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Action observation therapy impact on mirror neurons combined with acupuncture for upper limb motor impairment rehabilitation in stroke patients

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Abstract:

OBJECTIVE: Upper limb (UL) dysfunction rehabilitation in stroke patients is complicated in the clinic. Action observation therapy's (AOT) impact on mirror neurons (MNs) has been observed and made applications in related brain disease treatment. Acupuncture mentioned in the present study mainly stimulates peripheral nerves for neuronal plasticity. However, the clinical effect of AOT impact on MNs and acupuncture irritate afferent nerve fibers in combination for UL motor impairment rehabilitation after stroke is still unclear. In the present study, we investigate the central and peripheral neural stimulation meanwhile for UL recovery with stroke patients.

METHODS: In this clinical study, 82 stroke patients recruited with impaired UL were randomly assigned to three groups. Twenty-four cases were in the AOT group, 28 cases were in the AOT combined acupuncture treatment group, and 30 cases were in the acupuncture treatment group. All volunteers were scored for limb function through the Fugl–Meyer Assessment of the Upper Extremity (FMA-UE), the Action Research Arm Test, and the modified Barthel Index (BI) before and after a systematic treatment according to the groups. Meanwhile, conventional physical therapy was also implemented for all cases.

RESULTS: Before the specific intervention, the scores of FMA-UE, FMA-UE, and BI with all stroke patients have no significant statistical difference ($P > 0.05$). After the corresponding treatment, we assessed UL function again at 4 and 8 weeks. At 4 weeks, the patients with AOT showed a significant increase in BI scores compared to the acupuncture group ($P < 0.05$). At 8 weeks, the FMA-UE scores of the patients with AOT combined with acupuncture were significantly increased than acupuncture alone ($P < 0.05$). We also observed that the BI scores of the combination and the AOT group both were improved compared to the acupuncture group with significant statistical analysis ($P < 0.05$).

CONCLUSIONS: Based on the MNs theory, we adopted AOT impact on MNs which would be a promising rehabilitation technique, especially combined with acupuncture treatment in UL recovery of stroke. Mirror therapy seems to be effective for central neuronal plasticity, but for action or AOT, there is still insufficient evidence to recommend its optimal strategy and neuromodulation mechanism. Here, research on the MNs-based AOT technique with acupuncture in UL dysfunction with stroke patients is recommended.

TRIAL REGISTRATION: http://www.chictr.org.cn (identifier: ChiCTR2300077010).

Keywords:

Action observation therapy, acupuncture, mirror neurons, stroke, upper limb dysfunction

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Introduction

Worldwide, 15 million people are committed to stroke each year, with 5 million of those becoming permanently disabled with hemiparesis and spasticity.[1] Among the dysfunctions caused by stroke, over 55%~75% of patients are suffering from upper limb (UL) motor impairment and are having great difficulties in their daily lives.[2] Although the therapeutic technology for UL impairment after stroke have been studied before, there are still significant challenges for its fully recovered.

Mirror neurons (MNs) were discovered serendipitously in 1992.[3] The striking feature of many MNs is that they fire not only when a monkey is performing an action, such as grasping an object using a power grip but also when the monkey passively observes a similar action performed by another. Meanwhile, MN codes, both "my action" and "your action," were originally found in area F5 of the ventral premotor cortex (PMC)[4] and the inferior parietal lobule of the monkey brain.[5] There is now a substantial body of evidence suggesting that MNs are also present in the human brain.[6] Based on the MN findings, Mirror therapy has been proposed for clinical applications, which employ flat mirror imaging to copy the movement picture of the healthy limb to the affected side for encouraging patients to imagine the movement of the injured limb inducing its recoverment.[7] Initially, it was used in the treatment of phantom limb pain,[8] now adopted to research on stroke rehabilitation. Action observation therapy (AOT) activates the motor areas of the MN system (MNS) to improve motor function by generating motor representations.[9] Stroke with internal capsule damage may be alleviated through mirror imagery. It's worth noting that there might exist the retained MNs with suppressed or unfired above action potential threshold. AOT may stimulate these MNs by delivering visual input to enhance limb motor function recovery. It has been supported by studies showing the bilateral ventral anterior motor cortex, bilateral superior temporal gyrus, auxiliary motor area, and contralateral inferior parietal limbic gyrus were be activated in stroke patients.[10] Visual feedback therapy based on the MN theory is suggested as useful for the UL dysfunction rehabilitation and the motor-related cortical function improvement after stroke.[11] AOT impact on MNs has been shown a potential therapy for motor dysfunctions with stroke.

