Laterality in Responce of Brain Activity during Mirror Therapy using Near-infrared Spectroscopy

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Key words : Mirror Therapy, Near-infrared spectroscopy, Supplementary motor area, Prefrontal area, Regional cerebral blood flow

Summary

This study presents the activation of left the prefrontal area by Mirror Therapy (MT) targeted to improve the function of the upper arms. The subjects were eight right handed females who were going to receive MT for the first time. Cortical brain activity was compared through oxygen ized hemoglobin ([oxy-Hb]) using near infra-red multi-channel oxygen monitor, during resting image training (IT). The result showed a significant increase of [oxy-Hb] in the lower left prefrontal area during the subjects imagined their fixed left hand and their right hand was in motion. Our data sujest that the greater importance of the lower left prefrontal area than the lower right prefrontal to feel a mirror image illusion in the case of right-handed person.

Introduction

Mirror Therapy is a physical therapy to influence the reconstruction of body image by activating the prefrontal or motor area by giving an optical illusion by means of a mirror image as centripetal information to the brain [1)]. MT has the effect of eliminating phantom limbs and pain by creating the physical illusion of limbs by letting the limb-less patient see mirror [2,3)] . MT also works in the recovery from motor paralysis after stroke through physical therapy by convincing the patient that the paralyzed upper limb functions well through the mirror image of healthy side of upper limb [4,5)].

Measurements of brain blood flow in finger movement in critical and mildly affected groups of after stroke patients showed the latter group had a tendency to a higher quantity of blood flow to the anti-parallel supplementary motor area. MT is effective with the patients with mild left side paralysis or sense disturbance among those with brain neuron damage [6,7)]. Often left hemi-paralysis patients after stroke have a disturbed right hemisphere of the brain with a healthy left half. Localization of function of left and right hemispheres may alter the effects of MT. The mechanism of MT working with patients with left hemi-paralysis patients, is unclear.

This study presents the difference between left and right brain function by measurement of blood flow in left and right motor area during MT by using near-infrared spectroscopy.

Methods

1. Subjects were eight healthy right handed females (Average age 21 ±1 year) who had never experienced MT. Their right handedness was confirmed by a skill test [8)] .
2. Measurement of [oxy-Hb]. A functional near-infared multi oxygen monitor (FNIRS, Shimazu) was employed for measurement of activity of the brain cortex. Measurements were carried out at a part of the left and right prefrontal lobes, temporal lobes and parietal lobe. The probes of irradiation of near-infared and the detection probes were arranged in 3x5

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Fig.1. Position of measurement by FNIRS.
A channel is in between illumination fiber and light-receptor fiber. The position is determined to cover from parietal to frontal area following the international rule 10-20 method. The left and right inferior prefrontal area correspond to the arrows.

Fig.2. Mirror box.
Healthy side of upper limb is inserted into one opening of box, and disturbed upper limb is inserted into the other opening. Healthy arm is observed in mirror. The subject creates an illusion that her disturbed arm is moving by watching the mirror.

lattices with an interval of 3cm and fixed by fibers for light (Fig. 1).

3. Mirror box. The box has openings in both sides to place each upper limb, and one of the limbs is covered by the back of the mirror to show the other limb which is observed in the mirror. The box has another opening to place and remove the mirror, so that without themirror one can observe the upper limb directly and with mirror-in, the other upper limb can bee seen in the mirror (Fig. 2). The position of mirror was adjusted to show the upper limb in the mirror but visually reflected as the other upper limb. The upper limb hidden by the mirror was fixed with weight and harness as though it was physically impaired.
4. Procedure. Timing of (1) rest: 10 sec.,(2) IT: 30 sec., (3) rest: 20 sec., (4) MT: 30 sec., (5) rest: 10 sec. were chosen. TM was carried out once to right and left upper limb respectively.

(1) Work in rest period: Subject was directed to watch a circle on a piece of paper placed in front of her and continue for 20 sec. after IT work, and for 10 sec. after MT after the first 10 sec.

(2) Image training work: To compare IT and MT, subject was directed to imagine the identical movement of unfixed upper limb while watching the movement of fixed upper limb. The period was for 30 sec. Subject repeatedly bent and extended fingers seen in the mirror following a metronome rhythm (1Hz).

(3) MT work: The subject was directed to repeatly bend and extend her fingers seen in the mirror following a metronome rhythm (1Hz). Although the subject could not observe her fixed upper limb, she was directed to imagine the movement as though she is moving it by herself.

5. Statistical analysis.

The changes of [oxy-Hb] collected in FNIRS was compared. Since the mirror neuron [1,9] of the basic nerve area located in bilateral interior prefrontal area, [oxy-Hb] measured by detection probes, of these area was analyzed. The value of

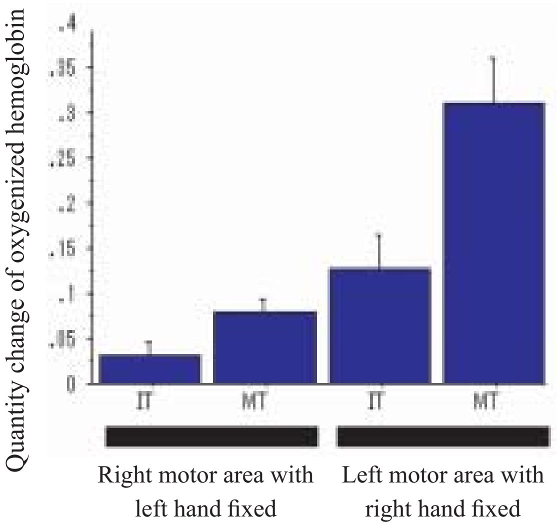

Fig.3. Quantitative changes of oxygenized hemoglobin of lower prefrontal area during IT and MT in the brain area (inferior prefrontal area, contralateral upper limb was fixed) in response with imaging. A significant interaction is observed on blood flow in bilateral prefrontal area (F [3,28]=14.10, P<0.01). Blood flow of left prefrontal area during MT (watching the image in mirror of right hand in motion with left hand fixed) is significantly higher than the blood flow of right prefrontal area during IT (imagining the motion of fixed right hand while watching movement of the left hand) (Bonferroni, **P<0.01). When imagining the left hand in motion while it is fixed, by moving right hand, blood flow of lower prefrontal area is meaningfully higher during MT than in IT (Bonferroni,*P<0.05), n=8.

