REVIEW

MIRROR THERAPY- An Approach to Regain Upper Extremity Function Post Stroke- Appraisal of the current Literature

Abhilasha Gundesha [1] Vasanti Joshi[1] Shaila Sabnis[1]

ABSTRACT

Introduction- In the recent literature, there are a number of new techniques being evaluated for their efficacy in the treatment of upper extremity dysfunction post stroke. Recovery of upper extremity is crucial for independence in activities of daily living. Mirror Therapy is an innovative technique which may help regain function post stroke.

Method- For the present literature review, we focussed on Mirror Therapy for treatment of upper extremity post stroke. We analyzed publications of the last 5 years (2005 to 2010) from PUBMED, using the key words "stroke", "upper extremity" and "mirror therapy". Only Randomised Controlled Trials, Literature Reviews and Meta-analysis published in English language were selected for the review.

Results- Out of a total of 24 articles accessed, 15 articles pertaining to Mirror Therapy for upper extremity function post stroke were analyzed.

Conclusion- The present literature review shows that mirror therapy may prove to be a valuable tool for the treatment of upper extremity dysfunction post stroke. It also shows that mirror neurons may play an important role in observation based learning. However, the underlying mechanisms for the use of mirror therapy need further evaluation.

Key Words- Mirror therapy, Stroke, Upper extremity function

MIRROR THERAPY- AN APPROACH TO REGAIN UPPER EXTREMITY FUNCTION POST STROKE

Stroke is an acute onset of neurological dysfunction, which can have devastating effects on the quality of life of the affected individual. The recovery of hand is an important step towards independence in activities of daily living. There are a number of interventions used for regaining function in the upper extremity post stroke. For the present literature review, we focussed on Mirror Therapy for treatment of upper extremity post stroke. We analyzed publications of the last 5 years (2005 to 2010) from PUBMED, using the key words "stroke", "upper extremity" and "mirror therapy". Only Randomised Controlled Trials, Literature Reviews and Meta-analysis published in English language were selected. Out of a total of 24 articles accessed, 15 articles pertaining to Mirror Therapy for upper extremity function post stroke were analyzed.

ABOUT STROKE AND RECOVERY OF FUNCTION

Stroke or Cerebrovascular Accident (CVA) is an acute onset of neurological dysfunction due to an abnormality in cerebral circulation with resultant focal neurological deficit, which corresponds to the areas affected. Stroke is the leading cause of long term disability in adults and is frequently associated with severe loss of motor capacity1. The neurological impairments lead to persistent limitation in activities of daily living. Recovery of hand is crucial to perform activities of daily living, but it is often incomplete and variable2.

It has been demonstrated that the functional deficits after stroke are determined by factors that represent the amount of structural damage and the cortical facilitation caused by activity and environment.

The adult brain was for a long time considered as hard-wired, with little potential for change. Thus, any kind of injury to this hard-wired structure was considered permanent with recovery a difficult possibility. The brain was considered as a 'standard model' consisting of large number of modules, which work autonomously without much interaction with each other. Neurological disorders in this view result from permanent irreversible injury to one or more such modules. This is now viewed as incorrect and could mislead when applied to the individuals who suffer from damage to brain structures. Over the years it has been demonstrated that recovery is possible even with extensive nervous tissue damage. This has led to a paradigm shift from a 'serial hierarchical modular view' to a more 'dynamic view' of the brain[3].

Recovery of function is the "re-acquisition of movement skills lost through injury". In its strictest definition, the performance of the required skills is identical in every way to pre-injury performance. In a less strict interpretation of recovery, performance is achieved through variations in the pre-injury movement patterns. Recovery from stroke is generally fastest

[1]Sancheti Institute College of Physiotherapy, Pune, India.