Acupuncture, as a minimally invasive technique, has been widely used for improving symptoms of a variety of health problems in China and worldwide.[12] The damaged motor ability always use acupuncture as a common therapy, which is supposed meridian circulation would open up,blood flow tends to normal the spasm become alleviation.[13] Stimulating acupoints through acupuncture can stimulate brain cells to activate after stimulation and promote the establishment of cerebrovascular collateral circulation in patients.[14] The most commonly used acupuncture points for the treatment of motor disorders are GV20, GB20, LI4, ST36, SP6, LI11, GB39, and motor scalp area.[15] In the present study, based on the theory of meridian in Traditional Chinese Medicine, we have chosen the acupoints consisting of "Baihui (GV20)," "Sishencong (EX-HN1)," "Hegu (LI4)," "Binao (LI14)," "Shousanli (LI10)," "Quchi (LI11)," "Jianyu (LI15)," and "Neiguan (PC6)." The "Baihui (GV20)" point is located on the top of the head and is connected to the brain, so it can awaken the brain and open the mind. "Sishencong (EX-HN1)" is defined as the extrameridian points, the front and back points are on the line of circulation of the Governor pulse, and the left and right points are adjacent to the Foot Taiyang bladder meridian. This point can strengthen the brain, improve intelligence, and calm the mind.[16] Other acupoints belong to "the large intestine channel of Hand-Yangming," which are mainly located in the arms and hands with functions of nourishing Yang, promoting the production of the body fluid, inducing free movement of the bowels, and improving UL myodynamia.[17] Central neuroplasticity is further promoted through peripheral nerves by acupuncture stimulation.

In the present study, we investigated the rehabilitation means, including AOT, acupuncture, and the combination therapy that effect in UR treatment after stroke. We would reveal the two accessible approaches of AOT motivate MNs in the brain and acupuncture stimulate afferent nerve fiber,that whether exert the maximum neuronal function modulation and superior to AOT or acupuncture usage in clinic alone.

Methods

Research participants

A total of 82 patients with UL dysfunction were recruited from the Jing'an Northern Medical Consortium of Shanghai within 6 months after the stroke occurred, and the experimental period was from January 2022 to December 2022. All the participants were randomly assigned to three different groups, including the acupuncture group (Group 1), the AOT combined with acupuncture group (Group 2), and the AOT group (Group 3).

Case diagnosis criteria

The patients were aligned with the criteria for cerebral infarction as delineated in the Chinese Guidelines for the Prevention and Treatment of Cerebrovascular Diseases, orchestrated by the Neurology Branch of the Chinese Medical Association in 2004. Diagnosis of cerebrovascular disease (cerebral infarction) was confirmed through CT or magnetic resonance imaging examinations. The study design secured approval from the Medical Ethics Committee, under the clinical trial registration identifier YL-2021422-01. All patients were candidly apprised of the trial particulars and provided their signed informed consent.

Inclusion and exclusion criteria

The inclusion criteria encompassed the following stipulations: (i) definitive diagnosis of a first-onset ailment within a 6-month, characterized by stable condition, lucid consciousness, and UL dysfunction; (ii) age from 30 to 80; (iii) capability to sign the informed consent document and fulfill training and evaluations with satisfactory compliance; (iv) right-hand dominance; (v) educational attainment surpassing primary school level; (vi) UL dysfunction without originating from skeletal muscle disorders; (vii) Brunnstrom grade spanning II to IV of the distal joint in the affected UL; and (viii) absence of cognitive impairment, with a Mini-Mental State Examination score exceeding 17.

The exclusion criteria were delineated as follows: (i) acute hypertension or cardiopulmonary ailments; (ii) severe joint discomfort; (iii) individuals with pronounced visual, auditory, or comprehension impairments; (iv) deformities prevalent in the ULs and hands; (v) bilateral cerebral lesions, bilateral limb dysfunction, or lesions situated within the cerebellum or brainstem; (vi) progressive stroke or subarachnoid hemorrhage occurrences; (vii) severe cognitive impairment, poststroke depression, or severe aphasia; (viii) instances of traumatic brain injury or tumor presence; and (ix) noncooperation or lack of informed consent endorsement from the patient or their family members.

