.6° ± 7.06° in MT group ($p < 0.02$); flexion increased from 50.5° ± 9.5° to 63.8° ± 15.5° ($p < 0.02$); pronation from 38.5° ± 7.5° to 57.1° ± 11.2°, $p < 0.05$; supination from 41.4° ± 7.3° to 48.5° ± 9.7°, $p < 0.08$ in the same group. In the CT group, we found small improvements, but only in pronation ($p < 0.05$). Elbow joint testing shows improvements in flexion in MT group ($p < 0.05$). For shoulder, we did not find any statistically significant improvement in any groups.

The MT group had better results, as an effect of the mirror therapy. MT has produced significant improvements when was added to the conventional treatment. From these findings, it can be concluded that there is a significantly greater effectiveness of mirror therapy in stroke patients compared to control treatment.

Discussions

In our study, all the patients received a conventional stroke rehabilitation program for the upper limb, consisting in neurorehabilitation techniques, electrical stimulation and occupational therapy (5 half-hour sessions a week, for 6 weeks). The MT group received beside this program 30 min of mirror therapy. After 6 weeks of treatment, patients of MT showed improvements in the Brunnstrom stage ($p < 0.005$), in the Fugl–Meyer Assessment ($p < 0.01$), in the Ashworth Scale only for elbow ($p < 0.02$), wrist ($p < 0.04$) and the Bhakta test ($p < 0.04$) compared to the CT group. Most improvements were found in the wrist articulation for extension ($p < 0.02$), flexion ($p < 0.02$), pronation ($p < 0.05$) and in elbow only for flexion ($p < 0.05$). For shoulder, we did not find any statistically significant improvement in any groups. Both MT and CT were well tolerated and no relevant adverse event was recorded during the study.

Motor recovery follows a fairly typical schedule in stroke patients, with earlier progress in proximal, global patterns of movement and later (and often incomplete) improvement of the distal abilities. More conscious effort is needed—compared to brute, primitive patterns of movement—when performing fine precise gestures. Intensive/enriched rehabilitation procedures are usually targeting this latter part of the recovery process, and although they seem to be effective, it is not clear how they work. They add to classical motor approaches a multimodal stimulation and, probably more important, constant stimulation of conscious control mechanisms, endurance and skilled movement, sensory attention—through all these mechanisms motor enrichment therapies might activate dormant plasticity mechanisms [23].

When its normal activity is disrupted, the brain tries to reach equilibrium in the least "expensive" way. On a clinical level, when a limb is impaired for a long period of time, learned non-use adds to the initial dysfunction, and the limb is no longer taken into account as the patient manages all actions with the functional limb (emergence of working compensatory behaviors inhibits the use of the available, but underused motor systems) [24]. On a cortical reactivity level, the initial dysbalance of hemispheric activity may be followed by an inhibition of the lesion side by the healthy hemisphere, thus preventing it from fully reaching its potential [25, 26]. Temporary non-functional areas tend to lose their functional connections and in time may become permanently mute/non-functional [27].

'Proper visual input' provided by MT may substitute for some of the missing proprioceptive input from the affected body side [28, 29]. Facilitation of self-awareness, increased spatial attention, and intense concentration required to complete the bimanual task might contribute to better resource utilization and improved quality of movement [27].

It has been shown that incorporating mirror therapy into the conventional stroke rehabilitation program during the early stages [30, 31] of treatment, but also in early chronic stroke [32, 33] and applying it for a sufficiently long period might generate a supplementary improvement of the upper limb function.

Our treatment program was comparable to other studies in terms of intensity and duration [30–33]. Based on the data in the literature and on previous experience, we have appreciated that half an hour rehabilitation sessions suffice, avoiding excessive stress on the patient—mental effort that was required during the MT training was very tiring for the patients, as some of them stated that "I feel less tired when I'm walking for 1 h" or "I feel that something it's happening in my brain, I feel that it works and it is tired." The therapist had the task to ensure the full collaboration of the patient. As we have stated before, attention and complexity of the task are important characteristics that are crucial for the ability of a procedure to induce long-term neuroplasticity [27].

In our study, there was a tendency for better results in patients that had started rehabilitation (and MT) immediately after the stroke, but the size of the study group was not large enough to allow a clear conclusion. As stroke survivors acquire incorrect movement patterns, it is more difficult to replace them with normal motor behavior, and MT could help in correcting these issues.

One of the limitations of our study is the lack of a comprehensive cognitive evaluation (as the impact of attention-dependent techniques might reversely correlate with the patient's cognitive loss). Since we have anticipated an important role for patients' degree of involvement, initial patient selection has discarded patients with major cognitive loss, and none of the included patients showed signs of significant depression. Still, a detailed evaluation might provide information on the exact cognitive domain that has the most importance for rehabilitation.

Adding MT to classical rehabilitation had beneficial effects in terms of motor abilities. The rehabilitation gains were important during treatment, but might be easily lost—especially in case of acute and subacute patients—if rehabilitation ceases [27]. Only few of the previous studies have had a long-term follow-up [32]. Whether the advantage generated by the use of MT persists in time remains to be established, and follow-up might have brought interesting data about the therapeutic effect of our approach.

The tools that we have used to evaluate motor performance provided basic, clear information. Evolution of these parameters during the study (improvement of movement both in distal joints and the elbow, but not in the shoulder) suggests that use of more complex, function-oriented tests (as the 9-hole Pegboard test, Wolf motor function [34], and possibly box and block test or action research arm test [31]), might provide further information on the possible impact of MT use on daily activities.

Our study has shown that after 6 weeks of treatment, the MT group improved more than the CT group in most of the functional parameters of the hemiparetic upper extremity as measured by the Fugl–Meyer Assessment. These results indicate that MT can be effective in improving motor functions in stroke patients. Still, the small number of subjects in our study decreases the statistical power to detect differences between groups, and does not allow us to fully generalize our results.

Conclusions

This study shows that 30 min 5 days of week for 6 weeks of mirror therapy in addition to a conventional stroke rehabilitation program was beneficial in terms of motor recovery of upper limb.

Acknowledgments The research is not financed.

Conflict of interest The authors declare that they have no conflict of interest.

Ethical standard The authors declare that participation were voluntary, all subjects gave their informed consent before entering the study. The study was carried out in accordance with the Helsinki Declaration.

Informed consent Informed consent for publication was obtained from the patient.

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