Address for correspondence: Abhilasha Gundesha
Sancheti Institute College of Physiotherapy,
Sancheti Institute for Orthopaedics and rehabilitation, Pune, Maharashtra, India
Email - abhilasha.gundesha@gmail.com

in the first few weeks after onset, with measurable neurological and functional recovery occurring in the first 1 to 3 months after stroke. Patients continue to make functional gains at a reduced rate for up to 6 months or longer after the insult. Some patients may demonstrate prolonged recovery with improvements occurring over a period of years, especially in the areas of language and visuospatial function[1].

Recovery of function is based on two mechanisms: compensatory and restitution. It is likely that both occur simultaneously in many cases. Compensatory processes are described as functional reorganization or functional adaptation, which means completely different neural circuits take up the functions of the damaged circuits. This involves a reorganisation of neuronal networks. Training leads to a redistribution of representations to non-damaged areas of sensory cortex via reorganization. Restitution or restorative recovery is the resolution of temporary changes of the injured neural tissue, such as edema. Central Nervous System (CNS) plasticity is also said to account for continuing recovery. Neural plasticity has been defined as "the ability of the brain to change and repair itself". Several explanations have been offered to account for plasticity. Plastic reorganization is mainly said to occur by an alteration in the synaptic connections or unmasking of existing dormant neuronal connections. These changes in neuronal potentiations are seen with learning under normal conditions as well as post injury, when a number of active circuits are damaged. Thus, the alternative circuits are called upon to function. These structural and functional changes may take days to weeks to develop, depending on the extent of damage and stimulation of the brain through activity[4].

Neuroscience based rehabilitation is gaining strength as a way to improve outcome, even in situations where the deficit appears to be permanent. Understanding the effect of rehabilitative techniques on brain plasticity is potentially important in providing more effective and longer lasting motor recovery. With the advent of techniques such as Transcranial Magnetic Stimulation (TMS) and Functional Magnetic Resonance Imaging (fMRI), it is now possible to non-invasively map the motor regions of the brain. These help us to determine the cortical representation areas of muscles producing movement. A number of different rehabilitative methods to improve upper limb function post stroke are extensively being studied. Most of these methods concentrate on direct and repetitive practice with the affected extremity. Mirror Therapy, on the other hand relies on activity of the unaffected side, the image of which is superimposed on the affected side.

CONCEPT OF MIRROR THERAPY

MIRROR THERAPY is an innovative treatment modality which relies on the potential for creating visual illusions. Ramachandran and Rogers5 were the first to introduce the use of these visual illusions created by a mirror for the treatment of phantom limb pain. By superimposing the intact arm on the phantom limb using a mirror reflection, patients reported the sensation that they could move and relax the often cramped up phantom limb and experience pain relief6. After this pioneering work done for amputees7, use of mirror therapy was further explored in patients with other pain syndromes, such as complex regional pain syndrome, brachial plexus injuries and rehabilitation of hand after surgeries[8,9,10,11].This concept further progressed in the field of rehabilitation by being tested in the process of stroke recovery.

In mirror therapy, a mirror is placed in the midline of the body, beside the unaffected limb, blocking the view of the affected limb. This creates the illusion that the affected hand is moving when in fact the unaffected hand is moving. Observation of these illusory movements performed by the affected hand are said to lead to the generation of intended actions, engaging motor planning and execution. The temporary interruption of circuits in stroke often leads to more permanent 'learned paralysis', which is the basis for long term disability5. Visual feedback gained through Mirror Therapy may prove to accelerate recovery of function.

PROPOSED MECHANISMS FOR THE WORKING OF MIRROR THERAPY

The hemiparesis that follows stroke is partly attributed to 'learned paralysis' which happens because there is a discrepancy between the motor commands sent by the brain and the loss of visual and proprioceptive input of action execution (due to the paralysis). Stevens and Stoykov12 suggested that mirror therapy creates visual feedback of successful performance (positive feedback) of the observed action with the impaired limb. The visual impression may substitute for the decreased proprioceptive information, thus helping to recruit the premotor cortex and creating an intimate connection between visual input and premotor areas. Thus, this decreases the discrepancy between motor intentions, proprioceptive and visual feedback to some extent.