Therapeutic methods

All three groups were subjected to a standard UL rehabilitation protocol: optimal limb positioning (modifying the position of the affected and healthy side while supine, adjusted bi-hourly); exercise therapy (engaging in shoulder joint release, scapula movement both actively and passively, initiating UL separation movement, ameliorating abnormal muscle tension, and enhancing motor control of the UL, for 60 min per session, daily, 5 days weekly, over 8 weeks); and occupational therapy (utilizing frosted boards, stick insert boards, and other techniques to exercise UL flexion, extension, and hand grip functions while encouraging the initiation of daily living activities such as face washing, teeth brushing, eating, and dressing with the aid of the healthy limb, for 30 min per session, daily, 5 days weekly, for 8 weeks).

In addition to the routine UL rehabilitation, the AOT group took part in AOT training utilizing a specialized treatment apparatus devised based on MN theory (MNST V1.0, Suzhou Mingsite Medical Technology Co., Ltd.). This apparatus related UL movement audio-visuals to patients, urging them to attentively observe, and subsequently emulate and practice the demonstrated movements with the affected limb during and post viewing. Each session spanned 20 min, conducted daily, 6 days weekly, for an 8-week duration.

The acupuncture group received acupuncture therapy, employing disposable sterile AC needles (Huatuo brand) for sanitizing the relevant acupoints. The acupuncture was administered at specific acupoints: Baihui point (flat puncture 15–20 mm), Sishencong point (flat puncture 13–20 mm), Quchi point on the affected side (perpendicular insertion 25–40 mm), Shousanli point on the affected side (perpendicular insertion 25–40 mm), Neiguan point on the affected side (perpendicular insertion 13–25 mm), Jianyu point on the affected side (needle directed toward Jiquan, depth 50–75 mm), Binao point on the affected side (perpendicular or oblique insertion 20–40 mm), and Hegu point on the affected side (perpendicular insertion 13–20 mm). Optimal results were associated with local sensations of soreness, numbness, bloating, or meridian conduction, with each session lasting 20 min, conducted daily, 5 days weekly, over 8 weeks [the specific acupoints are shown in Figure 1].

The AOT combined with the acupuncture group was introduced to combined therapy, maintaining a consistent order of treatment of AOT therapy preceding acupuncture treatment.

Observational indicators

(1) The Fugl–Meyer Assessment of the Upper Extremity (FMA-UE) was employed to compare the scores among the three groups, aiming to discern alterations in their conditions. The FMA-UE delves into patients' reflex reactions, coordinated flexor and extensor muscle movements, isolated motions, wrist functionality, hand coordination prowess, and movement pace. It comprises 33 elements, with a cumulative score of 66 points, With a higher score indicates a more significant functional recovery. (2) The modified Barthel Index (BI) was utilized to gauge the daily living capabilities of the patients, with a maximum score of 100 points. A higher score is indicative of superior daily living abilities. (3) The Action Research Arm Test (ARAT) was administered to assess the hand functionality of patients across the three groups, examining their capability to execute a range of motion and grip tasks.

Assessment methods

At the conclusion of 0, 4, and 8 weeks of training, evaluations were carried out on the activities of daily living (ADL) and UL function, alongside administering the ARAT. The evaluation adopted a single-blinded methodology, ensuring the evaluator remained uninformed of the patient's group allocation, thereby maintaining an unbiased assessment environment.

Statistical analysis

The statistical analysis was performed using SPSS 25.0 (IBM Corporation, Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation for normally distributed data or median (interquartile range) for nonnormally distributed data. The repeated-measures analysis of variance (ANOVA) was employed to analyze the FMA-UE scores across various time points (0, 4, and 8 weeks) and to examine the interaction effect between time and group, as well as the main effects of time and group. If a significant interaction effect or main effect was found, *post hoc* tests using the Bonferroni correction were conducted for pair-wise comparisons. Simple-effect analysis was performed to compare group differences at each time point and to compare time differences within each group. Categorical variables were presented as frequencies and percentages, and intergroup comparisons were conducted using the Chi-square test or Fisher's exact test, as appropriate. A two-tailed $P \leq 0.05$ was considered statistically significant. Partial eta-squared (ηp^2) values were reported to indicate effect sizes for the repeated-measures ANOVA.