the rest period was subtracted from IT working period and MT/IT working period to find the increase of oxygenized hemoglobin. Two way analysis of variance was used for statistic analysis followed by Bonfferoni-type post-hoc analysis. The significant value was set less than 5%.

Results

Dinamic [oxy-Hb] analysis in the left inferior prefrontal area during IT work and MT work in right hand movement watching the mirror (left hand fixed) and in left hand movement looking in the mirror (right hand fixed) showed a meaningful interaction of [oxy-Hb] of left and right inferior prefrontal areas (F[3,28]=14.10, P<0.01) (Fig. 3). A following analysis showed that the changes of [oxy-Hb] of the left inferior prefrontal area during MT (left hand fixed, right hand motion in the mirror) was meaningfully higher than the right inferior prefrontal area during IT (moving left hand, imaging right hand in the mirror as if it were in motion in the mirror) (Bonferroni, P<0.01). When the left hand is fixed but the image of it is moving by moving the right hand, [oxy-Hb] in the left inferior prefrontal area is higher with MT than IT (Bonferroni, P<0.05).

The result of analysis in the prefrontal area during IT work and MT work when watching the image created by moving right hand (left hand is fixed) and of [oxy-Hb] in right inferior prefrontal area when the subject is watching a mirror image of moving left hand (right hand fixed) showed no difference of interaction of [oxy-Hb] in the bilateral prefrontal area between IT and MT (F[3,28]=0.86, P=0.47) (Fig.4).

Discussion

Due to the illusion created by watching mirror image of a moving upper limb in place of an other fixed upper limb, the blood flow into the contralateral brain was significantly increased. This phenomenon was more significant in left inferior prefrontal area in MT work than in IT work. Rudy et al. analyzed local brain blood flow by Positron Emission Tomography during self motion imaging and showed the activation of left primary motor area, left prefrontal area, left supplementary motor area and left inferior prietal area [11]. Tanji et al. showed that the function of prefrontal area contains both coordination of optical information and motion and induction of physical movement by converting optical information into motion [12,13]. The function of motor prefrontal area is indispensable for making illusion from mirror, especially the possibility

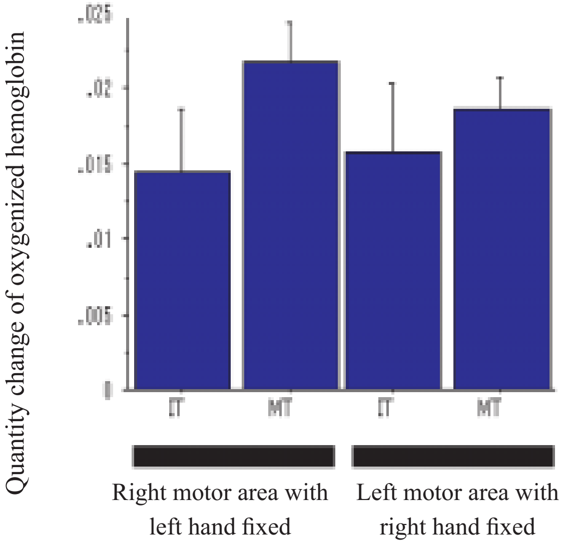

Fig.4. Quantitative changes of oxygenized hemoglobin of inferior prefrontal area during IT and MT in the brain area (inferior prefrontal area with ipsilateral upper limb was fixed) in response to physical activity. Interaction of blood flow of left and right prefrontal are was not detected between IT work and MT work, after 2way analysis of variance of the blood flow in right inferior prefrontal area (F[3.28]= 0.86, P=0.47), n=8.

that neuronal basis is located in inferior prefrontal area.

When a subject creates out the perception of self-motion imaging from an illusion in MT, a coordinated action of left primary motor area, left motor prefrontal area, left complementary area and left inferior parietal area will occur and thus there is a possibility MT may not be effective if left hemi-cerebral hemisphere has a disturbance. The effect of MT for hemi-paralysis patients after stroke is more significant with left hemisphere patients [14,15)]. In the case of autism in children, the action level of their inferior prefrontal area is reduced, and their mirroring system to observe the motion of others is not well functioning [16-18)]. There is a possibility of non-effectiveness of MT in the cases of high order brain dysfunction, i.e. damage to left hemisphere of cerebral and autism. Thus further investigation is necessary.

In this study, changes of the amount of oxygenized hemoglobin in parietal to frontal area of subjects was measured by means of FNIRS. It has been shown, after statistic analysis on selected left and right inferior frontal area, that for the determination of the position, a higher precision magnetic resonance image is required to know exactly brain area of the subject, because of the limitation in space resolution of FNIRS.

The difference of blood flow of inferior prefrontal area synchronizing with upper limb in motion and the major effect of MT were not observed. It has been suggested that left inferior prefrontal cortex play more important role than right inferior prefrontal area to feeling the illusion from mirror image. However, involvement of somatosensory area is also important when formatting recognition depended upon physical perception formed by illusion. For MT to be more effective in physical therapy, a study of the more detailed activation mechanism of brain function in the areas including somatic, optical, and motor area is required.

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