Restoring some congruency between visual input and motor output can lead to an unlearning of 'learned paralysis' in stroke patients. Visual feedback has always had the capacity to influence kinesthesis during active movement13. The mirror can be used to get a 'motor copy' of the affected limb, especially while attempting bimanual upper extremity movements. A number of studies showing the efficacy of bimanual training for upper extremities post stroke are present14. Mirror therapy may prove to be an important adjunct in rehabilitation, especially during the initial phase when the individual may not be able to initiate fruitful activity in the affected upper extremity. This will also prove useful when other therapies such as Constraint- Induced Movement Therapy, Robotic assisted therapy and

Task- specific training are anticipated, as all these programs are more effective if some initiation of movement in the affected extremity is possible.

Movement observation modulates not only motor cortex excitability, but also cortical somatosensory representations. Viewing a simulated body part enhances discrimination ability both in normal and brain-damaged individuals, accompanied by changes in excitability of the primary somatosensory cortex[15]. With the help of mirror, successful action signals of the paretic limb can be sent to the brain. This is otherwise a difficult task due to the weakness post stroke. Visual images of movement can be generated independent of overt behavioural output of a paretic limb. Actions generated using this visual imagery adhere to the same movement rules and constraints that physical movements follow[12]. Areas active during action observation are similar to those active during actual movement. Neural networks involved in motor imagery and motor execution overlap. Garry et al1[6] performed TMS during mirror illusion in healthy adults, and found increased excitability of primary motor cortex (M1) of the hand behind the mirror. Other areas which have been found to be active are premotor and parietal areas, basal ganglia and cerebellum[17].

In healthy volunteers it was demonstrated that the Premotor Cortex (PMC) is involved bilaterally during learning of finger movement skills and during performance of complex finger movement sequences with the dominant and non-dominant hands18. Motor recovery after cortical infarction in the middle cerebral artery territory appears to rely on activation of premotor cortical areas of both cerebral hemispheres. Mirror illusion is also seen to target the PMC and this could be one of the mechanisms for recovery in subjects, using mirror therapy. Recruitment of the PMC may thus help in motor rehabilitation.

Neuroimaging and neurophysiological studies in humans indicate that neural structures known to be involved in action execution become active during action observation. This link is further supported by behavioural studies showing that execution of a given action is positively or negatively modulated by observation of the same or a different action. The regions of the brain, which were traditionally considered responsible for motor planning and motor control, appear to play a role in perception and comprehension of action[19]. The same is true for the observation of a movement. During observation of a movement, areas in the PMC become activated that are also active when the (same) movement is executed.

Vision plays a very important role in guiding the perception of our body scheme. Dohle et al[20] used fMRI to explore how guidance of motor acts is influenced by the visually perceived body scheme. They found that when subjects viewed their hand as their opposite hand, i.e., the right hand was seen as the left hand and vice versa, activation in the visual cortex was lateralized opposite to the seen hand. This demonstrated for the first time that our body scheme to which vision relates our environment is already represented at the level of visual cortex. Owing to the fundamental organization principle of the human brain, incoming information (e.g., visual or somatosensory) about each half of the body is projected to the primary sensory representations in the cortex of the contralateral cerebral hemisphere. From there the incoming information is projected to the multisensory parietal cortex, which constructs a coherent body image subserving postural control and goal directed motor behaviour. Thus, action generation and action perception are closely related and built on a coherent body image[21].

Whereas most of the studies have found activation of the PMC, Michielsen, Smits et al[22], who investigated the neuronal basis for the effects of mirror therapy in patients with stroke, using fMRI, found that during bimanual movement, the mirror illusion increases activity in the precuneus and the posterior cingulate cortex. A network including both the precuneus and posterior cingulate cortex is reported to be associated with mental representation of the self. More specifically, research has showed that the precuneus is activated when actions are perceived as being self-controlled and during self-centred mental imagery strategies, whereas the cingulate cortex becomes activated during spatial navigation and has been found to process information about the spatial positions of the limbs in monkeys. The mirror illusion of an affected hand, which is seen as moving normally, thus seems to increase alertness and spatial attention towards this hand.