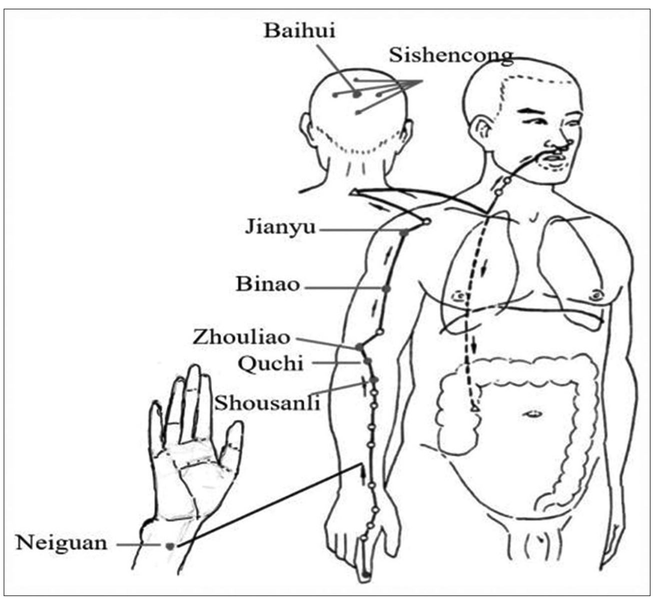

Figure 1: Acupoints adopted in the clinical trial. Figure 1 illustrates the locations of the following acupoints on the human body. Baihui (GV20): Located at the vertex of the head. Sishencong (EX-HN1): Four points located anterior, posterior, and lateral to the Baihui point. Jianyu (LI15): Located on the lateral side of the shoulder, at the anterior region of the acromion. Binao (LI14): Located on the lateral aspect of the upper arm, at the level of the deltoid insertion. Quchi (LI11): Located at the lateral end of the elbow crease, at the midpoint of the line joining the lateral epicondyle of the humerus and the lateral end of the elbow crease. Shousanli (LI10): Located on the radial aspect of the forearm, 3 cun proximal to the wrist crease. Neiguan (PC6): Located on the volar forearm, 2 cun proximal to the wrist crease, between the tendons of the palmaris longus and flexor carpi radialis muscles

Results

Baseline data

A total of 82 patients were included in this study. All the participants were randomly assigned to three different groups, including the acupuncture group (Group 1), with 24 males and 6 females, aged from 49 to 78, with an average age of 69.00 ± 6.86. The AOT combined with the acupuncture group (Group 2) consisted of 21 males and 7 females, aged from 55 to 77, with an average age of 68.36 ± 5.32 years. The AOT group (Group 3) comprised 17 males and 7 females, aged from 60 to 80, with an average age of 68.04 ± 5.33. The summary of subject characteristics is shown in Table 1. A statistical analysis of the general data from the three groups revealed no significant differences ($P > 0.05$), indicating that the data are comparable among the groups.

Comparison of the Fugl–Meyer Assessment of the Upper Extremity scores in the three groups

The repeated-measures ANOVA showed a significant interaction effect between time and group ($F = 7.213$, $P < 0.001$, $\eta p^2 = 0.154$) and a significant main effect of time ($F = 383.794$, $P < 0.001$, $\eta p^2 = 0.829$) on the FMA-UE scores. However, the main effect of the group was not significant ($F = 1.912$, $P = 0.154$, $\eta p^2 = 0.046$). *Post hoc* tests using the Bonferroni correction revealed that the FMA-UE scores of all three groups significantly improved in each treatment cycle and follow-up cycle ($P < 0.05$). Simple-effect analysis showed that in the 8th week, the FMA-UE score in the combined treatment group was significantly higher than that in the AC group ($P = 0.003$). There were no significant differences in the FMA-UE scores between groups at other time points [Table 2 and Figure 2].