CONCEPT OF MIRROR NEURONS

Mirror Neurons seem to play a central role in motor learning associated with observation and execution. These neurons are present in the premotor area of both monkeys and humans and are said to be active during observation of meaningful movements[15]. These neurons are called mirror neurons because the observed action seems to be ‘‘reflected,’’ as in a mirror, in the motor representation for the same action of the observer[19]. Some authors suggest that these neurons are found in frontal as well as parietal lobes. These lobes/areas are rich in motor command neurons, each of which fires to orchestrate a sequence of muscular activity to produce simple skilled movements such as reaching for and grasping an object, manipulation of objects etc. Remarkably, a subset of these neurons- mirror neurons- also fire when a person merely WATCHES another individual perform the same movement. They allow you to perceive and feel the action performed by another person and thus empathize[3].

Mirror neurons were initially discovered in monkeys. In 1987, Rizzolatti et al.[23] found that a group of cells in monkey area F5, in the pre-motor cortex fired when a monkey reached for a peanut. These neurons also fired when the monkey saw the experimenter reaching for the peanut. When the peanut was occluded behind a screen the same neurons fired when the experimenter reached for the object behind the screen. However, when the peanut was removed before the screen was put in place these neurons did not fire. These results suggest that mirror neurons are involved in the coding of goal directed actions. In other words, mirror neurons are related to intentional behaviour and seem to be involved in understanding the actions of others.

There is some evidence of the existence of a mirror neuron system in humans. Using TMS, researchers[24] have found the influence of mirror neurons on motor activity. In one of these studies, single pulse TMS was delivered to the motor cortex while subjects were observing an experimenter grasping three-dimensional (3D) objects. It led to an increase in motor evoked potential (MEP) amplitude recorded from precisely those hand muscles, which are normally recruited when the observed action is actually performed by the observer. Control conditions involving both visible actions (tracing geometrical figures in the air) or objects (the same 3D objects seen in the actions) did not cause this change. These results throw some light on the existence of mirror neurons in humans[19]. Many researchers do believe they may play a role in (motor) learning. However, according to Vries et al[25] no systematic studies exist in the field of neurological rehabilitation that employ observation based activation for the re-learning of motor control.

Mirror neurons necessarily involve interactions between multiple modalities like vision, motor commands and proprioception, which suggest that they might be involved in the efficacy of mirror visual feedback in stroke. Stroke paralysis results partly from actual permanent damage and partly from a form of 'learned paralysis' that can be potentially unlearned using a mirror. An additional possibility is that the lesion is not always complete; there may be a residue of mirror neurons that have survived but are 'dormant' or whose activity is inhibited and does not reach threshold. Thus, practising with the mirror can help stimulate these dormant neurons by providing the visual input to revive them[3].

The same hypothesis of mirror neurons also receives confirmation from Eng et al[26], who used virtual reality technology to create visual feedback. The patients were made to watch videos of movements performed by healthy individuals, presented via a computer screen. The patients were then made to try to use their paretic arm to make similar movements. This method was found to be superior to a program of conventional therapy used in the control group.

The mirror system is a classic example of the fundamental interdependence, demonstrating the most intimate interrelationship between motor neurons and sensory neurons as well as between motor regions (in the frontal lobe) and somatosensory regions (in the parietal lobe)[19]. In a nutshell, mirror neurons are bimodal visuomotor neurons that are active during action observation, mental stimulation (imagery) and action execution. Mirror neurons are now generally understood to underlie the learning of new skills by visual inspection of the skill.

CLINICAL APPLICATIONS: MOTOR REHABILITATION OF UPPER EXTREMITY AFTER STROKE

The activation of premotor neurons during simple observation of actions is a highly appealing feature for rehabilitation of motor functions. A chronic motor disorder is observed in a large number of patients who survived stroke. The use of action observation as a form of rehabilitation is definitely intriguing when it comes to helping patients with severe paresis for whom active rehabilitation may be difficult. More generally, action observation as a form of training in rehabilitation has been recently proposed on theoretical grounds[27, 28].