Comparison of changes in the Barthel index scores in the three groups

The repeated measures ANOVA showed significant interaction effects between time and group ($F = 4.411$, $P = 0.005$, $\eta p^2 = 0.100$), main effects of time ($F = 261.034$, $P < 0.001$, $\eta p^2 = 0.768$), and main effects of group ($F = 5.204$, $P = 0.008$, $\eta p^2 = 0.116$) on BI scores. *Post hoc* tests using the Bonferroni correction revealed that the BI scores of all three groups significantly improved in each treatment cycle and follow-up cycle ($P < 0.05$). Simple

Table 1: Summary of subject characteristics

Group	Gender		Age		
	Male	Female	Mean±SD	Minimum	Maximum
1	24	6	69.00±6.86	49	78
2	21	7	68.36±5.32	55	77
3	17	7	68.04±5.33	60	80
Total	62	20	68.50±5.87	49	80

Data are presented as mean±SD of each group and condition. SD: Standard deviation effect analysis showed that in the 4th week, the BI score in the AOT treatment group was significantly higher than that in the AC group ($P = 0.043$). In the 8th week, the improvement in BI scores in the AOT combined with the AC treatment group and the AOT treatment group was significantly greater than that in the AC group [$P < 0.05$, Table 3 and Figure 3].

Comparison of changes in the Action Research Arm Test scores among the three groups

The repeated-measures ANOVA showed a significant interaction effect between time and group ($F = 6.285$, $P = 0.001$, $\eta p^2 = 0.137$) and a significant main effect of time ($F = 315.437$, $P < 0.001$, $\eta p^2 = 0.800$) on ARAT scores. However, the main effect of the group was not significant ($F = 0.941$, $P = 0.395$, $\eta p^2 = 0.023$). *Post hoc* tests using the Bonferroni correction revealed that the ARAT scores of all three groups significantly improved in each treatment cycle and follow-up cycle ($P < 0.05$). Simple-effect analysis showed no significant differences in ARAT scores between groups at any time point [Table 4 and Figure 4].

Discussion

The incidence of stroke is increasing globally, and although many individuals can regain walking skills, a large number of them will present suboptimal functional recovery of the UL.[18] A substantial number of advanced rehabilitation strategies have been applied

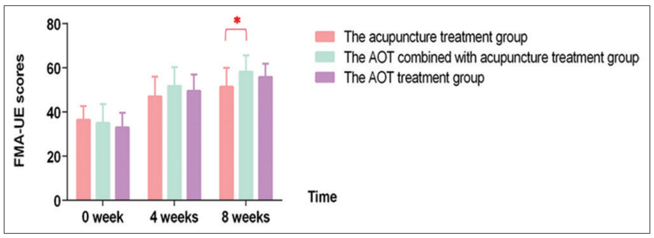

Figure 2: Comparison of the Fugl–Meyer Assessment of the Upper Extremity (FMA-UE) scores in the three groups. Figure 2 illustrates the changes in the FMA-UE scores over time for the three treatment groups. Data are presented as mean ± standard deviation. The graph depicts the changes in the FMA-UE scores for 0, 4, and 8 weeks for three different treatment groups: acupuncture treatment group (Group 1), action observation therapy (AOT) combined with acupuncture treatment group (Group 2), and AOT treatment group (Group 3). The data points on the graph represent the mean FMA-UE scores, and the error bars indicate the standard deviation at each time point for the respective groups. *Post hoc* analysis revealed that at week 8, the FMA-UE score in Group 2 (AOT + acupuncture) was significantly higher than that in Group 1 (acupuncture only), as indicated by the asterisk (*). By presenting the data as mean ± standard deviation, the figure effectively illustrates the overall trend and variability in FMA-UE scores across the three treatment groups over time. AOT: Action observation therapy, FMA-UE: Fugl–Meyer Assessment of the Upper Extremity