The role of motor learning in hand motor recovery presents certain questions, since the goal is to re-establish previously learned motor skills rather than new skills. A person with stroke may have lost a significant portion of the brain tissue supporting the neural circuits associated with the execution of movements. On the other hand, this situation might be ideally suited for the use of observation/execution matching and motor imitation, which could potentially provide a re-assembly of the incomplete (but not totally lost) networks[19, 27].

There are two main features of observation with the intention of imitation that could promote plasticity in the appropriate networks for hand motor skill. First is that the distributed networks for motor imitation involve multiple sensory inputs (visual, auditory, and proprioceptive), making it possible to activate the system using different inputs. Thus, the widespread distributed nature of the network suggests many anatomical and physiological options for obtaining proper activation. Second is that activation of the network for observation/execution matching produces an increase in the excitability of the corticospinal path even in the absence of overt movements[5, 19].

EVIDENCE FOR THE EFFECT OF MIRROR THERAPY ON UPPER EXTREMITY REHABILITATION POST STROKE

In a randomized crossover design study on chronic stroke patients, Altschuler et al[29] reported an improved range of motion, speed and accuracy of arm movement in stroke patients who were trained with mirror therapy. Although this study had a small size, it was one of the first studies showing the effectiveness of mirror therapy on hand movements post stroke. It laid down the foundation for the forthcoming researchers. Subsequently, Sathian *et al* [13] reported a significant recovery of grip strength and hand movement of the paretic arm in chronic stroke patients after 2 weeks of an intense mirror therapy program. Also, Stevens and Stoykov[12] found that 3 to 4 weeks of mirror therapy in stroke patients lead to a significant improvement of Fugl-Meyer Assessment scores, active range of motion, movement speed, and hand dexterity. These studies did show some improvement in hand function, however they lacked proper randomisation. It was Sütbeyaz et al[30], who reported an improvement in motor recovery and motor functioning in a randomised controlled trial with a sample size of 40 stroke patients. These were measured using Brunnstrom stages and Functional Independence Measure (FIM) respectively. They found no effect of mirror therapy on spasticity.

In a recent study conducted by Angelo Cacchio, Elisabetta De Blasis et al[31] on acute stroke patients, it was found that mirror therapy effectively reduced pain and enhanced upper limb motor function in stroke patients with upper limb Complex Regional Pain Syndrome type1 (CRPSt1). Similarly, Christian Dohle, Judith Püllen et al[15] conducted a study on acute stroke patients and found that patients undergoing mirror therapy regained more distal function than control therapy patients. Mirror therapy was also found to improve recovery of surface sensibility.

TMS has been used to explore the neural basis of mirror therapy. It could be shown that motor evoked potentials (MEPs) were largest in the mirror condition (viewing a mirror-reflection of the active hand in a mirror oriented in the mid-sagittal plane) compared with both an inactive (viewing the inactive hand) and a central (viewing a mark positioned between hands) viewing condition. The authors concluded that the excitability of MI ipsilateral to unilateral hand movement is facilitated by viewing a mirror reflection of the moving hand[17]. This finding provides neurophysiological evidence supporting the application of mirror therapy in stroke rehabilitation.

CONCLUSION

This review shows that there are several studies which provide evidence that a positive effect of mirror therapy could be found on upper extremity motor recovery. From the literature available, it can be concluded that mirror therapy may accelerate recovery of function. However, the mechanisms for the effect of Mirror Therapy need further evaluation. Also, the treatment parameters like duration, intensity, frequency, type of movements do not have universal consensus yet.

However, it is clear that mirror therapy is a simple, inexpensive, promising, patient-directed treatment, which can prove to be an important adjunct in the treatment of upper extremity in stroke patients.

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