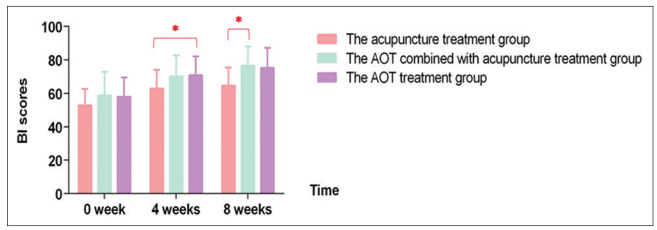

Figure 3: Comparison of the Barthel Index (BI) score changes in the three groups. Figure 3 illustrates the changes in BI scores over time for the three treatment groups. Data are presented as mean ± standard deviation. The graph depicts the changes in BI scores for 0, 4, and 8 weeks for three different treatment groups: acupuncture treatment group (Group 1), action observation therapy (AOT) combined with acupuncture treatment group (Group 2), and AOT treatment group (Group 3). The data points on the graph represent the mean BI scores, and the error bars indicate the standard deviation at each time point for the respective groups. Simple-effect analysis indicated that at week 4, the BI score in Group 3 (AOT) was significantly higher than that in Group 1 (acupuncture only), as denoted by the asterisk (*). At week 8, the improvement in BI scores in Group 2 (AOT + acupuncture) and Group 3 (AOT) was significantly greater than that in Group 1 (acupuncture only), also marked with asterisks (*). By presenting the data as mean ± standard deviation, the figure effectively illustrates the overall trend and variability in BI scores across the three treatment groups over time. AOT: Action observation therapy, BI: Barthel index

Table 2: Comparison of the Fugl–Meyer assessment of the upper extremity scores in the three groups

Group	0 week	4 weeks	8 weeks	*F*	*P*	ηp²
1	36.37±6.11	46.97±8.93	51.33±8.47			
2	34.93±8.55	51.71±8.40	58.07±7.47			
3	32.92±6.59	49.46±7.45	55.83±5.97			
Time				383.794	0.000	0.829
Group				1.912	0.154	0.046
Time × group				7.213	0.000	0.154

Data are presented as mean±SD of each group and condition. SD: Standard deviation

Table 3: Comparison of the Barthel index score changes in the three groups

Group	0 week	4 weeks	8 weeks	*F*	*P*	ηp²
1	52.80±9.88	62.87±11.24	64.60±10.89			
2	58.79±14.05	70.18±12.56	76.61±11.36			
3	57.83±11.65	70.88±11.13	75.21±12.04			
Time				261.034	0.000	0.768
Group				5.204	0.008	0.116
Time × group				4.411	0.005	0.100

Data are presented as mean±SD of each group and condition. SD: Standard deviation

Table 4: Comparison of the Action Research Arm Test scores in the three groups

Group	0 week	4 weeks	8 weeks	*F*	*P*	η^2_p
1	27.93±9.78	35.27±10.55	40.40±8.90			
2	23.50±12.40	35.18±11.73	43.00±10.61			
3	20.88±10.69	31.58±10.48	40.38±10.24			
Time				315.437	0.000	0.800
Group				0.941	0.395	0.023
Time × group				6.285	0.001	0.137

Data are presented as mean±SD of each group and condition. SD: Standard deviation

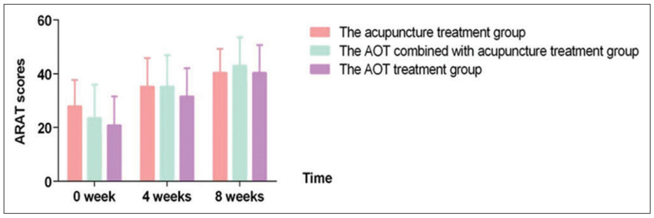

Figure 4: Comparison of the Action Research Arm Test (ARAT) score in the three groups. Figure 4 illustrates the changes in ARAT scores over time for the three treatment groups. Data are presented as mean ± standard deviation. The graph depicts the changes in ARAT scores for 0, 4, and 8 weeks for three different treatment groups: acupuncture treatment group (Group 1), action observation therapy (AOT) combined with acupuncture treatment group (Group 2), and AOT treatment group (Group 3). The data points on the graph represent the mean ARAT scores, and the error bars indicate the standard deviation at each time point for the respective groups. By presenting the data as mean ± standard deviation, the figure effectively illustrates the overall trend and variability in ARAT scores across the three treatment groups over time despite no significant differences between the groups. AOT: Action observation therapy, ARAT: Action Research Arm Test

in UL rehabilitation, such as robot-assisted therapy,[19] constraint-induced movement training,[20] and virtual reality-based rehabilitation,[21] which are aimed at helping stroke survivors relearn motor skills through intensive training. These rehabilitation strategies have been reported to improve patients' motor functions by inducing experience-dependent neuroplasticity in their damaged hemispheres. However, the neuroplasticity resulting from intensive-based interventions may be limited if the residual motor functions of the patients are also extremely limited. Thus, the researchers are still exploring superior methods for its therapy. There is evidence to support the theory that cortical areas involved in motor execution can be activated by observing actions performed by others, which is attributed to the function of the MNS.[22] Various researchers have demonstrated that in humans, these brain areas (the inferior parietal lobe and the ventral PMC, as well as the caudal part of the inferior frontal gyrus) are activated following observation or motor imagery,[23] thereby facilitating subsequent movement execution by directly matching the observed or imagined action to the internal simulation of that action. Acupuncture is recommended by the World Health Organization as an alternative and complementary strategy for stroke treatment and for improving stroke care.[24] Acupuncture has been shown to promote cell proliferation in tissue damaged by ischemia. Affected areas involve the cortical peri-infarct area, ischemic and nonischemic cortex, the lateral ventricle, and the striatum.[25] Thus, several studies have indicated that acupuncture could inhibit contralesional brain activity while activating the ipsilesional motor cortex.[14,26] It indicated that acupuncture results in lateralization in unilateral stroke patients.[27] This lateralization may represent an enhancement of the compensatory process through acupuncture that redistributes function to the whole cortex, especially the unaffected hemisphere. In addition, studies[28,29] also showed that acupuncture could stimulate bilateral regions, modulate the whole-brain network, and enhance functional connectivity. This indicated that acupuncture could not only specifically regulate the bilateral dynamic balance of the brain but also modulate the whole brain network and functional connections as a whole.

In the study, AOT combined with acupuncture was observed to improve UL dysfunction after stroke, and the therapeutic effect was quantified by FMA-UE, BI, and ARAT scores. The scores of the three groups were improved compared with those before treatment, indicating that AOT, acupuncture, and AOT combined with acupuncture therapy are effective in the functional treatment of patients with UL dysfunction after stroke. It is worth noting that at 4 weeks, the BI score of the AOT group has been significantly improved compared with that of the acupuncture group, which shows that mirror therapy can have a positive impact on patients' ADL in a short time. Moreover, AOT combined with the acupuncture treatment group did not show significant advantages in improving the ability of daily living of patients compared with simple acupuncture treatment. In the 8th week, the effect of AOT combined with the acupuncture treatment group was significantly better than that of simple acupuncture treatment, which suggested that the synergistic effect of combined treatment gradually appeared. The findings further confirmed the long-term advantage of combination therapy in promoting the recovery of UL motor function. This may be attributed to the combination therapy can fully motivate the advantages of acupuncture and AOT impact on the MNs, which could promote repair and remodeling of neuronal functional binding more effectively through the synergy of multiple pathways and mechanisms. Meanwhile, the combination of both is more effective for neuroplastic. The present study has a limitation that the underlying neuroregulation mechanism of AOT and acupuncture in UL after stroke in different stages has not been clarified for the following work to do.

Conclusions

AOT based on mirror therapy can be an interesting technique of rehabilitation for stroke patients with simple and economic. There is also reported that some stroke individuals have still got little benefit from AOT. Manual acupuncture at particular acupoints activates afferent fibers that send signals to the spinal cord and brain. Both AOT and acupuncture can improve UL dexterity in hemiparesis after a stroke. The combination of AOT and acupuncture was observed to have a better effect than the single method at 8-week intervention. However, the possible neuronal mechanisms and the optimal combining form of AOT and acupuncture in different stroke stages should be discussed further.

Author contributions

Dilinuer Maimaitiaili and Jue Shi conceived the manuscript. Li Jin provided more guidance for carrying out experimental protocols. Yiwen Gu performed the experiments and analyzed the data. Yuanli Li designed the study and provided more guidance for writing the manuscript. Jin Shu also designed and provided the device and its parameters. All authors reviewed the manuscript and contributed to its writing.

Ethical policy and institutional review board statement

The study was approved by the Ethics Committee of Shibei Hospital of Jing'an District, Shanghai (Approval No.: YL-2021422-01, dated on April 22, 2021).

Declaration of Helsinki

We keep on the ethical principles underlying the Declaration of Helsinki for human medical research.

Patient consent

The participants were informed about all aspects of the study, and written informed consent was obtained from all the participants before the start of the study.

Data availability statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Financial support and sponsorship

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Conflicts of interest

There are no conflicts of interest.

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